Minimally Invasive Spine Intervention

Jörg Jerosch *Editor*

Springer

Minimally Invasive Spine Intervention

Jörg Jerosch
Editor

Minimally Invasive Spine Intervention

Springer

Editor
Jörg Jerosch
Meerbusch, Germany

ISBN 978-3-662-63813-2 ISBN 978-3-662-63814-9 (eBook)
https://doi.org/10.1007/978-3-662-63814-9

This book is a translation of the original German edition „Minimalinvasive Wirbelsäulenintervention“ by Jerosch, Jörg, published by Springer-Verlag GmbH, DE in 2019. The translation was done with the help of artificial intelligence (machine translation by the service DeepL.com). A subsequent human revision was done primarily in terms of content, so that the book will read stylistically differently from a conventional translation. Springer Nature works continuously to further the development of tools for the production of books and on the related technologies to support the authors.

Editorial Contact: Antje Lenzen

This Springer imprint is published by the registered company Springer-Verlag GmbH, DE, part of Springer Nature.
The registered company address is: Heidelberger Platz 3, 14197 Berlin, Germany

Foreword

Dear Readers,

One does not have to be a prophet to predict that the present work will represent a standard of minimally invasive spinal intervention within a very short time.

It is indeed an extraordinary work, in which not only a great deal of work but also extensive expertise has gone into it.

Precise, concise and accurate, this reference book presents itself. In addition to the basics, which also include the non-invasive area, all chapters with diagnostics and therapy are presented in detail and comprehensively. The structure of the work is clear and consistent. The contents in words and pictures are comprehensive, but in no way redundantly treated. The book inspires both the beginner and the expert by its logically designed structure and the consistent presentations.

All details of spinal treatment, starting with multimodal pain therapy and the treatment algorithm of landmark-assisted infiltration, which was already popularized by Jürgen Krämer, up to the latest endoscopic decompression procedures are comprehensively described.

This book is not only instructive and helpful for the specialist in clinic and practice but also for the colleague in training; in fact, it is required reading for anyone involved in the diagnosis and treatment of spinal pain. It is a pleasure to read this book, in almost every page the attention to detail is clearly noticeable.

The work is sure to be widely read and to have a grateful readership.

Fritjof Bock
Ravensburg, Germany
October 2018

Preface

Dear colleagues,

After the first edition in 2005 and the second edition in 2009 published by Deutscher Ärzteverlag, the third edition of the *Minimally Invasive Spinal Intervention* is now available.

We have again succeeded in convincing a large number of proven specialists in this field to sacrifice their free time for the preparation of the present manuscripts. The aim of the largely uniformly designed chapters was above all to give you, the reader, practical advice on how to carry out the respective procedures. Since the authors have largely adhered to the guidelines, this has also been achieved to a large extent. In any case, all the practical information on pre-interventional diagnostics and clarification is intended to help you in your everyday work.

Last but not least, the billing chapter and sections on reimbursement in individual chapters give you a good orientation on this not always easy topic. Of course, it does not set legally binding recommendations in the EBM or GOÄ.

In addition to the authors, I would like to express my special thanks to the staff at Springer Verlag, especially Ms. Antje Lenzen and Ms. Barbara Knüchel, with whom it is always a pleasure to realize joint projects. I would also like to thank Irène Leubner for her meticulous editing and the very good time management in the communication with the authors.

Jörg Jerosch
Neuss, Germany
Autumn 2018

Contents

Contributors

Ludwig W. Ackermann Department of Minimally Invasive Pain Therapy and Neuromodulation, Paracelsus Clinic Bremen, Bremen, Germany

Julian Ramin Andresen Faculty of Medicine, Sigmund Freud Private University, Vienna, Austria

Reimer Andresen Institute for Diagnostic and Interventional Radiology/Neuroradiology, Westküstenklinikum Heide, Adakdemic Teaching Hospital of the Universities of Kiel, Lübeck and Hamburg, Heide, Germany

Klaus Birnbaum Faculty Member of the Rheinisch-Westfälische Technische Hochschule Aachen, Orthopaedic Practice Clinic Hennef, Hennef, Germany

Hans Raimund Casser DRK Pain Center Mainz, Mainz, Germany

Dzmitry Dabravolski Center/Clinic for Spine Surgery and Spine Therapy of the Fichtelgebirge Hospital, Selb, Germany

Timm Joachim Filler Section for Clinical Anatomy, Heinrich-Heine-University (HHU) Düsseldorf, Düsseldorf, Germany

Raimund Firsching Department of Neurosurgery, Medical Faculty/University Hospital, Magdeburg, Germany

Stephan Grüner Cologne, Germany

Mathias Herwig Orthopaedics, Trauma Surgery and Sports Medicine, Johanna Etiennne Hospital, Neuss, Germany

Alexander Hölzl German Center for Orthopaedics, Department of Spine, Waldkliniken Eisenberg, Eisenberg, Germany

Ulrich Hubbe Department of Neurosurgery, University Medical Center Freiburg, Freiburg, Germany

A. Igressa Beta Klinik, Bonn, Germany

Jörg Jerosch Clinic for Orthopaedics, Trauma Surgery and Sports Medicine, Johanna Etienne Hospital, Neuss, Germany

Martin Komp Center for Spine Surgery and Pain Therapy, Center for Orthopedics and Trauma Surgery of the St. Elisabeth Group—Catholic Clinics Rhine-Ruhr, St. Anna Hospital Herne/University Hospital Marienhospital Herne/Marienhospital Witten, Herne, Germany

Michael Kraus ORTHIX Center, Augsburg, Germany

Andreas Lahm Tumor Center, Kliniken Maria Hilf Mönchengladbach, Academic Teaching Hospital of the RWTH Aachen, Mönchengladbach, Germany

Martin Legat Schmerz Zentrum Zofingen AG, Zofingen, Switzerland

Marcela Lippert-Grüner Faculty of Medicine Charles University Prague Clinic of Rehabilitation Medicine, Faculty Hospital Královské Vinohrady, Praha, Czech Republic

Harry Merk Clinic for Orthopaedics and Orthopaedic Surgery, Ernst-Moritz-Arndt University Greifswald, Greifswald, Germany

Guido Ostermann Orthopaedic Neurosurgical Centre, Recklinghausen, Germany

Sebastian Radmer Center for Movement Medicine, Berlin, Germany

Sebastian Ruetten Center for Spine Surgery and Pain Therapy, Center for Orthopedics and Trauma Surgery of the St. Elisabeth Group—Catholic Clinics Rhine-Ruhr, St. Anna Hospital Herne/University Hospital Marienhospital Herne/Marienhospital Witten, Herne, Germany

Gerd Sandvoss Meppen, Germany

Kai-Michael Scheufler Dortmund Hospital, Neurosurgery, Dortmund, Germany

Markus Schneider Medical Center alphaMED, Bamberg, Germany

Björn Carsten Schultheis Hospital Neuwerk "Maria von den Aposteln", Mönchengladbach, Germany

Axel Schulz Private Practice for Orthopedics, Lüdenscheid, Germany

Jochem Schunck Clinic for General Orthopaedics and Rheumatology, Eduardus Hospital, Cologne, Germany

Stefan Schu Department of Neurology, Sana Kliniken Duisburg, Duisburg, Germany

Günter Schütze Pain Therapy Dortmund, Dortmund, Germany

Uwe Schütz Clinic for Diagnostic and Interventional Radiology, University Hospital Ulm, Ulm, Germany

Theodoros Theodoridis Viktoria Clinic Bochum, Bochum, Germany

Andreas Veihelmann SHR Health Center Bad Herrenalb, Sports Clinic Stuttgart, Stuttgart, Germany

Patrick A. Weidle Hospital Neuwerk "Maria von den Aposteln", Mönchengladbach, Germany

Christian Wille Neurosurgical Practice Neuss, Neuss, Germany

Mathias Wollny Medimbursement, Tarmstedt, Germany

Abbreviations

ADL	Activities of daily living
ALIF	Anterior lumbar interbody fusion
ASE	Connecting segment disease
ASIPP	American Society of Interventional Pain Physicians
BK or BKP	Balloon kyphoplasty
BSP	Balloon Acroplasty
CRPS	Complex regional pain syndrome
CSPA	Cervical spinal nerve analgesia
DLIF	Direct lateral interbody fusion
DRG	Diagnosis-related case groups
DRG	Dorsal spinal ganglion
DSF	German Pain Questionnaire
DVO	Scientific umbrella organization osteology
EBM	Uniform valuation standard
ED	Effective dose
EDS	Spinal endoscopy, epiduroscopy
EKT	Epidural catheter therapy
ETD	Endoscopic transforaminal discectomy
FBSS	Failed back surgery syndrome, persistent pain after spinal surgery
GOÄ	Medical fee schedule
HED	Skin entry dose
HRQOL	Health-related quality of life
IASP	International Association for the Study of Pain
ICRP	International Commission on Radiological Protection
IDET	Intradiscal electrothermal therapy
IGOST	Interdisciplinary Society for General, Orthopaedic and Trauma Surgery Pain Therapy
InEK	Institute for the Hospital Remuneration System
ITN	Intubation anaesthesia
KEDOQ	Core documentation and quality assurance in pain therapy
LLIF	Lateral lumbar interbody fusion
LSPA	Lumbar spinal nerve analgesia
MED	Microendoscopic discectomy
MIODL	Mobile intraoperative fluoroscopy
MMST	Multimodal pain therapy
NPSI	Neuropathic Pain Symptom Inventory
NSAID	Non-steroidal anti-inflammatory drugs
OD	Organ dose
OLIF	Oblique lumbar interbody fusion
OPS	Operation and procedure code

PCCL	Patient-related complexities and comorbidities
PDA	Peridural analgesia
PKP	Percutaneous kyphoplasty
PLIF	Posterior lumbar interbody fusion
PMMA	Polymethyl methacrylate (bone cement)
PRT	Periradicular therapy
PSA	Personal protective equipment
PVP	Percutaneous vertebroplasty
QST	Quantitative sensory testing
RCT	Randomized controlled trial
RFK	Radiofrequency kyphoplasty
RFS	Radiofrequency sacroplasty
SCS	Spinal cord stimulation
SIG	Sacroiliac joint
SIS	Spine Intervention Society
TENS	Transcutaneous electrical nerve stimulation
TLIF	Transforaminal lumbar interbody fusion
TNF	Tumour necrosis factor
VAS	Visual analogue scale
VSP	Vertebrosacroplasty
WISE	World Initiative on Spinal Endoscopy
XLIF	Extreme lateral interbody fusion
ZSP	Cement sacroplasty

Billing Proposals for Interventional Procedures on the Spine

G. Sandvoss

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_1

1

1.1 The Bielefeld Settlement Table of the Professional Association of German Neurosurgeons

The Expert Committee of the Professional Association of German Neurosurgeons (BDNC) presents here for the first time a billing table (as of 8/2018) in which, in addition to the minimally invasive standard treatments, the current billing modalities according to the uniform assessment scale (EBM), physician fee schedule (GOÄ), operation and procedure code (OPS) and diagnosis-related case groups (DRG) as well as the examination times are listed (Table 1.1).

It was intended that the list would be tabulated according to the new EBM or the new GOÄ, but the German Medical Association (BÄK) and the National Association of Statutory Health Insurance Physicians (KBV) have not yet issued an update as of February 2018.

This purely informative open-ended table is freely available to all physicians with the request that comments and suggestions for additions be sent to the author.

Table 1.1 Bielefeld billing table of the Professional Association of German Neurosurgeons for minimally invasive standard treatments of the spine (as of 8/2018)

Operation/therapy measure	EBM	GOÄ	OPS	DRG	Test time (in min)	Simultaneous surgery (in min)
Endoscopic SIG denervation and capsular coagulation + SIG arthrosis	Not listed in EBM	3300, 2121 × 2[i], 5295 × 2.5 intraop.	5–811.4e; 5–059.b	I28B		
PRT BW	34,503: 1 × daily	2583A° or 476 × 3,5; 477; 5295	8–914.1–		25	
PRT + CT	34,505: 1 × daily; 34260[a]	2583A° od. 476 × 3,5; 477; 5378; 5377	8–914.1–		25	
Racz	(P2) 31252; 31,504; 31,669; 31,670	469; 474; 475; 5345A[e]; 5346A[d]; 5351 (2281[c])	3–13 × Epidurography; 5–038.20		36	
IDET	Not listed in EBM	2598A + 2282	5-83a.1–			
PASHA	Like temp. Ganglion stimulation or Racz; 30,723	469; 474; 475; 5345A[e]; 5346A[d]; 5351 (2570)	5–039.38; 5–039.j0; 1–203.1		36	
Transsacral block	30,731; 34,280 (KM 34260 if applicable)	476 + 477; 5295; if applicable 370	8–915		5	
Lumbar plexus analgesia	30,731; KM 34260[b]	5295; 370; 476; 477	8–915		5	
Plexus analgesia	30,731	476 + 477	8–915		5	
Facet denervation BW	34,503: 1 × daily 1 segment (4 segments required)	Open 2120A[f] /joint; percutaneous 2598A[g] = 3 joints	5–830.2 or 5-83a.0–		25	
Endoscopic facet denervation (PE!)	(O2) 31242; 31,503; 31,614; 31,615; 34,280	3300; 2 × 2580[h]	5–059.b; 5–041.5		25	
Facet infiltration BW	34,503: 1 × daily	5295; 301; 491; (5070 if applicable)	8–917.1–		25	
Reischauer blockade	30,724 or 30,722	476 + 477	8–914.-		3	

(continued)

Table 1.1 (continued)

Operation/therapy measure	EBM	GOÄ	OPS	DRG	Test time (in min)	Simultaneous surgery (in min)
Laser discectomy 34,260 +	(D3) 31133; 31,504; 31,616; 31,617	476; 477; 706; 2566 (or 2281 × 2^i)	5–831.8; 3–131		44	
Volume reduction of the intervertebral disc 34,260 +	(D3) 31133; 31,504; 31,616; 31,617	474; 475; 3300; 2281 × 2^i	5–831.8; 3–131		44	
Microdiscectomy	(D5) 31135; 31,505; 31,618; 31,619; 34,280	5295 × 2,5; 301; 2566	5–831.2		72	
Microdiscectomy + scattered sequestrum	(D5) 31135; 31,505; 31,618; 31,619; 34,280	5295 × 2,5; 301; 2566; 2574	5–831.2; 5–831.0		72	
Microdiscectomy + facet denervation	(D5) 31135; 31,618; 31,619; + 15 min + tube	5295 × 2,5; 301; 2566; 2120A/ joint	5–831.2; 5–830.2		72	+ 15
Cloward + cage	(D5) 31135; 31,505; 31,618; 31,619: + 30 min + tube	5295 × 2,5; 301; 2565; 2574; 2286; 5260 × 2,5	5–831.2; 5–832.0; 5-83b.7–		72	+ 30
Spinal stenosis	(D5) 31135; 31,505; 31,618; 31,619	5295 × 2.5; 301; 2566; 2574; 5260 × 2.5 intraop.	5–831.2; 5–839.6–; 5–832.4		72	
Endoband disc	(D3) 31133; 31,504; 31,616; 31,617	2566 × 2^i; 3300; 5260; (5070 if applicable); 706	5–831.5; 3–131		44	
Ganglion stimulation temporary	(P2) 31252; 31,504; 31,669; 31,670	469 better 474; 475; 2570 × 1,7; 661A	5–039.j0; 1–203.1		36	
Ganglion stimulation permanent	(P5) 31255; 31,674; (30740)	469 better 474; 475; 2570 × 3,5; 661A (possibly 3096A)	5–039.j0; 1–203.1		72	
DCS/HF test stimulation	(P6) 31256; 31,675; 31,676; 34,280	2570 × 1,7; 5295; 832 × 3,5 multiple or 661A	5–039.32 ff; 5–059.80 (5–059.81)		83	
DCS/HF stimulation	(P6) 31256; 31,675; 31,676; 34,280; (30740)	2570 × 3,5; 5295; 661A (or 3095A; 3096A)	5–039.34 ff; 5–059.82 (5–059.83)		83	

TENS	30,712	832; 661A			3	
PDA	30,731; (30740)	472 one-time; 473 catheter; 474 > 5 h; 475	8–910		5	
Pain pump lumbar 34,280 +	(P2) 31252; 31,504; 31,669; 31,670; 30,750	2540; 2421; 305; 5295; 661A; 265	5–038.4-		36	
Pump filling/reprogramming	30,740 or 30,751: Baclofen	470; 265; 661A			5	
Kyphoplasty	Not listed in EBM	2332 if applicable. 2333; 2286 × 2^{i}; 2 × 643A × 3.5 intraop. + tube	5–839.a-			
Vertebroplasty	Not listed in EBM	2332 if necessary 2333; 311; 5260 × 2,5	5–839.9–; 8–202.-	I09C		
Spineoplasty	Not listed in EBM	2332 if necessary 2333; 2286; 2258; 311; 5260 × 2,5	5–839.9–; 5–835.9; 5–032.7; 8–202.-	I09C		
Lumbar disc prosthesis	(D7) 31137; 31,507; 31,621 + 30 min + tube	2287A; 2566; 2292; 5295 × 2,5; 5260 × 2,5 intraop.	5–839.1–; 5–832.0		120	+ 30
Cervical disc prosthesis	(D7) 31137; 31,507; 31,621 + 60 min + tube	2287A; 2565: 5260 × 2,5; 5295 × 2,5	5–839.1–; 5–832.6; 5–832.0		120	+ 60
Interspinous spreaders	Not listed in EBM	2566A (LG Hannover) or 2566 + 2284 or 2566 + 2286	5–839.b–			
Interspinous internal fixator (Aspen)	(D6) 31136; 31,507; 31,621	2287; 5295 × 2.5 intraop.	5-83b.4–		83	
Navigation WS		5378 × 2,5 intraop; 5377 or 2562 (LG Wiesbaden)	5-83w.2–			
Acupuncture lumbar spine	30,790 (1 × min. 40 min); 30,791	1, 7, 831A, 269 or 269a				
Pain management	CT approval for 300 patients 30,700; 30,702; 30,706; 30,708	15, 30a (min. 60 min), 31a, 34				

(continued)

Table 1.1 (continued)

Operation/therapy measure	EBM	GOÄ	OPS	DRG	Test time (in min)	Simultaneous surgery (in min)
Epiduroscopy	Not listed in EBM	687 analog	1–698.1			
Epiduroscopic OP adhesiolysis	Not listed in EBM	2570 analog[j]	5–059.b; 1–512.2; 5–036.6			

SIG sacroiliac joint; *PRT* periradicular therapy; *Racz* Racz catheter (epidural neurolysis); *IDET* intradiscal electrothermal therapy, *PASHA* multifunctional electrode; *BW* image converter; DCS/HF posterior cord stimulation with high frequency; *TENS* transcutaneous electrical nerve stimulation; *PDA* peridural anaesthesia; *KM* contrast medium

[a]34260: KM administration during PRT: This is not a pharmacotherapeutic but a diagnostic application to exclude a faulty injection in root cysts

[b]34260: KM administration in lumbar plexus analgesia (Theissig 2008)

[c]2281 analogously recognized for Racz catheters: OLG Stuttgart, judgement of 19.11.2009–7 U 60/09, ArztR 9/2010 p. 247–248

[d]Racz catheter: GOÄ 5345A + 5346A + 5351 + 474 AG Miesbach, judgement of 2.9.2010–2 C 652/09

[e]Racz catheter: GOÄ 5345A + 5351 + 474 + 5070 + 2281 analog +5298 + 706: LG Würzburg, judgement of 4.1.2011–14 O 3117/07

[f]Open facet denervation: Hamburg-Norderstedt District Court, judgment of 13.11.2006—Gesch. No.: 41 C 246/00: PRT: 2583 analog (chemical neurolysis), open facet denervation 2120 per joint. LG Hannover, judgement of 28.11.2006—Gesch. No.: 2 O 97/05; interspinous spacer X-Stop 2566A next to 2120, if no "decompression" took place

[g]Percutaneous minimally invasive facet denervation: LG Stuttgart, judgement of 26.6.2009–4 S 83/08: GOÄ 2598a covers stereotactic, image converter-controlled or navigated denervation of three facet joints

[h]2 × 2580 in endo-facet denervation: the superior and inferior branches of the Luschkae recurrent nerve

[i]ArztR 11/2004 p. 403–407: Billing of radical surgery of a malignant thyroid tumour as a target service. Judgment of the BGH of 13.5.2004—III ZR 344/03: Double calculation of the main service to fill the "planwidrigen Regelungslücke". Wiesbaden Regional Court, ruling of 18.5.2016–5 O 113/13: Recognition of no. 2562 analogously for preoperative navigation on the spine.

[j]AG Gelsenkirchen 201 C 14/18 and AG Iserlohn dated 14.1.2016–41 C 171/15

Reference

Theissig F (2008) Anatomische Grundlagen der lumbalen Plexusanästhesie. Dissertation, Ludwig-Maximilians-Universität zu München

Interdisciplinary Multimodal Inpatient Pain Therapy

H. R. Casser

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_2

2

2.1 Introduction and Definition

Chronic therapy-resistant back pain simultaneously encompasses somatic, psychological and social dimensions, which are captured by an interdisciplinary assessment and require multimodal therapy.

Indication Criteria for an Interdisciplinary Multimodal Therapy Program (Arnold et al. 2009)

- High severity of disease with significant biopsychosocial consequences
- Failure of prior unimodal pain treatment, pain-related surgical/interventional intervention, or withdrawal treatment
- Pain-related impairment of the quality of life and the execution of life
- Somatic or psychosocial concomitant disease with demonstrable influence on the occurrence of pain
- The psychological and social stresses are not an expression of an independent psychiatric or cerebral disease
- Presence of risk factors for further pain chronification

Interdisciplinary multimodal therapy is understood as the simultaneous, integrated in approach as well as conceptually coordinated treatment of patients with chronic pain. Doctors from several specialties, psychotherapists and physiotherapists are permanent members of the treatment team. The joint assessment of the course of treatment within regular team meetings and the involvement of all therapists are obligatory (Casser et al. 2013b). Diagnostics and treatment are carried out according to an integrative concept with a behavioural medical orientation. The focus is on medical and psychotherapeutic treatment, education, relaxation procedures and physical exercise programmes (Arnold et al. 2009).

In the diagnosis-related group system (DRG system), this form of therapy is firmly established by the operation and procedure code (OPS, in the currently valid version 2018) as OPS code 8-918 "Multimodal pain therapy" and is therefore also relevant to remuneration.

The programmes can be carried out on an outpatient, day-care or inpatient basis. The evidence base for multimodal pain therapy is now indisputable, especially for back pain (Flor et al. 1992; Guzman et al. 2002; Schonstein et al. 2002; Jensen Stochkendahl et al. 2007; Hildebrandt and Pfingsten 2009). With regard to costs, it has also been demonstrated that multimodal therapy programmes for back pain are successful in the long term and bring about a significant reduction in costs in the further course of action (Nagel and Korb 2009).

A prerequisite of a multimodal therapy program should be the indication assessment (see overview above on indication criteria) by an interdisciplinary pain assessment (Casser 2016), as required in the case of therapy resistance after 6 or 12 weeks at the latest (National Health Care Guideline 2017).

2.2 Interdisciplinary Multimodal Assessment

Back pain patients with recurrent or persistent pain who are still at the beginning of the chronification process but are at increased risk of chronification, as well as patients who are already at a higher stage of chronification and for whom previous mono- or multidisciplinary treatment has not led to success, should undergo a sound assessment by means of an interdisciplinary assessment (Casser 2016). This assessment should be carried out in an open-ended manner, which may result in different consequences:

- Further treatment on an outpatient basis by a general practitioner or specialist with specific therapy recommendations or
- the initiation of an outpatient, day-care or inpatient multimodal therapy programme depending on the results of the assessment, the prognosis of the back pain and the individual circumstances (Arnold et al. 2009).

The components of the assessment are already described by the OPS code 1-910 "multidisciplinary algesiological diagnostics". With regard to an interdisciplinary assessment prior to comprehensive multimodal pain therapy, the contents, the disciplines involved and the scope of an assessment were developed by the Ad Hoc Commission "Multimodal Interdisciplinary Pain Therapy" of the German Pain Society (Casser et al. 2013a).

Components of an Interdisciplinary Multimodal Pain Assessment

- Detailed medical history and orienting physical examination (orthopaedic, neurological, if necessary rheumatological), if necessary additional imaging and electroneurographic procedures and invasive measures as well as test procedures and standardised clinical interviews, optionally with the involvement of other medical specialties
- Psychological/psychosomatic diagnostics with anamnesis, behavioural observation and assessment of the psychopathological status
- Physio-, moto-, ergotherapeutic findings
- Social medical assessment
- Team meeting with summary diagnosis description and coordination of further procedure, if necessary individual therapy program
- Final discussion with the patient

Preferably, the documentation of this assessment should be complete and standardized. The pain data collection and evaluation system with structural data, the core data set including the German Pain Questionnaire (DSF), the determination of the degree of chronification (MPSS), the recording of the pain diagnosis and the relevant diagnostic and therapeutic measures (Casser et al. 2013a) developed by the German Pain Society (Deutsche Schmerzgesellschaft e. V.) within the framework of the Core Documentation and Quality Assurance in Pain Therapy (KEDOQ) is suitable for this purpose.

With regard to the quality requirements of a back pain assessment, as already formulated by the expert panel of the Bertelsmann Foundation (2007), the following should be considered with regard to the practitioner classification: the pain therapist with ongoing recertification, the orthopaedist with the additional qualification "manual medicine", the medical and psychological psychotherapist with pain therapy qualification, the neurologist, the physiotherapist with manual medical knowledge of everyday, functional and stress tests and pain therapy experience as well as a specialist in spinal column surgery for the assessment of surgical options or previous surgical measures. Previous surgical measures should be consulted.

The involvement of orthopaedic surgeons and neurosurgeons has proven to be useful in the case of back pain in order to discuss these measures at an early stage and to assess surgical indications in advance on an interdisciplinary basis, also with the aim of providing differentiated patient information. However, it presupposes basic pain therapy experience on the part of the surgeon and unconditional acceptance into the assessment team.

2.3 Therapy Contents of the Interdisciplinary Multimodal Pain Therapy

The central components of multimodal pain therapy (MMST) are medical and psychological treatment, education, relaxation and physical exercise.

The therapy is based on a common "philosophy" of assessment and treatment of chronic pain with the aim of functional pain management and physical, psychological and social (re-)activation of the patient (Arnold et al. 2014). This includes close follow-up in the form of team meetings in which all treatment providers discuss goal setting, treatment progress and problems. This should take place at least once a week, in addition to ongoing consultation between team members and daily ward rounds. The collation of various findings

from the patient's medical history and treatment and the jointly agreed treatment strategy, which must be constantly updated, means that the overall treatment is significantly more effective than the individual measures of multimodal treatment (Huge et al. 2010; Pfingsten 2001). This requires a professional, appreciative, empathic and resource-oriented therapeutic attitude of all team members towards the patient, but also towards each other. In this context, the limits of the therapeutic possibilities of the individual disciplines and their methods must also be critically reflected, especially since causal treatment is often not possible or only possible to a limited extent.

After a detailed interdisciplinary assessment, the indication-specific selection of the approach is made by creating an individual treatment plan that takes into account the resources of the individual patient (Arnold et al. 2014).

Interdisciplinary measures in the narrower sense also include interdisciplinary ward rounds with the participation of all attending physicians, psychotherapists, physiotherapists, nursing therapists and social workers, with discussions as close in time as possible to the patient contact, which should be the focus of the ward rounds. In addition, interdisciplinary case discussions and joint examinations at the bedside or in the therapy rooms with interdisciplinary staffing are suitable for intensive care, especially in problem cases.

Criteria of true interdisciplinarity are the awareness of a shared responsibility, the performance of joint examinations and assessment of findings, a transparent communication process and a constant exchange of information within the team with avoidance of diagnostic or therapeutic "commissioned work" (Loeser 1998).

2.3.1 Special Medical Tasks

Doctors from various disciplines bear medical and legal responsibility for the patient in interdisciplinary consultation. This includes a professionally correct diagnosis and assessment, the review of the treatment indication, the risk education as well as the therapy not only of the pain but also of existing comorbidities up to communication with medical services and payers (Arnold et al. 2014).

Special medical tasks include daily ward rounds, patient information and education, special medicinal pain therapy (introduction and changeover as well as withdrawal) and, after careful indication, targeted manual medical measures or therapeutic local and regional anaesthesiological procedures. Particular importance is attached to individual medical consultations and follow-up examinations, in which the biopsychosocial model of the disease, the knowledge about measures of the interdisciplinary team as well as individual questions and solution options are presented to the patient and discussed with him. In addition, the doctor is responsible for writing the final report on the basis of the interdisciplinary findings with a formulation of the diagnoses, the course of the disease to date and the further procedure.

2.3.2 Psychotherapeutic Aspects of Treatment

Psychotherapeutic diagnosis and therapy are usually carried out in a multimodal interdisciplinary programme for chronic back pain patients. In addition, constellations may naturally arise in the course of psychotherapeutic work that necessitate outpatient or inpatient therapy in a psychosomatic or psychotherapeutic setting.

From experience, it is imperative that the task of interdisciplinary multimodal therapy is to align these additional treatment paths with the patient's individual pain experience, because otherwise the patient will continue to maintain the split between psyche and body and the therapy effects will stand side by side (Casser et al. 2013a).

The National Health Care Guidelines (NVL 2017) recommend progressive muscle relaxation (Jacobson 1939) and multimodal embedded behavioral therapy for the treatment of

chronic low back pain. Depth psychological approaches have also developed in recent years and are used in multimodal settings (Senf and Gerlach 2011).

Essential for long-term therapeutic success is the systematic instruction of both relaxation techniques and concrete behavioural therapy approaches with a focus on the independent adoption and manifestation of these approaches in the patient's everyday life.

> The central treatment goal of a multimodal therapy for chronic pain is the restoration of objective and subjective functional ability ("functional restoration"), which is accompanied by an increase in the patient's ability to control and sense of competence and is supported therapeutically in a resource-oriented manner (Arnold et al. 2009).

As with the general goals of multimodal pain therapy, the reduction of impairment and the improvement of quality of life are in the foreground even before pain reduction. Especially for patients with chronic back pain, this order is significant, because with a prevalence of occurring back pain within a year of 40–60%, a complete freedom from pain seems rather illusory. As Pfingsten and Nilges (2012) point out, the affliction of back pain may also lie in the unwillingness to put up with normal impairments of well-being due to general developments in health care. Due to increased expectations of health and freedom from complaints, this leads to pathological disturbances in normal physical phenomena.

Psychotherapeutic sub-goals in the therapy of chronic back pain are currently to be seen in the communication of a biopsychosocial model of the disease, further in the motivation for long-term behavioural change, in the promotion of perception of limits, feelings and needs, in the promotion of the ability to relax and body perception, in the reduction of catastrophizing and fear-avoiding coping approaches as well as in the reduction of helplessness and withdrawal. If the symptoms are unchangeable, it may be necessary to promote acceptance of the unavoidable and to support the development of new perspectives.

Kröner-Herwig (2000), representing many authors, clearly states that freedom from pain cannot be an appropriate goal. She emphasises that the teaching of an appropriate model of pain must also include the acceptance of pain as a necessary and natural phenomenon.

Especially the inclusion of psychological variables in the model of chronic pain is essential for the success of therapy, but also means a great challenge for patients with a pronounced somatic clinical picture.

In recent years, a whole range of different therapeutic approaches have been developed, which have mainly been investigated and evaluated in the context of chronic back pain. Essential in the German-speaking area and as a starting point for the therapy of chronic back pain is the cognitive-behavioural approach of Basler (2001).

For back pain, the concept of Fear Avoidance (Pfingsten 2001) is central in both research and therapy. It is complemented by the Avoidance-Endurance model (Hasenbring and Verbunt 2010). Fears of pain resulting from exercise are triggered by catastrophizing evaluations of harm or future harm (catastrophizing; Sullivan et al. 2001) and lead to maladaptive sparing and misbehavior that perpetuates and even exacerbates pain and its propagation. Deconditioning of the muscular system, passivity in shaping one's life and later depressive reactions are the result. Therapeutic concepts similar to those of anxiety confrontation have emerged for this purpose (Goubert et al. 2002). The procedure consists in the guided confrontation of the patient with the movement and the pain. By changing catastrophizing assumptions, the experience is facilitated that due to exercise and physical conditioning using quota schedules (timed exercises that are increased over a period of time), pain decreases. Patients learn the relationship between passive rest and increasing pain. With the help of the quota plans, they gradually increase their performance and in this way regain confidence in their body.

Furthermore, there is evidence that flexible goal adjustment tends to support the management of chronic back pain and improves the success of therapy (Schmitz et al. 1996).

2

In recent years, the concept of accepting the unchangeable part of pain complaints has gained acceptance (Dahl et al. 2005). This is primarily concerned with dissolving static coping attempts that do not achieve improvement by promoting an accepting attitude. This creates space to mourn the situation that has arisen on the one hand, and on the other to develop new perspectives in life management that can once again satisfactorily fill the patient's life despite the pain. This concept is usefully supplemented by concepts of mindfulness (Heidenreich and Michalak 2003), in which the patient is taught the skills of attentively perceiving himself, his body and the environment with its manifold relationships. The central point here is to allow perception to stand value-free in its contrasts of pleasant/unpleasant and thus to achieve a detachment from often unhelpful cognitions or emotions that are based on rigid norms and values.

Motivational concepts (Rau et al. 2008) have been developed and evaluated for motivating patients to change their behaviour, which is often the result of multimodal therapy for chronic back pain. The transfer of physical exercise, relaxation and modified coping approaches is essential for the maintenance and expansion of good therapy results through multimodal therapy.

Essentially, psychotherapeutic treatment of chronic back pain is based on the following content (Kröner-Herwig 2000; Kröner-Herwig and Pfingsten 2012):

- **Education**, which refers to the teaching of a biopsychosocial model of disease. This also includes teaching the importance of pain-related cognitions and emotions, acceptance-promoting measures and their background, as well as other special features of chronic back pain, psychotherapeutic approaches and multimodal therapy.
- **Relaxation:** PMR (progressive muscle relaxation according to Jacobson), which is recommended as a therapy component in the National Treatment Guideline for Low Back Pain, has proven to be particularly effective. However, relaxation alone is not sufficient; it requires, above all, good preparation with embedding in the patient's individual disease model as well as regular practice that goes beyond the application in the multimodal therapy period and must be consistently continued in everyday life. This requires sufficient information about the meaning and effect of relaxation on pain, the change of unrealistic expectations (fast freedom from pain in and after relaxation, the occurrence of exclusively pleasant bodily experiences, etc.) as well as the decatastrophization of unpleasant physical phenomena that usually occur especially at the beginning of relaxation (intensification of pain, twitching, circulation problems afterwards, etc.).
- **Biofeedback** can be used on the one hand to map the ability to relax in patients with low body awareness and simultaneous high resistance to this measure as a feedback and motivational aid. It can also be used to provide feedback on the correlation between psychological and physical factors. It is also possible to control physical exercises with the help of a portable device.
- The focus is on **therapy** according to the above-mentioned approaches, especially the Fear-Avoidance or the Avoidance-Endurance model as well as the promotion of acceptance and mindfulness.

> In order to teach patients modified behavioural patterns, e.g. consistent relaxation and physical exercises as well as stamina, which they should maintain after multimodal therapy, it is necessary to focus early on the transfer to everyday life, which must also be discussed and in part completed during therapy.

In therapy, the obstacles to implementation should be addressed, and the patient should be prepared by means of special exercises (e.g., promoting social competence in demarcation situations) or suggestions from the group setting. In most cases, subsequent outpatient behavioural therapy proves useful in supporting the difficult transfer. In the case of more profound psychological difficulties of

the patients, a subsequent depth psychological therapy may also be necessary.

> It is important to always practice self-help strategies and methods to cope with pain. The communication of one's own direct experience is highly significant for transfer and change (Frede 2011).

In the case of co-morbidity with a mental illness or particularly stressful environmental or living conditions, the decision on further psychotherapeutic treatment is essential. This must be discussed with the patient and embedded in his or her individual illness model. The extent to which inpatient, day-care or outpatient treatment is necessary must be decided on an individual basis according to the severity of the mental disorder. Experience has shown, however, that such therapies were particularly useful and helpful when patients had previously received a clear classification of the mental disorder or mood disorder with regard to their pain model, because they then experienced these measures as integrated.

2.3.3 Exercise Therapy

The contribution of the movement therapy disciplines, primarily physiotherapy and sports therapy but also occupational therapy and mototherapy, is based on the analysis of the elements of movement, in particular the assessment of strength, mobility, coordinative abilities and endurance, the survey of the movement status and the assessment of movement behaviour and vegetative reactions, in addition to the medical functional examination (Arnold et al. 2014). The aim of movement therapy measures is to restore physical functional capacity and activity as far as possible in coordination with the organ-specific findings and the patient's ideas. Particularly in physiotherapy, the often lacking knowledge and experience of patients regarding physical functions, but also the lack of awareness of individual possibilities of influence, must first be changed in chronic pain patients through education and instruction as well as exchange in the group. This includes pointing out measures to influence physiological reactions, e.g. through biofeedback. The frequently existing deficits of body perception, recognizable by pathological posture, altered muscle tone and movement patterns as well as disturbed body schema, especially in chronic pain patients, require training of body perception with regard to sensitivity, proprioception and sensory perception, supported by biofeedback, electromyography (EMG), mirror therapy and ultrasound. The often increased level of tension is tried to be influenced with tone regulation through active variation, relaxation, guided perception, breath tension and biofeedback. Changes in the autonomic nervous system are counteracted by stress management through exercise and sport as well as relaxation techniques and physical therapy measures. Problem areas such as physical functional impairments taking into account structural as well as functional changes, deconditioning due to inappropriate sparing and non-use, fear-avoidance behaviour, lack of confidence in physical performance and misjudgement of physical performance with marked overstraining behaviour require ongoing assessment of the functional capacity of the locomotor organs (clinical reasoning). Furthermore, the treatment spectrum also extends to individual and group therapeutic measures for local and global stabilisation, mobilisation and coordination improvement, activity increase through pacing programmes, reconditioning through sport, strength and endurance training as well as self-exercises, balancing of loading and unloading and development of self-help strategies in continuation and deepening of the psychotherapy taking place in parallel.

> Particularly reduced dysfunctional physical performance due to rest or constant pronounced overstraining behaviour can be corrected by pacing programmes and graded activity or confrontation ("exposure") in cooperation with psychotherapists. The same applies to the restoration of the ability to work supported by work conditioning or work hardening.

In individual cases, passive physiotherapeutic measures may also be indicated for a lim-

ited period of time in coordination with the team, e.g. the application of heat, cold or chirotherapy.

2.3.4 Algesiological Specialist Assistance

The role of health care and nursing or medical assistance professions in the context of MMST is sometimes underestimated. Especially in the inpatient setting, the realization of activation and functional recovery of patients is inconceivable without the support of the nursing team. Information and behaviour can be conveyed in this way to both the team and the patients. In addition, nursing therapy takes over important administrative and organisational activities that exceed the genuine nursing activities. Behavioural observation of patients over 24 h in the inpatient area as well as in everyday life situations with the information gained from this by the nursing team is of great importance for the interdisciplinary team (Arnold et al. 2014). Corresponding further training opportunities for algesiological specialist assistance are increasingly being used.

2.3.5 Results

Prospective studies show positive and long-term effects for MMST with regard to a reduction in complaints as well as disease symptomatology and also the use of health care services for different pain diseases and patient groups (Hechler et al. 2014; Schiltenwolf et al. 2006; Häuser et al. 2009; Brömme et al. 2015; Buchner et al. 2006; Gunreben-Stempfle et al. 2009; Hildebrandt and Pfingsten 2009; Mattenklodt et al. 2008; Nagel and Korb 2009; Pöhlmann et al. 2009; Schütze et al. 2009).

Internationally, systematic reviews and meta-analyses also demonstrate the effectiveness of multimodal pain management programs for chronic back pain (Kamper et al. 2014), fibromyalgia syndrome (Häuser et al. 2009), and other pain syndromes (Scascighini et al. 2008).

However, MMST is also effective for specific pain syndromes in connection with psychological factors. For example, highly significant improvements in pain intensity and function were shown in various neuropathic pain syndromes (Seddigh et al. 2014). Similarly, MMST is recommended for refractory chronic shoulder pain with pain-maintaining behaviors (Diercks et al. 2014) as well as for chronic headaches.

In the area of chronic rheumatic complaints, there is also a multimodal rheumatological complex treatment (OPS 8-983) with consideration of the functional restriction and the extent of pain at the beginning and at the end of the inpatient stay. If the treatment of chronic pain syndromes, in particular myofascial complaints, fibromyalgia or stably controlled inflammatory rheumatic diseases with clear psychosocial factors, is in the foreground, MMST (OPS 8-918) should be given preference.

First results of a prospective multicenter study on the effectiveness of multimodal musculoskeletal complex therapy (OPS 8-977) with special consideration of manual medical and physiotherapeutic measures as well as psychotherapeutic involvement show significant improvements regarding pain intensity and functional status in chronic vertebragen pain syndromes at the end of complex treatment (Smolenski et al. 2014; Niemier et al. 2018).

A real improvement in the care of chronic pain sufferers can only be achieved through the widespread implementation of multimodal pain therapy programs in the health care system. To this end, the structural and organizational prerequisites would have to be created, e.g. in the form of a disease management program (DMP Back Pain), in order to use the form of treatment throughout Germany and across sectors if the need is proven.

2.4 Supply Structures

The unsatisfactory situation of back pain patients has long been attributed to inadequate medical and health care structures. For example, the only evidence-based form of

therapy available for therapy-resistant chronic treatment cases, interdisciplinary multimodal treatment, is not available locally for many patients.

In a dissertation at the DRK Pain Center in Mainz, it was demonstrated that, especially in the case of chronic back pain patients, it takes an average of 17 years from the onset of complaints until they are presented to a pain center with an interdisciplinary, multimodal diagnostic and therapeutic treatment program (Fig. 2.1).

The Bertelsmann Expert Panel "Back Pain" (2007) has developed a treatment pathway based on the therapy algorithm of the IGOST (Interdisciplinary Society for General, Orthopaedic and Trauma Surgery Pain Therapy) (Casser 2008). It covers all forms of back pain and includes a 3-level concept. Already in primary care, a severity-oriented allocation of back pain patients is required, as is the direct allocation of patients suspected of chronification with psychosocial risk factors to the interdisciplinary level for assessment (Fig. 2.2).

A differentiation is made at the primary care level (general practitioner or specialist):

- Emergencies (dark red flags) are referred to a surgically oriented spine center,
- Patients with special spinal disorders (red flags) are presented to the specialist (level 2) and
- Patients with complex back pain with psychosocial abnormalities (yellow flags) using the Heidelberg (HKF-R 10) or Örebro short questionnaire are referred to an interdisciplinary pain centre for assessment (level 3).

If the symptoms do not improve or worsen, the patient must be referred to the next higher level after 4 weeks at the latest, or if he/she is still unable to work.

Whereas in the first level, in addition to the above-mentioned screening, a detailed explanation of the patient and, if necessary, symptomatic therapy measures take place in accordance with the guidelines, further diagnostics and therapy take place in the specialist level (second level), if necessary also with the consultation of other specialists. In the case of psychosocial risk factors (HKF-R 10) or lack of improvement in symptoms over 8 weeks or 4 weeks of incapacity to work, the patient belongs to the interdisciplinary pain therapy level, where first of all a comprehensive assessment and, if necessary—resulting from this—an outpatient, day-care or inpatient multimodal therapy programme takes place with final evaluation and prognostic statement on further treatment and fitness for work.

The pilot project of the IGOST/FPZ-IV back pain care algorithm conducted throughout Germany included 9455 patient records with 1220 participating physicians and 123 networks in collaboration with 27 different, predominantly regional health insurance funds during the period studied, 2006–2008 (Lindena et al. 2016). Analysis of the data

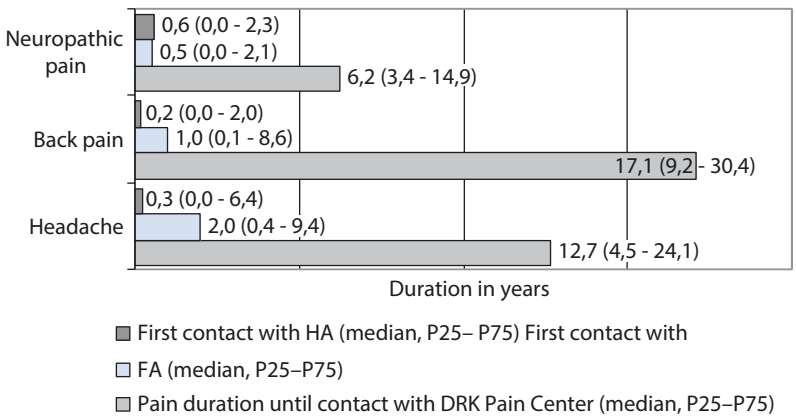
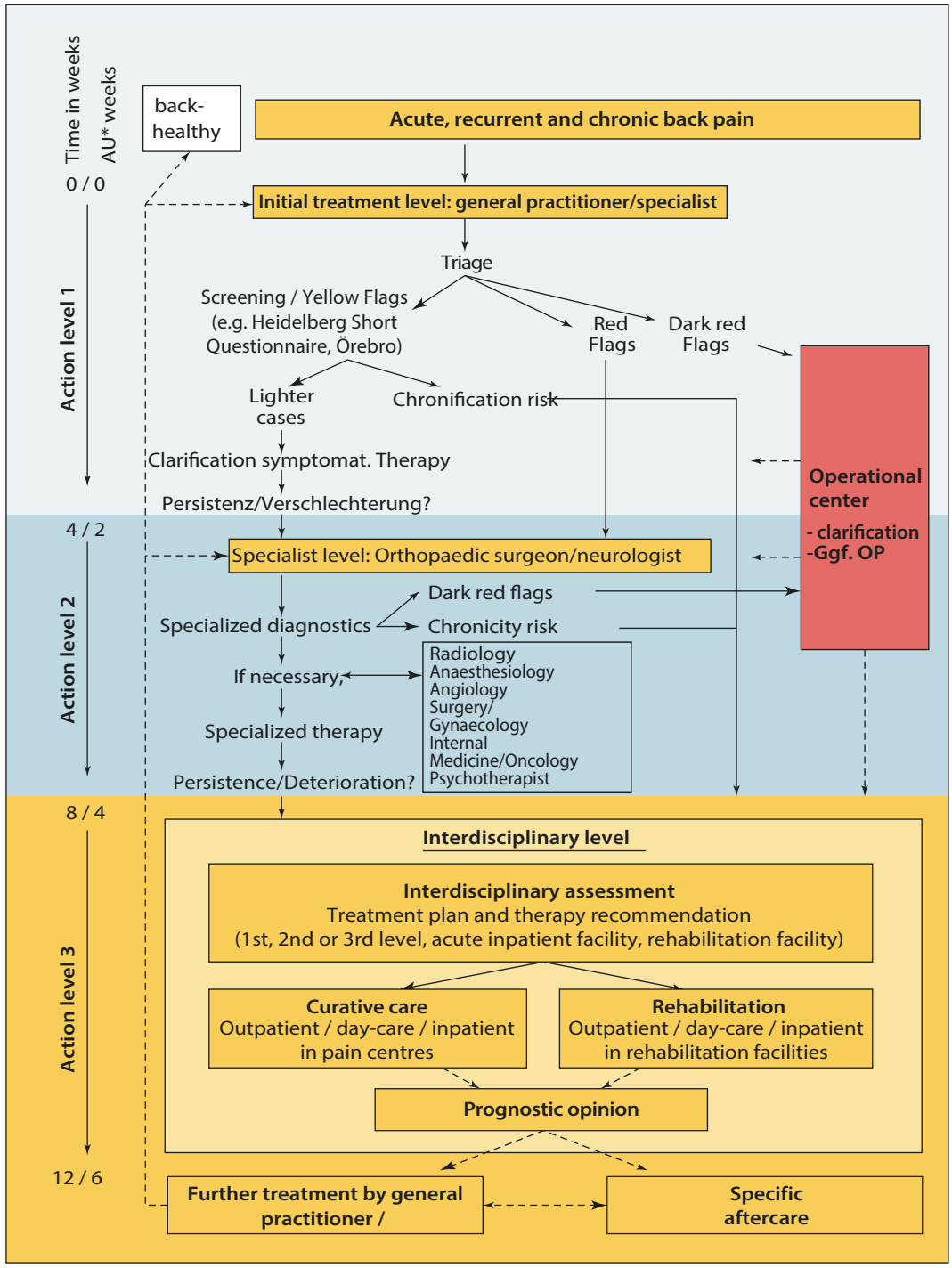


Fig. 2.1 Time spans from the onset of pain symptoms to first contacts with the respective medical care. *HA* general practitioner; *FA* specialist. (From Casser et al. 2013b; adapted from Sorg 2008)

Supply path / algorithm
Summarized presentation

2



* AU = incapacity for work

Fig. 2.2 Care pathway/algorithm back pain. *AU* incapacity for work. (From Casser et al. 2013b; Bertelsmann Expert Panel 2007)

confirmed the practicality of the 3-level model. The interface definitions, in particular the referral of patients with psychosocial risk factors (yellow flags) based on the HKF-R 10 to the third interdisciplinary level, were followed in 82% with a patient proportion of 40% selected for an interdisciplinary assessment based on the HKF-R 10. Overall, all patients showed a reduction in pain intensity of 2–3 points on the numerical rating scale, with an increase in activity. Deficits were shown in the insufficient capacity to act of the 3rd (interdisciplinary) level, which does not have sufficient structures and remuneration in the outpatient area.

Figure 2.3 depicts the actual-target situation of current back pain care and shows the potential for improvement. Taking into account the current supply situation in Germany, these goals will only be achievable in the medium term.

2.5 Quality Assurance

A prerequisite for the effectiveness of interdisciplinary multimodal pain therapy (IMST) are high requirements for the structural and process quality of treatment, as defined by the ad hoc commission "Multimodal Pain Therapy" of the German Pain Society (Arnold et al. 2009). The German Pain Society therefore initiated the quality assurance project KEDOQ-Pain "Core documentation and quality assurance of pain therapy" in 2008 (Casser et al. 2012). The aim of the project is nationwide and cross-sectoral external quality assurance and the development of

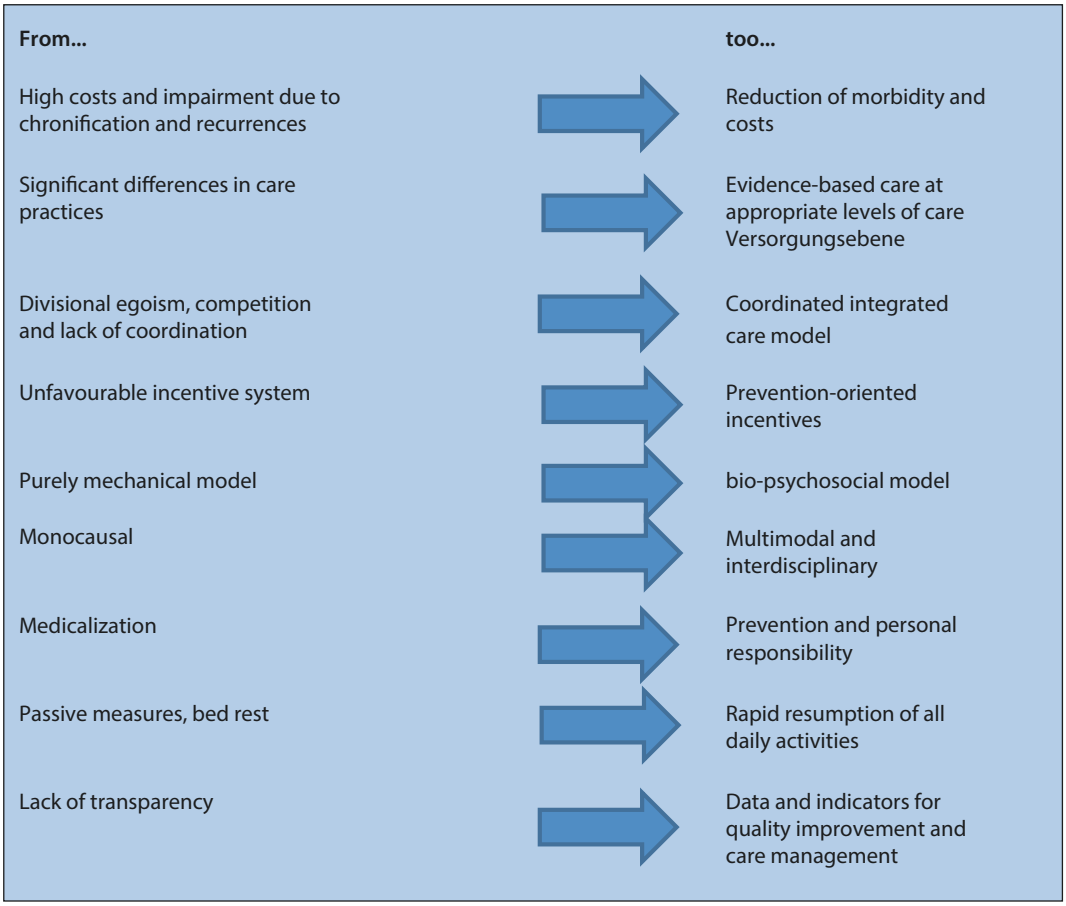


Fig. 2.3 Actual-target situation of current back pain care. (From Casser et al. 2013b; adapted from Bertelsmann Expert Panel 2007)

quality indicators in specialized pain therapy, especially for interdisciplinary multimodal pain therapy. In addition, a broad database is to be generated that will enable independent health care research free of particular interests. The basis of KEDOQ-Pain is a broadly agreed core data set that includes essential pain-relevant parameters that are collected at the beginning of therapy, at the end of treatment and during follow-up. The German Pain Questionnaire (DASS) developed by the German Pain Society (Nagel et al. 2002) serves as the data basis at the beginning of therapy.

2.6 Conclusion and Outlook

Interdisciplinary multimodal pain therapy programs (IMST) are oriented towards the treatment goals of functional restoration and a biopsychosocial model. According to the experts involved, the therapy contents presented in the consensus paper (Arnold et al. 2009) are suitable for achieving these goals. They must be supported by a closely cooperating interdisciplinary treatment team. So far, experience has been gained mainly in day-care and inpatient treatment settings. Low-threshold outpatient multimodal programmes are hardly widespread and should be further developed and evaluated in the future. They need to be guided by the principles and guidelines discussed here. The principles of MMST, namely the biopsychosocial view of pain, multimodal and interdisciplinary approaches in diagnosis and treatment of acute pain syndromes as well, can help to counteract the chronification of pain.

References

Arnold B, Brinkschmidt T, Casser HR, Gralow I, Irnich D, Klimczyk K, Müller G, Nagel B, Pfingsten M, Schiltenwolf M, Sittl R, Söllner W (2009) Multimodale Schmerztherapie—Konzepte und Indikation. Schmerz 23:112–120

Arnold B, Brinkschmidt T, Casser HR et al (2014) Multimodale Schmerztherapie für die Behandlung chronischer Schmerzsyndrome. Schmerz 28: 459–472

Basler H-D (2001) Chronische Kopf- und Rückenschmerzen. Psychologisches Trainingsprogramm. Vandenhoeck und Ruprecht, Göttingen

Bertelsmann Stiftung, Experten-Panel Rückenschmerz (Hrsg) (2007) Gesundheitspfad Rücken. Leitfaden. www.bertelsmann-stiftung.de/bst/de/media/xcms_bst_dms_21536__2.pdf. Accessed on 16.07.2018

Brömme J, Mohokum M, Disch AC et al (2015) Interdisziplinäre multimodale Schmerztherapie vs. Konventionelle Therapie—Eine Kostenanalyse bei Patienten mit chronischen Rückenschmerzen. Schmerz 29:195–202

Buchner M, Zahlten-Hinguranage A, Schiltenwolf M et al (2006) Therapy outcome after multidisciplinary treatment for chronic neck and chronic low back pain. Scand J Rheumatol 35:363–367

Casser HR (2008) Der chronische untere Rückenschmerz. Nervenheilkunde 4:251–263

Casser HR (2016) Spezifischer, nicht-spezifischer, akuter/subakuter und chronischer Rückenschmerz: definition. In: Casser HR, Hasenbring M, Becker A, Baron R (Hrsg) Rücken- und Nackenschmerzen. Springer, Berlin

Casser HR, Hüppe M, Kohlmann KJ, Lindena G, Maier C, Nagel B, Pfingsten M, Thoma R (2012) Deutscher Schmerzfragebogen (DSF) und standardisierte Dokumentation mit KEDOQ-Schmerz. Schmerz 26:168–175

Casser et al (2013a) Interdisziplinäres Assessment zur multimodalen Schmerztherapie. Schmerz 27:363–370

Casser et al (2013b) Schmerzen an der Wirbelsäule. In: Baron et al (Hrsg) Praktische Schmerzmedizin, 3. Aufl. Springer, Berlin/Heidelberg

Dahl J, Wilson KG, Luciano C, Hayes SC (2005) Acceptance and commitment therapy for chronic pain. Context Press, Reno

Diercks R, Bron C, Dorrestijn O et al (2014) Guideline for diagnosis and treatment of subacromial pain syndrome: a multidisciplinary review by the Dutch Orthopaedic association. Acta Orthop 85(3):314–322

Flor H, Fydrich T, Turk DC (1992) Efficacy of multidisciplinary pain treatment centers: a meta-analytic review. Efficacy of multi-disciplinary pain treatment centers: a metaanalytic review. Pain 49:221–230

Frede U (2011) Praxis der Schmerztherapie—kritische Reflexion aus der Patientenperspektive. In: Kröner-Herwig B, Frettlöh J, Klinger R, Nilges P (Hrsg) Schmerzpsychotherapie, 7. Aufl. Springer, Heidelberg, S 686–700

Goubert L, Francken G, Crombez G, Vansteenwegen D, Lysens R (2002) Exposure to physical movement in cornich back pain patients: no evidence for generalization across different movements. Behav Res Ther 40:415–429

Gunreben-Stempfle B, Grießinger N, Lang E et al (2009) Effectiveness of an intensive multidisciplinary headache treatment program. Headache 49:990–1000

Guzman J, Esmail R, Karjalainen K et al (2002) Multidisciplinary rehabilitation for chronic low back pain: systematic review. Cochrane Database Ayst Rev 1:CD000963

Hasenbring M, Verbunt JA (2010) Fear-avoidance and endurance-related responses to pain: new models of behavior and their consequences for clinical practice. Clin J Pain 26:747–753

Häuser W, Bernardy K, Arnold B et al (2009) Efficacy of multicomponent treatment in fibromyalgia syndrome: a meta-analysis of randomized controlled clinical trials. Arthritis Rheum 61(2):216–224

Hechler T, Ruhe AK, Schmidt P et al (2014) Inpatient-based intensive interdisciplinary pain treatment for highly impaired children with severe chronic pain:randomized controlled trial of efficacy and economic effects. Pain 155:118–128

Heidenreich T, Michalak J (2003) Achtsamkeit ("Mindfulness") als Therapieprinzip in Verhaltenstherapie und Verhaltensmedizin. Verhaltenstherapie 13: 264–274

Hildebrandt J, Pfingsten M (2009) Vom GRIP zur multimodalen Schmerztherapie Orthopade 38:885–895

Huge V, Müller E, Beyer A et al (2010) Patients with chronic pain syndromes. Impact of an individual outpatient therapy program on pain and health-related quality of life. Schmerz 24:459–467

Jacobson E (1939) Progressive relaxation. University of Chicago Press, Chicago

Jensen Stochkendahl M, Christensen HAW, Hartvigsen J et al (2007) Manuelle Untersuchung der Wirbelsäule. Ein systematischer, kritischer Review zur Reproduzierbarkeit. Man Med 45:301–308

Kamper SJ, Apeldoorn AT, Chiarotto A et al (2014) Multidisciplinary biopsychosocial rehabilitation for chronic low back pain. Cochrane Database Syst Rev 9:CD000963. https://doi.org/10.1002/14651858.CD000963

Kröner-Herwig B (2000) Rückenschmerz. Fortschritte der Psychotherapie, Hogrefe, Göttingen

Kröner-Herwig B, Pfingsten M (2012) Verhaltenstherapeutische Methoden. In: Hildebrandt J, Pfingsten M (Hrsg) Rückenschmerz und Lendenwirbelsäule. Elsevier, München, S 356–365

Lindena G, Strohmeier M, Casser R (2016) Integrationsversorgung für Patienten mit Rückenschmerzen. Daten aus dem IGOST-FPZ-KONZEPT OUP 6:379–387

Loeser JD (1998) Desirable characteristics for pain treatment facilities: report of the IASP taskforce. In: Bond MR, Charlton JE, Woolf CJ (eds) Proceedings of the 6th world congress on pain. Elsevier, Amsterdam, pp 411–415

Mattenklodt P, Ingenhorst A, Wille C et al (2008) Multimodal group therapy for the elderly with chronic pain: concept and results in a before and after comparison. Schmerz 22:551–561

Nagel B, Korb J (2009) Multimodale Therapie—nachhaltig wirksam und kosteneffektiv. Orthopade 38:907–912

Nagel B, Gerbershagen HU, Lindena G, Pfingsten M (2002) Entwicklung und empirische Überprüfung des Dt. Schmerzfragebogens der DGSS Schmerz 16:263–270

Nationale Versorgungsleitlinie (2017) Nicht-spezifischer Kreuzschmerz. Langfassung 2. Aufl. Version 1. AWMF Register-Nr.: nvl-007. http://www.leitlinien.de/mdb/downloads/nvl/kreuzschmerz/kreuzschmerz-2aufl-vers1-lang.pdf. Accessed on 18.07.2018

Niemier K, Seidel W, Psczolla M et al (eds) (2018) Schmerzerkrankungen des Bewegungssystems. De Gruyter, Berlin

Pfingsten M (2001) Multimodale Verfahren – auf die Mischung kommt es an. Schmerz 15:492–498

Pfingsten M, Nilges P (2012) Psychologische Evaluation: Schmerz- und Verhaltensdiagnostik. In: Hildebrandt J, Pfingsten M (eds) Rückenschmerz und Lendenwirbelsäule. Elsevier, München, pp 150–162

Pöhlmann K, Tonhauser T, Joraschky P et al (2009) The Dachau multidisciplinary treatment program for chronic pain. Schmerz 23:40–46

Rau J, Ehlebracht-König I, Petermann F (2008) Einfluss einer Motivationsintervention auf die Bewältigung chronischer Schmerzen. Ergebnisse einer kontrollierten Wirksamkeitsstudie Schmerz 22:575–585

Scascighini L, Toma V, Dober-Spielmann S, Sprott H (2008) Multidisciplinary treatment for chronic pain: a systematic review of interventions and outcomes. Rheumatology 47:670–678

Schiltenwolf M, Buchner M, Heindl B et al (2006) Comparison of a biopsychosocial therapy (BT) with a conventional biomedical therapy (MT) of subacute low back pain in the first episode of sick leave: a randomized controlled trial. Eur Spine J 15:1083–1092

Schmitz U, Saile H, Nilges P (1996) Coping with chronic pain: flexible goal adjustment as an interactive buffer against pain-related distress. Pain 67:41–51

Schonstein E, Kenny DT, Keating J et al (2002) Work conditioning, work hardening and functional restoration for workers with back and neck pain: review. Cochrane Database Syst Rev 4:CD001822

Schütze A, Kaiser U, Ettrich U et al (2009) Evaluation of a multimodal pain therapy at the university pain Centre Dresden. Schmerz 23:609–617

Seddigh S, Rothgangl C, Maihöfner (2014) Multimodale Therapieprogramme bei neuropathischen Schmerzen wirksam? Schmerz 28(Suppl 1):38–39

Senf W, Gerlach G (2011) Psychodynamische Psychotherapie bei chronischen Schmerzen. In: Kröner-Herwig B, Frettlöh J, Klinger R, Nilges P (Hrsg) Schmerzpsychotherapie, 6. Aufl. Springer, Heidelberg, S 116–134

Smolenski UC, Seidel W, Scholler M et al (2014) Ergebnisse einer multizentrischen Studie der ANOA-Kliniken, Auswertung 2015. Vortrag im Rahmen des DKOU-Kongresses, Berlin

Sorg (2008) Analyse der Versorgungswege von Patienten mit primär therapieresistenten subakuten und chronischen Schmerzen im DRK-Schmerz-Zentrum Mainz. Dissertation, Universität Erlangen-Nürnberg

Sullivan MJL, Thorn B, Haythornthwaite J, Keefe F, Martin M, Bradley LA, Lefebvre JC (2001) Theoretical perspectives on the relation between catastrophizing and pain. Clin J Pain 17:52–64

Treatment Algorithm for Neuropathic Pain Syndrome

C. Wille

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_3

3.1 Introduction

3

Pain is a leading symptom of numerous diseases across all clinical specialties. Patients with chronic pain are therefore also found in every specialty. Awareness and knowledge of the special pathomechanisms of chronic pain and the significance of neuropathic pain for chronification and resistance to therapy are nevertheless surprisingly underdeveloped in the medical profession and lead in practice to underuse and years of suffering on the one hand and to inefficient overdiagnosis and overtherapy on the other.

According to the current definition of the Neuropathic Pain Special Interest Group of the International Association for the Study of Pain (NeuPSIG of the IASP), **neuropathic pain is** the direct consequence of damage to or disease of somatosensory nerve structures in the peripheral or central nervous system (Treede et al. 2008; Jensen et al. 2011). According to the location of the lesion, a distinction is made between peripheral and central neuropathic pain, whereby mixed forms are not infrequently encountered in the chronic course of pain.

From a pathophysiological perspective, it is also true that any pain condition—regardless of the cause—can entail structural and functional changes in pain-conducting, –processing and -controlling nervous system parts in a function of duration and intensity. These phenomena of peripheral and central sensitization are summarized as wind-up (Ji et al. 2013; Kuner 2015; Pitcher and Henry 2000; Woolf 2011; Xu and Lu 2011). This ultimately results in pain that becomes increasingly endowed with neuropathic components over time and becomes increasingly refractory to conventional therapeutic interventions (Fig. 3.1). Neuropathic pain components can therefore occur in any chronic pain process, with corresponding negative consequences in terms of disease severity and treatability. This circumstance was taken into account with the introduction of the mixed pain concept, e.g. for chronic musculoskeletal pain conditions, and with a multiple revision of the definition and grading system of neuropathic pain, including secondary neuropathic pain conditions (Baron and Binder 2004; Finnerup et al. 2016; Freynhagen and Baron 2009).

Neuropathic pain is common and, moreover, often underdiagnosed and undertreated (Breivik et al. 2006; Haanpää 2013). An important challenge for the clinician is to recognize neuropathic pain in order to initiate adequate diagnosis, initiate promising therapies and counteract further chronification. With a primary pharmacological therapy resistance of 20–40%, at best every third patient with chronic neuropathic pain can be treated satisfactorily in the long term with conservative therapy measures (AWMF 2012; Breivik et al. 2006). As there has been little improvement in the reality of care and therapy innovation in recent years, this assessment is likely to remain valid.

The effectiveness of conventional medicinal and multimodal pain therapy concepts remains limited in this patient group. In the

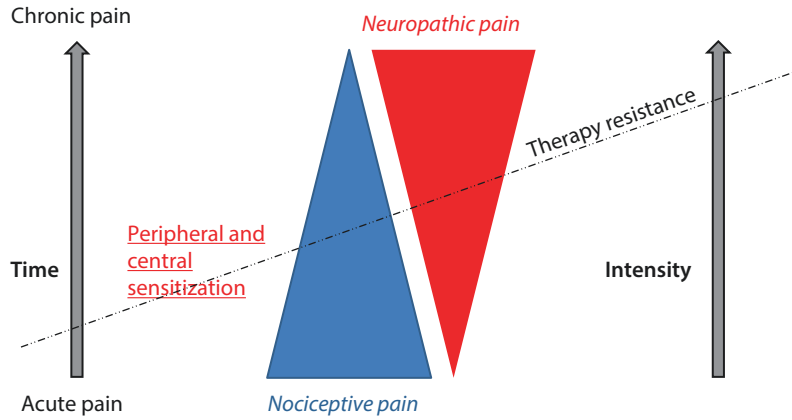


Fig. 3.1 Any chronic pain condition will develop neuropathic pain components in a function of time and intensity through peripheral and central sensitization

end, the neuropathic pain component often proves to be resistant to treatment, although affected patients have undergone all measures of the monocausal and also multimodal therapy spectrum, including medication according to the WHO step-by-step scheme, infiltrations, acupuncture, causal surgical therapies, physiotherapy and psychotherapy—sometimes repeatedly. Experience has shown that people with chronic pain who are considered to be out of treatment for years are at risk of consuming painkillers or tranquilizers with dependence potential to a considerable extent. In addition, poorly controlled neuropathic pain should not be underestimated for its significant risk of comorbidity, including depression, cardiovascular disease, and autoimmune disorders. Social complications and early retirement further threaten lives already compromised by the disease (pain) burden. Especially in order to avoid social complications such as job loss and early retirement, which cause many times the costs compared to the actual treatment costs, a stringent, timely and optimal care of the affected persons is necessary. However, this all too often fails due to the realities of outpatient care in Germany.

It has been demonstrated many times that methods of modern minimally invasive, neuromodulative pain therapy (e. g. spinal cord stimulation, SCS, and neurostimulation of the dorsal root ganglion, DRG) represent additional, effective and, not least, cost-effective alternatives when conservative therapy concepts have been exhausted in patients with chronic pain (Kumar et al. 2007; Mekhail et al. 2018; Simpson et al. 2009; Visnjevac et al. 2017). However, even after more than 40 years of use, numerous technological innovations and a significant improvement in the evidence base, neuromodulation – by means of so-called pain pacemakers – is currently more of a niche treatment with low therapy penetration, limited user group and massive reservations among pain therapists working purely conservatively.

Now, however, the discussion seems to be fueled: Not least under the impression of the opioid crisis in the USA, new recommendations of the International Neuromodulation Society (INS) could lead to a paradigm shift (Jones et al. 2018; Ostling et al. 2018). Waiting until affected pain patients are already years out of treatment before giving them a chance for innovative minimally invasive pain treatment options, e.g. SCS or DRG stimulation, is increasingly being questioned. Instead, there are suggestions that the indications for neuromodulatory procedures in this patient group should be made earlier in the course of the pain disease, following established guidelines. This currently propagated therapeutic attitude is reflected in the following algorithm for the procedure in neuropathic pain syndrome.

Expanding the user base and incorporating them into multimodal care structures will be critical to implementing such a paradigm shift, as will the behavior of payers for these therapies, which have been shown to be cost-effective but remain costly (Farber et al. 2017; Kumar and Rizvi 2013; Mekhail et al. 2011; Zucco et al. 2015).

3.2 Epidemiological Data

Chronic pain is pain that lasts longer than 6 months. In Europe, about 95 million people are affected by chronic pain. In Germany, there are about 11 million people who have chronic pain (Frettlöh et al. 2009). The prevalence of neuropathic pain in the overall population is 3.3–8.2% depending on the study design and evaluation tools used (Haanpää et al. 2011). Other analyses report the prevalence as 6.9–10% (van Hecke et al. 2014). Despite the fact that the screening tools used must be assessed with caution with regard to their specificity and sensitivity when used in the general population, the number of patients affected by neuropathic pain in the German population alone can be assumed to be several million. Their share in the group of patients who have to live with chronic pain is likely to be correspondingly high.

3.3 Diagnosis of Neuropathic Pain

The recognition of neuropathic pain is a prerequisite for targeted diagnosis and adequate therapy. Guidelines for the diagnosis of neuropathic pain have been published by the European Federation of Neurological Societies (EFNS), by the NEUPSIG of the IASP and by the Guidelines Commission of the German Neurological Society (DGN) (Cruccu et al. 2010; Haanpää et al. 2011; Wasner 2012). The S1 guideline "Diagnosis of neuropathic pain" of the DGN is currently being revised and should be merged into a guideline "Diagnosis and therapy of neuropathic pain".

In addition to recommending a detailed history and thorough neurological examination, all guidelines distinguish tools for screening measures to assess neuropathic pain (Üçeyler and Sommer 2011).

The anamnesis should record information on the onset and duration of pain, temporal characteristics, pain character and pain localisation. The aim is a neuroanatomically plausible classification of the symptoms as a basis for further diagnostics. In addition, special pain characteristics such as a resting pain maximum, burning or electrifying shooting pain are indicators of the presence of neuropathic pain. Also anamnestic information about therapy resistance, for example to conventional painkillers such as non-steroidal anti-inflammatory drugs (NSAIDs), can be indicative of a neuropathic pain component. The author of this chapter does not share the consensus opinion of the DGN that the medical history alone must provide "sufficient information on a relevant lesion or disease of the peripheral or central somatosensory system" to diagnose neuropathic pain. Neuropathic pain conditions are far too heterogeneous in cause and downright occult, especially in the area of post-inflammatory neuralgias, for this information to be adequately provided as early as the history-taking of affected patients. Secondary neuropathic pain due to chronic nociceptive pain conditions would not be recorded according to this diagnostic algorithm (Finnerup et al. 2016).

The clinical neurological examination is used to record somatosensory symptoms that may typically be the result of lesions of afferent pathways. A distinction is made between negative symptoms such as hypaesthesia and hypalgesia and positive symptoms such as spontaneous pain and evoked forms of pain (Table 3.1).

Screening tools in the form of standardized questionnaires are an efficient way of assessing the probability of the presence of neuropathic pain, especially in the outpatient setting. The differentiation into a certain, probable and improbable neuropathic pain component enables a more targeted indication for further diagnostics or adequate therapy. Validated questionnaires for the qualitative and quantitative assessment of neuropathic pain are available with DN4 (Douleur Neuropathique en 4 Questions), LANSS (Leeds Assessment of Neuropathic Symptoms and Signs), NPQ (Neuropathic Pain Questionnaire), NPSI (Neuropathic Pain Symptom Inventory) and painDETECT (Bennett et al. 2007). PainDetect and NPSI have been validated in German (Freynhagen et al. 2006, 2016). PainDetect also records pain intensities according to analogue scale and pain locations. The questionnaires are also suitable for monitoring progress. Chronification questionnaires (e.g. according to Korf or Gerbershagen) offer the possibility of estimating a degree of chronification, which in turn correlates with the prevalence of psychological comorbidity, pain-related disability and social impairment (Pfingsten et al. 2000; Nagel et al. 2002; Klasen et al. 2004). For therapy planning and the estimation of the prospects of success of curative therapy approaches in ultima-ratio situations (e.g. fusion surgery in spinal surgery), these tools should play a greater role in the indication, since the degree of chronification influences the therapy outcome (Schiltenwolf and Klinger 2008).

Most assessment tools are the subject of extended neurological and radiological diagnostics or the experimental research environment and ultimately serve to establish the diagnosis, for example, in order to open the door to causal therapy options or to identify causal pathologies in the case of nerve compression syndromes. The DGN guideline pri-

Table 3.1 Positive and negative somatosensory symptoms

		Symptom	Definition
Negative symptoms		Hypaesthesia	Reduced sensation of non-painful stimuli
		Pallhypaethesia	Reduced sensation of a vibratory stimulus
		Hypalgesia	Reduced sensation of painful stimuli
		Thermhypaethesia	Reduced sensation of a warm or cold stimulus
Positive symptoms	Spontaneous	Paresthesia	Non-painful persistent tingling sensation
		Dysesthesia	Unpleasant sensation
		Shooting pain attack	Electrifying shocks of seconds duration
		Superficial pain	Painful persistent, often burning sensation
		Mechanical dynamic allodynia	Painful perception of a mild, normally non-painful stimulus
	Evoked	Mechanical static allodynia	Painful perception of a static, normally non-painful pressure on the skin
		Mechanical pin prick allodynia	Strong perception of pain triggered by a mildly stinging stimulus that is not normally painful or is mildly painful
		Cold allodynia	Strong perception of pain triggered by a normally non-painful or slightly painful cold stimulus
		Heat allodynia	Strong perception of pain triggered by a normally non-painful or slightly painful heat stimulus

marily mentions quantitative sensory testing (QST), skin biopsy and neurophysiological examinations using evoked potentials as assessment tools (Wasner 2012). QST examines the complete spectrum of somatosensory fibers with 13 different thermal and mechanical stimuli, which are offered in standardized form in ascending and descending order in the affected skin area (Maier et al. 2010). Different neuropathic pain types or pain disorders exhibit different sensory profiles in this regard, thus enabling the definition of subgroups (Vollert et al. 2017). It is a subjective procedure that requires the patient's cooperation. However, due to the considerable time required and the necessary experience in the implementation and evaluation of the QST, this test battery does not currently play a role in the everyday and, above all, outpatient care of patients with neuropathic pain, but rather has significance in scientific and expert questions.

Traditional neurophysiological examination techniques such as the determination of sensory and motor nerve conduction velocities (NLG), electromyography (EMG) and the recording of sensory and motor evoked potentials (sSEP, MEP) serve to detect and localise a disease of the somatosensory system. However, thin or non-myelinated, pain-conducting pathways are not detected by these procedures. An inconspicuous finding here does not rule out a neuropathic pain syndrome based on a somatosensory lesion. The recording of evoked potentials after stimulation of thinly myelinated Aδ-fibers, such as laser-evoked potentials (LEP), offers the possibility of narrowing this gap.

Imaging techniques such as magnetic resonance imaging and, last but not least, nerve sonography are used to identify pathological morphological changes that may be causative for the development of neuropathic pain. However, the exact knowledge of the pain

pattern and the neurological findings is decisive for the targeted indication, questioning and interpretation of the findings.

In summary, the diagnosis of neuropathic pain in clinical practice relies heavily on the physician's knowledge as well as a careful history and physical examination. Validated questionnaires to determine the probability of neuropathic pain are simple and efficient tools.

3.4 Therapy of Neuropathic Pain

The treatment options for neuropathic pain can be roughly divided into causal curative and symptomatic therapies. If a causal pathology with curative treatability can be confirmed in the clarification, there is the option of treating the neuropathic pain accordingly along with the cause. Surgical treatment options for nerve constriction syndromes and nerve root compression syndromes are a classic example of this.

If there is no causal therapy as for example in the case of post-zoster neuralgia or if the curative therapy approach was unsuccessful, symptomatic treatment remains.

Due to the heterogeneity of neuropathic pain syndromes and limitations of pharmacotherapy in particular with regard to tolerability and effectiveness, individually successful treatment is considered difficult. The agreement of realistic therapy goals requires information about the nature of the pain type, therapy effectiveness and side effects. Patient education should be an essential part of the therapeutic process, especially in our health care system. Especially in the chronic course, the realization and insight of the patient that the hope for a curative treatment is unrealizable prevents the risk for overtherapy and overdiagnosis by physician hopping and promotes therapy motivation and adherence. Realistic therapeutic goals of conservative, non-interventional treatments are formulated as a pain reduction of 30–50%, an improvement in sleep and quality of life, and a preservation of the ability to work and the social fabric (AWMF 2012). The necessity of regular, sometimes also close-meshed follow-up visits to monitor the clinical course, the effectiveness of the therapy and, of course, the adjustment of the therapy is the reason for a complex therapeutic process, which is unfortunately insufficiently represented in the current, mainly outpatient, care situation in Germany. Particularly in the case of changes in the pain pattern, a diagnostic re-evaluation must also take place in the course of chronic pain patients, on the one hand in order not to overlook new diseases and on the other hand perhaps to find a cause of pain with curative therapy potential in the course of the disease.

Existing guidelines of the DGN and the EFNS, among others, name a central pharmacotherapy as a therapeutic principle, around which further therapeutic measures are grouped in the sense of a multimodal interdisciplinary treatment depending on the course of treatment (AWMF 2012; Attal et al. 2010). Following the biopsychosocial disease model of chronic pain, the therapy of neuropathic pain is based on 3 pillars according to these guidelines: pharmacotherapy, psychotherapy, physical and occupational therapy.

However, the symptomatic therapy of neuropathic pain should rest on 4 pillars. The fourth pillar, interventional pain therapy, which includes neuromodulative procedures such as epidural spinal cord stimulation, has often been scotomized or marginalized. However, interventional pain management should be an integral part of an efficient treatment algorithm for neuropathic pain that does not leave it to chance whether the affected person may gain access to an effective and often more evidence-based therapy years later.

3.4.1 Pharmacotherapy

Current recommendations for pharmacotherapy include the anticonvulsants gabapentin and pregabalin, tricyclic antidepressants such as amitryptiline, and selective serotonin and norepinephrine reuptake inhibitors (SSNRIs) such as duloxetine as monotherapy and in combination. Capsaicin and lidocaine patches and Botox-A injections may be useful adjuncts for peripheral neuropathic pain. ◘ Table 3.2

Table 3.2 Pharmacotherapy of chronic neuropathic pain (first-line agents[a])

Active substance	Dosage	NNT[b]	Active ingredient group	Side effects
Gabapentin	Starting dose 3 × 100 mg/d maximum dose 3600 mg/d	6,1–9.6	Ca-channel-active antiepileptic drugs	Fatigue, concentration disorders, dizziness, visual disturbances, weight gain, oedema
Pregabalin	Starting dose 2 × 25 mg/d maximum dose 600 mg/d	3.9–11	Ca-channel-active antiepileptic drugs	Fatigue, concentration disorders, dizziness, visual disturbances, weight gain, oedema
Duloxetine	Starting dose 1 × 30 mg/d maximum dose 120 mg/d	3.4–14	Antidepressants (SSNRI)	Nausea, loss of appetite, constipation, fatigue, dry mouth, anxiety, sweating
Venlafaxine	Starting dose 1 × 37.5 mg/d maximum dose 225 mg/d	3.4–14	Antidepressants (SSNRI)	Nausea, loss of appetite, art. Hypertension, insomnia, constipation, fatigue, dry mouth, anxiety, sweating
Amitryptiline	Starting dose 1 × 10 mg/d	2.5–4.2	Tricyclic antidepressants	Urinary retention, constipation, visual disturbances, fatigue, confusion, cardiac arrhythmia, dry mouth, weight gain

SSNRI selective serotonin-norepinephrine reuptake inhibitors

[a]Only first-line agents recommended for the treatment of neuropathic pain were included in this presentation. Agents with missing or weak evidence, such as opiates and topicals, are not included

[b]*NNR*: number needed to treat, corresponds to the number of patients to be treated in order to achieve pain control of 50% or more in one patient

provides an overview of medication, dosages, common side effects and treatment efficacy.

While the use of opiates of WHO levels 2 and 3 was still considered ubiquitously possible and in part useful in the above-mentioned guidelines, a clear paradigm shift is emerging here in recent publications. In 2016 and 2017, Cochrane reviews on the use of tramadol, codeine, hydromorphone, oxycodone, morphine, fentanyl, buprenorphine and methadone for the treatment of neuropathic pain were published with the clear statement that there is no evidence or, as exclusively in the case of tramadol, only very weak evidence for the efficacy of these substances in neuropathic pain (Wiffen et al. 2015, 2016; Stannard et al. 2016; Gaskell et al. 2016; Derry et al. 2016; McNicol et al. 2017; Cooper et al. 2017; Duehmke et al. 2017). This is in fact in marked contrast to the previous guideline presence and current prescribing practice in Germany.

3.4.2 Psychotherapy

Neuropathic pain is characterized by high pain intensities and particularly distressing features. Rapid chronification and frequent resistance to therapy are highly likely to produce psychological comorbidity such as depression and anxiety disorders. Even in patients with pre-existing psychopathologies, these have a reciprocal aggravating effect in connection with chronic pain. Depending on the severity and duration of the disease, psychotherapeutic support is certainly useful and indicated, but often fails due to very long waiting times in the reality of outpatient care. In the inpatient setting, psychotherapy is an essential component of multimodal pain therapy. The diagnostically and therapeutically challenging topic of somatization disorders, i.e. a psychiatric group of illnesses in which pain and other somatic symptoms are at least partially psychogenically caused, is touched

upon here. In particular, chronic pain patients with non-conclusive history, clinical findings and diagnosis should be explored in this regard, not least because other potentially curative therapeutic options arise here and interventional pain therapy measures would be contraindicated according to guidelines. Controlled studies and meta-analyses on the effectiveness of psychotherapy as cotherapy in the treatment of neuropathic pain are lacking. Studies on the use of psychotherapeutic interventions in other chronic painful diseases such as fibromyalgia and rheumatoid arthritis show a moderate improvement in terms of disease management, physical activity and behaviour, especially with long-term use (Bernardy et al. 2018; Prothero et al. 2018).

3.4.3 Physical and Occupational Therapy

The usefulness and necessity of physiotherapeutic and, above all, occupational therapy measures are generally accepted, at least at guideline level. Since neuropathic pain in particular is associated with a rapid loss of function, possibly exacerbated by negative symptoms such as hypaesthesia and paresis, this area of therapy serves not only to relieve pain but also in many ways to maintain or restore function. In neuropathic pain, dysregulation and relieving posture are the source of secondary problems and the spread of pain. The so-called pain reflex inhibition, a complex of mechanisms that disrupts functions and coordination at multiple levels of the CNS up to the primary motor cortex, cannot be antagonized by pain control alone, especially in the chronic course of pain. In addition, physiotherapeutic interventions, such as lymphatic drainage techniques, have the potential to delay or stop the progression or aggravation of neuropathic pain in certain clinical pictures, for example by improving microcirculation. In analogy to psychotherapy, it can be assumed that only long-term and regular physiotherapeutic care will produce relevant effects. This special need for care is not reflected in the everyday care of the German health care system. In the meantime, exceptions have been defined in the catalogue of remedies for physical therapy for some pain diseases, such as complex regional pain syndrome (CRPS), which make the prescription budget-neutral for a limited period of time. The introduction of the chronic pain (CS) indication code, which enables the budget-neutral prescription of physiotherapy for patients aged 70 and over without a time limit, is also helpful in this respect. For the majority of chronic pain patients, however, long-term and regular care is not guaranteed due to budgeting and the threat of recourse. Controlled studies with statements on the effect strength and cost-effectiveness of physiotherapeutic measures are also lacking here.

3.4.4 Interventional and Neuromodulatory Therapies

The spectrum of interventional treatment options for neuropathic pain is broad, ranging from infiltration therapies to lesional procedures to neuromodulatory therapies, ultimately broad but not fully represented in the content of this book. A rough classification of these treatments according to expected efficacy into short-, medium-, and long-term effective therapies is useful and has implications for their place in the treatment algorithm (Fig. 3.2).

Infiltration therapies such as plexus anaesthesia, stellate blocks, periradicular infiltrations, peripheral nerve blocks are valuable as short-acting measures for pain control and from a diagnostic point of view. In the inpatient and outpatient setting, time can be gained until medicinal or other treatment strategies can take effect. The ability to treat the patient, e.g. with physiotherapeutic measures, can be significantly improved or even established. With the help of infiltrations, not only can a neuroanatomical assignment of the pain afference be made possible, but at the same time the question can be answered as to where, in the case of therapy resistance, a neuromodulative therapy measure might be promising. Examples of this are radicular

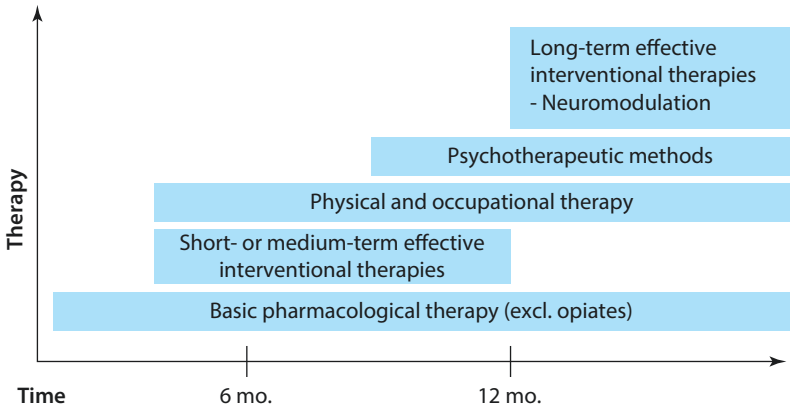


Fig. 3.2 Therapy algorithm for the treatment of neuropathic pain

blocks with local anaesthetic for the selection of promising intervention levels for spinal ganglion stimulation.

Traditional lesional procedures have clearly taken a back seat to neuromodulative interventions as effective procedures in the medium term. However, thermal lesions, e.g. for lumbar facet syndrome, most recently using endoscopic techniques, or for certain forms of trigeminal neuralgia, still have a place in the treatment of otherwise therapy-resistant pain. Neurotomy procedures also continue to be used as salvage strategies in joint and general surgery.

Non-lesional pulsed radiofrequency therapy as the most recent interventional therapy method for the treatment of neuropathic pain with a duration of action that can also be assumed in the medium term will certainly become more important in the future (Vanneste et al. 2017). Basically, the radiofrequency signal is similar to the application to the thermal lesion. However, the electric field strength is controlled by a high-precision temperature sensor at the electrode tips to prevent tissue heating above 42 °C. The consideration of the development was to avoid the denaturing effects of high temperatures and their complications and to achieve only a temporary disturbance, which has a positive effect on the pain sensation. In addition to the effect of low heating (below the protein denaturation limit of 45 °C), electric field effects and immune and gene modulatory effects are discussed as mechanisms of action analogous to implant-based neuromodulation (Hailong et al. 2018; Ramzy et al. 2018).

The technique is simple and low-risk. Above all, anaesthetists with knowledge of sonographic catheter placement for regional anaesthesia and interventional orthopaedic surgeons, plastic surgeons and neurosurgeons would have the tools to use this technique at any time. Since 2014 at the latest, the evidence base has improved significantly, so that the current resistance on the part of payers in Germany to reimburse this treatment appears increasingly questionable.

Implant-supported neuromodulative therapy methods are available as potentially effective long-term methods in the form of peripheral nerve stimulation, spinal ganglion stimulation, epidural spinal cord stimulation and ultimately brain stimulation. Since the introduction and availability of implantable pulse generators about 30 years ago, epidural spinal cord stimulation (SCS) in particular has proven its efficiency many times in the treatment of chronic neuropathic pain but also non-neuropathic pain (Mekhail et al. 2018). The significance, indications, prerequisites and implementation of SCS for the treatment of chronic pain are described in an interdisciplinary S3 guideline for the German health care system (AWMF 2013). This guideline is currently due for revision, as the last 10 years have seen enormous technological advances and considerable diversification in terms of implants, stimulation paradigms and stimulation targets, and resulting treatment options. The introduction of high-frequency stimulation paradigms such as HF 10 (continuous stimulation at 10 KHz) or Burst

(stimulation with 500-Hz salvos of a special waveform) has not only modified the type of implantation (implantability under anaesthesia) but also, most importantly, improved stimulation comfort and therapy efficiency (Kapural et al. 2016; Deer et al. 2018). Since high-frequency stimulation paradigms are operated without patient perceptual awareness, scientific testability has also been improved by the possibility of blinding (Schu et al. 2014). The introduction of spinal ganglion stimulation has led to a significant improvement in the treatability of peripheral neuropathic pain in particular (Deer et al. 2017; van Bussel et al. 2018).

3.4.5 Therapy Algorithm

Every therapy algorithm must be accompanied by a diagnostic algorithm (Fig. 3.3). The diagnostic algorithm includes an assessment of the probability of neuropathic pain (grading), a survey of pain-related individual impairment at the physical, psychological, and social levels, and diagnostics of causality. A regular evaluation should not only include the effectiveness of therapeutic measures but also the question of causality. Chronic pain conditions that are superficially classified as non-neuropathic should be re-evaluated with regard to neuropathic pain components, especially in cases of therapy resistance.

Figure 3.2 shows the therapy algorithm for the treatment of neuropathic pain. This algorithm naturally outlines an ideal that does not reflect the reality of care. With regard to neuropathic pain, a timeline should be observed in a therapy algorithm, especially in order to anticipate social and psychological complications. For deep brain stimulation (DBS) in the treatment of idiopathic Parkinson's disease, the concept of secondary treatment failure has been interpreted in such a way that if it is used too late, when the patient has already progressed too far in the disease-related social withdrawal, the primary treatment goals such as improvement of motor symptom control and reduction of medication are achieved, but secondary goals such as improvement of quality of life are missed. The same can be assumed for chronic pain patients. Especially for the established main indications of epidural spinal cord stimulation, it is necessary to demand that, after exhausting the conservative, causal and short- or medium-term effective interventional therapy spectrum, this therapy spectrum is evaluated in significantly affected patients after 1 year at the latest and offered if suitable. It is important that these patients remain integrated into multimodal care structures even

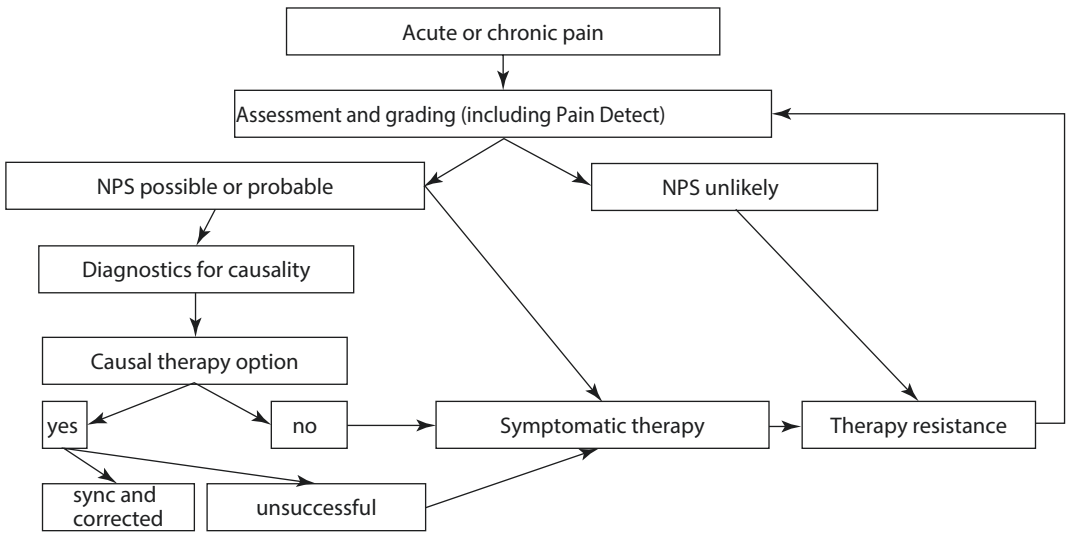


Fig. 3.3 Diagnostic algorithm. NPS neuropathic pain

after successful neuromodulative intervention. Not least because follow-up care is crucial for long-term stable and successful neuromodulative therapy management. Physician responsibility should also undergo an evolution along the aforementioned timeline. While initially for first attempts of drug therapy the care of general practitioner or specialist can be considered adequate, between month 6 and 12 a pain therapist should be involved in the treatment coordination. Ideally, these pain therapists should be familiar with and appreciate the interventional and neuromodulatory spectrum of therapies and select appropriate patients to consider an indication on an interdisciplinary basis. This would require the pain therapist to either become a practitioner or work closely with a practitioner. Currently, this is likely to be the case for only a minority of pain therapists working in Germany. In the author's observation, too many pain therapists resign themselves to therapy resistance and low effect levels of conservative therapies and focus their therapeutic efforts on training the patient to live with pain without even considering the neuromodulative therapy spectrum. Not to underestimate the importance of this therapeutic path would require a paradigm shift with a higher value of interventional pain therapies in the training curriculum of pain therapy as well as a balancing refocusing from "psycho" to "bio" in the biopsychosocial disease model of pain therapy. A successful therapy of chronic pain and especially chronic neuropathic pain will always require the change of perspective of an interdisciplinary treatment.

References

Attal N, Cruccu G, Baron R et al (2010) EFNS guidelines on the pharmacological treatment of neuropathic pain: 2010 revision. Eur J Neurol 17:1113–1123

Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF) (2012) Leitlinien für Diagnostik und Therapie in der Neurologie (S1). Pharmakologisch nicht interventionelle Therapie chronisch neuropathischer Schmerzen. AWMF-Registernummer: 030/114. https://www.awmf.org/uploads/tx_szleitlinien/030-114l_S1_Neuropathischer_Schmerzen_Therapie_2014-abgelaufen.pdf. Accessed on 18.07.2018

Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF) (2013) Epidurale Rückenmarkstimulation zur Therapie chronischer Schmerzen. AWMF-Registernummer: 041/002. https://www.awmf.org/leitlinien/detail/ll/008-023.html. Accessed on 15.08.2018

Baron R, Binder A (2004) How neuropathic is sciatica? The mixed pain concept. Orthopade 33:568–575. https://doi.org/10.1007/s00132-004-0645-0

Bennett M, Attal N, Backonja MM et al (2007) Using screening tools to identify neuropathic pain. Pain 127(3):199–203

Bernardy K, Klose P, Welsch P, Häuser W (2018) Efficacy, acceptability and safety of cognitive behavioural therapies in fibromyalgia syndrome – a systematic review and meta-analysis of randomized controlled trials. Eur J Pain 22:242–260. https://doi.org/10.1002/ejp.1121

Breivik H, Collett B, Ventafridda V et al (2006) Survey of chronic pain in Europe: prevalence, impact on daily life, and treatment. Eur J Pain 10:287–333. https://doi.org/10.1016/j.ejpain.2005.06.009

Cooper TE, Chen J, Wiffen PJ et al (2017) Morphine for chronic neuropathic pain in adults. Cochrane Database Syst Rev 5:CD011669. https://doi.org/10.1002/14651858.CD011669.pub2

Cruccu G, Sommer C, Anand P et al (2010) EFNS guidelines on neuropathic pain assessment: revised 2009. Eur J Neurol 17:1010–1018

Deer TR, Levy RM, Kramer J et al (2017) Dorsal root ganglion stimulation yielded higher treatment success rate for complex regional pain syndrome and causalgia at 3 and 12 months. Pain 158:669–681. https://doi.org/10.1097/j.pain.0000000000000814

Deer T, Slavin KV, Amirdelfan K et al (2018) Success using neuromodulation with BURST (SUNBURST) study: results from a prospective, randomized controlled trial using a novel burst waveform. Neuromodulation Technol Neural Interface 21:56–66. https://doi.org/10.1111/ner.12698

Derry S, Stannard C, Cole P et al (2016) Fentanyl for neuropathic pain in adults. Cochrane Database Syst Rev 10:CD011605. https://doi.org/10.1002/14651858.CD011605.pub2

Duehmke RM, Derry S, Wiffen PJ et al (2017) Tramadol for neuropathic pain in adults. Cochrane Database Syst Rev 6:CD003726. https://doi.org/10.1002/14651858.CD003726.pub4

Farber SH, Han JL, Elsamadicy AA et al (2017) Long-term cost utility of spinal cord stimulation in patients with failed back surgery syndrome. Pain Physician 20:E797–E805

Finnerup NB, Haroutounian S, Kamerman P et al (2016) Neuropathic pain: an updated grading system for research and clinical practice. Pain 157:1599–1606. https://doi.org/10.1097/j.pain.0000000000000492

Frettlöh J, Maier C, Gockel H, Zenz M, Hüppe M (2009) Patientenkollektiv deutscher schmerztherapeutischer Einrichtungen. Schmerz 23:576–591

Freynhagen R, Baron R (2009) The evaluation of neuropathic components in low back pain. Curr Pain Headache Rep 13:185–190

Freynhagen R, Baron R, Gockel U, Tölle TR (2006) Pain DETECT: a new screening questionnaire to identify neuropathic components in patients with back pain. Curr Med Res Opin 22:1911–1920. https://doi.org/10.1185/030079906X132488

Freynhagen R, Tölle TR, Gockel U, Baron R (2016) The painDETECT project – far more than a screening tool on neuropathic pain. Curr Med Res Opin 32:1033–1057. https://doi.org/10.1185/03007995.2016.1157460

Gaskell H, Derry S, Stannard C, Moore RA (2016) Oxycodone for neuropathic pain in adults. Cochrane Database Syst Rev 7:CD010692. https://doi.org/10.1002/14651858.CD010692.pub3

Haanpää M (2013) The assessment of neuropathic pain patients. Pain Manag 3:59–65. https://doi.org/10.2217/pmt.12.71

Haanpää M, Attal N, Backonja M et al (2011) NeuPSIG guidelines on neuropathic pain assessment. Pain 152:14–27

Hailong J, Hao R, Zipu J et al (2018) Pulsed radiofrequency improves neuropathic pain in chronic constriction injury rats through the upregulation of the transcription and translation levels of glial cell line-derived neurotrophic factor. Pain Physician 21:33–40

Jensen TS, Baron R, Haanpää M et al (2011) A new definition of neuropathic pain. Pain 152:2204–2205

Ji RR, Berta T, Nedergaard M (2013) Glia and pain: is chronic pain a gliopathy? Pain 154(Suppl 1):S10–S28

Jones MR, Viswanath O, Peck J et al (2018) A brief history of the opioid epidemic and strategies for pain medicine. Pain Ther 7(1):13–21. https://doi.org/10.1007/s40122-018-0097-6

Kapural L, Yu C, Doust MW et al (2016) Comparison of 10-kHz high-frequency and traditional low-frequency spinal cord stimulation for the treatment of chronic back and leg pain. Neurosurgery 79:667–677. https://doi.org/10.1227/NEU.0000000000001418

Klasen BW, Hallner D, Schaub C et al (2004) Validation and reliability of the German version of the chronic pain grade questionnaire in primary care back pain patients. Psychosoc Med 1:Doc07

Kumar K, Rizvi S (2013) Cost-effectiveness of spinal cord stimulation therapy in management of chronic pain. Pain Med 14:1631–1649. https://doi.org/10.1111/pme.12146

Kumar K, Taylor RS, Jacques L et al (2007) Spinal cord stimulation versus conventional medical management for neuropathic pain: a multicentre randomised controlled trial in patients with failed back surgery syndrome. Pain 132:179–188. https://doi.org/10.1016/j.pain.2007.07.028

Kuner R (2015) Spinal excitatory mechanisms of pathological pain. Pain 156:S11–S17. https://doi.org/10.1097/j.pain.0000000000000118

Maier C, Baron R, Tölle TR et al (2010) Quantitative sensory testing in the German research network on neuropathic pain (DFNS): somatosensory abnormalities in 1236 patients with different neuropathic pain syndromes. Pain 150:439–450. https://doi.org/10.1016/j.pain.2010.05.002

McNicol ED, Ferguson MC, Schumann R (2017) Methadone for neuropathic pain in adults. Cochrane Database Syst Rev 5:CD012499. https://doi.org/10.1002/14651858.CD012499.pub2

Mekhail N, Wentzel DL, Freeman R, Quadri H (2011) Counting the costs. Prof Case Manag 16:27–36. https://doi.org/10.1097/NCM.0b013e3181e9263c

Mekhail N, Visnjevac O, Azer G et al (2018) Spinal cord stimulation 50 years later. Reg Anesth Pain Med 43:1. https://doi.org/10.1097/AAP.0000000000000744

Nagel B, Gerbershagen HU, Lindena G, Pfingsten M (2002) Development and evaluation of the multidimensional German pain questionnaire. Schmerz 16:263–270. https://doi.org/10.1007/s00482-002-0162-1

Ostling PS, Davidson KS, Anyama BO et al (2018) America's opioid epidemic: a comprehensive review and look into the rising crisis. Curr Pain Headache Rep 22:32. https://doi.org/10.1007/s11916-018-0685-5

Pfingsten M, Schöps P, Wille T et al (2000) Classification of chronic pain. Quantification and grading with the Mainz pain staging system. Schmerz 14:10–17. https://doi.org/10.1007/s004820000060

Pitcher GM, Henry JL (2000) Cellular mechanisms of hyperalgesia and spontaneous pain in a spinalized rat model of peripheral neuropathy: changes in myelinated afferent inputs implicated. Eur J Neurosci 12:2006–2020. https://doi.org/10.1046/j.1460--9568.2000.00087.x

Prothero L, Barley E, Galloway J et al (2018) The evidence base for psychological interventions for rheumatoid arthritis: a systematic review of reviews. Int J Nurs Stud 82:20–29. https://doi.org/10.1016/j.ijnurstu.2018.03.008

Ramzy EA, Khalil KI, Nour EM et al (2018) Evaluation of the effect of duration on the efficacy of pulsed radiofrequency in an animal model of neuropathic pain. Pain Physician 21:191–198

Schiltenwolf M, Klinger R (2008) Patienten mit vorbestehender Schmerzchronifizierung und/oder psychischen Auffälligkeiten. Orthopade 37:990–996. https://doi.org/10.1007/s00132-008-1335-0

Schu S, Slotty PJ, Bara G et al (2014) A prospective, randomised, double-blind, placebo-controlled study to examine the effectiveness of burst spinal cord stimulation patterns for the treatment of failed back surgery syndrome. Neuromodulation Technol Neural Interface 17:443–450. https://doi.org/10.1111/ner.12197

Simpson E, Duenas A, Holmes M et al (2009) Spinal cord stimulation for chronic pain of neuropathic or ischaemic origin: systematic review and economic evaluation. Health Technol Assess (Rockv) 13:iii., ix–x:1–154. https://doi.org/10.3310/hta13170

Stannard C, Gaskell H, Derry S et al (2016) Hydromorphone for neuropathic pain in adults. Cochrane Database Syst Rev 5:CD011604. https://doi.org/10.1002/14651858.CD011604.pub2

Treede RD, Jensen TS, Campbell JN et al (2008) Neuropathic pain: redefinition and a grading system for clinical and research purposes. Neurology 70:1630–1635

Üçeyler N, Sommer C (2011) Neuropathic pain assessment – an overview of existing guidelines and discussion points for the future. Eur Neurol Rev 6:128. https://doi.org/10.17925/ENR.2011.06.02.128

van Bussel CM, Stronks DL, Huygen FJPM (2018) Dorsal column stimulation vs. dorsal root ganglion stimulation for complex regional pain syndrome confined to the knee: patients' preference following the trial period. Pain Pract 18:87–93. https://doi.org/10.1111/papr.12573

van Hecke O, Austin SK, Khan RA et al (2014) Neuropathic pain in the general population: a systematic review of epidemiological studies. Pain 155:654–662. https://doi.org/10.1016/j.pain.2013.11.013

Vanneste T, Van Lantschoot A, Van Boxem K, Van Zundert J (2017) Pulsed radiofrequency in chronic pain. Curr Opin Anaesthesiol 30:577–582. https://doi.org/10.1097/ACO.0000000000000502

Visnjevac O, Costandi S, Patel BA et al (2017) A comprehensive outcome-specific review of the use of spinal cord stimulation for complex regional pain syndrome. Pain Pract 17:533–545. https://doi.org/10.1111/papr.12513

Vollert J, Maier C, Attal N et al (2017) Stratifying patients with peripheral neuropathic pain based on sensory profiles. Pain 158:1446–1455. https://doi.org/10.1097/j.pain.0000000000000935

Wasner G (2012) Diagnostik neuropathischer Schmerzen. In: Diener H-C, Weimar C (eds) Leitlinien für Diagnostik und Therapie in der Neurologie. Thieme Verlag, Stuttgart

Wiffen PJ, Derry S, Moore RA et al (2015) Buprenorphine for neuropathic pain in adults. Cochrane Database Syst Rev 9:CD011603. https://doi.org/10.1002/14651858.CD011603.pub2

Wiffen PJ, Knaggs R, Derry S et al (2016) Paracetamol (acetaminophen) with or without codeine or dihydrocodeine for neuropathic pain in adults. Cochrane Database Syst Rev 12:CD012227. https://doi.org/10.1002/14651858.CD012227.pub2

Woolf CJ (2011) Central sensitization: implications for the diagnosis and treatment of pain. Pain 152(3 Suppl):S2–S15

Xu F, Lu T (2011) Introduction to skin biothermomechanics and thermal pain. Springer, Berlin/Heidelberg

Zucco F, Ciampichini R, Lavano A et al (2015) Cost-effectiveness and cost-utility analysis of spinal cord stimulation in patients with failed back surgery syndrome: results from the PRECISE study. Neuromodulation Technol Neural Interface 18:266–276. https://doi.org/10.1111/ner.12292

Landmark-Assisted Infiltrations and Injection Techniques on the Cervical, Thoracic and Lumbar Spine

T. Theodoridis

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_4

4.1 Introduction

Pain in the **cervical and lumbar spine** primarily originates in the lower motion segments. In the cervical segments **C5/6 and C6/7** and in the lumbar segments **L4/5 and L5/S1,** the most severe form and function disorders are found due to the particular stress situation at the bending point of the cervicothoracic transition and the lower lumbar spine. The spinal nerves with their outgoing branches are located in close proximity here. The head-neck transition in the area of the atlantooccipital and atlas/axis joints as well as the sacroiliac joints, which functionally belong to the lower lumbar motion segments and are also neurologically connected to them via the ramus dorsalis of the S1 root, are frequently involved in the pain process (Theodoridis et al. 2009a).

Pain syndromes in the **thoracic spine** play a minor role compared to those in the cervical and lumbar spine. This applies to both the frequency and the severity of the symptoms. Only 2% of all painful spinal syndromes affect the thoracic spine (Theodoridis and Krämer 2017).

4.2 Indication

With **landmark-assisted** injection treatments of the spine as **"single-shot techniques",** the treating physician, without the use of costly technical aids, literally has a **fast-acting** and **efficient therapeutic measure** "in his hand", which is usually so helpful that further more invasive measures are no longer necessary in the patient. These so-called **minimally invasive injection techniques**, in the form of epidural injections, nerve root blocks and facet and sacroiliac joint infiltrations are **segmental** local injections at the spine, which affect the region directly at the spinal canal or in the spinal canal itself. Analgesic, anti-inflammatory and decongestant preparations are **applied locally** to the point of origin of nociception in the motion segment. The primary disorder is thereby directly influenced (Theodoridis 2016).

Finally, a sustainable effect is achieved through physio-, movement-, posture- and behavioural therapy in the context of back school. These accompanying measures take place, as far as possible, during the injection treatment and should be continued after completion of the therapy.

The aim is, in addition to the rapid relief of symptoms, to avoid open surgery, which is prone to complications and can leave irreversible sequelae. This is not the case with a carefully conducted injection therapy (Theodoridis 2012).

Advancing the needles from dorsal can be done under X-ray image converter or CT control, but it is better to do it **landmark-guided**, i.e. according to **palpatory-anatomical landmarks,** in order to avoid the cumulative radiation exposure of repeated injections (Theodoridis 2007). In recent years, sonography-guided injection techniques have been increasingly used. However, this imaging method has limitations in terms of injection technique or injection site, notwithstanding its also high initial cost. Indications and techniques using X-ray fluoroscopy or CT control are described in the next chapters of this book.

4.3 Preinterventional Diagnostics

Before initiating injection treatment in the affected spinal segment, the diagnosis must be confirmed. A thorough assessment of the **general** and **specific medical history**, **clinical examination**, imaging of the affected spinal segment using the **imaging technique** required for the individual case and, if necessary, determination of the **laboratory status** should determine whether this treatment is indicated (see overview below). This will also help to determine whether there are any **contraindications** which, if not observed, could lead to complications.

4

Overview of Pre-Interventional Diagnostics Prior to Initiation of Injection Treatment of the Spine to Confirm the Diagnosis and Exclude Contraindications

- **General medical history:** allergies, diabetes, neurological seizure disorders, cardiovascular disorders, other concomitant diseases, taking blood-thinning medication, etc.
- **Special anamnesis:** pain anamnesis, acute, chronic, alarming symptoms ("red flag" e.g. weight loss, fever, paresis etc.), risk factors for chronification ("yellow flag" e.g. job dissatisfaction, psychosocial overload, passive basic attitude, heavy smoking, inadequate disease model conceptions etc.)
- **Clinical examination:** orthopaedic overall status (inspection, palpation, functional test), neurological/neuroorthopaedic examination, manual medical diagnostics
- **Imaging techniques:** X-ray, sonography, CT, MRI, etc.
- **Laboratory chemical examination:** blood count, coagulation, inflammatory parameters, etc.

4.4 Necessary Instruments

Tables 4.1, 4.2, 4.3 and 4.4 contain recommendations on the necessary instruments and the corresponding order addresses of the manufacturers for the following injection techniques on the spinal column.

Table 4.1 Disposable syringes

Product	Manufacturer/order address	Internet address
10 mL (Omnifix® Luer solo) B	B. Braun Melsungen AG D-34209 Melsungen	▶ www.bbraun.de
10 mL (Perifix® LOR Luer) B (loss of resistance)	„	▶ www.bbraun.de
5 mL (Omnifix® Luer solo) B	„	▶ www.bbraun.de
2 mL (Omnifix® Luer solo) B	„	▶ www.bbraun.de
1 mL (Omnifix® -F-Luer solo) B	„	▶ www.bbraun.de

Table 4.2 Disposable cannulas

Product	Manufacturer/order address	Internet address
0.80 × 120 mm 21 G (Sterican®) B	B. Braun Melsungen AG D-34209 Melsungen	► www.bbraun.de
0.60 × 80 mm 23 G (Sterican®) B	„	► www.bbraun.de
0.60 × 60 mm 23 G (Sterican®) B	„	► www.bbraun.de
Spinocan® 0.35 × 120 mm 29 G B	„	► www.bbraun.de
Guide cannula for Spinocan Pencan® 27 G + 29 G, 0.70 × 35 mm 22 G B	„	► www.bbraun.de
Spinocan® 0.70 × 75 mm 22 G B	B. Braun Melsungen AG D-34209 Melsungen	► www.bbraun.de
Coaxial interventional cannula iTP 0.60 × 100 mm 23 G iTP	Innovative tomography products GmbH D-44799 Bochum	► www.innotom.com

Table 4.3 Drugs

Product	Manufacturer/order address	Internet address
Mecain® 0.5%, ampoule 5 mL (active ingredient mepivacaine hydrochloride)	PUREN Pharma GmbH & co KG D-81829 Munich	► www.puren-pharma.de
Naropin® 2 mg/mL, ampoule 10 mL (active ingredient Robivacaine HCl)	Astra Zeneca GmbH D-22876 wedel	► www.astrazeneca.de
NaCl 0.9%, ampoule 10 mL B	B. Braun Melsungen AG D-34209 Melsungen	► www.bbraun.de
TriamHEXAL® 10 mg, ampoule 1 mL (active ingredient triamcinolone acetonide)	Hexal AG D-83607 Holzkirchen	► www.hexal.de

Table 4.4 Other

Product	Manufacturer/order address
Pulse oximeter	Practice supplies
Mouthguard	Practice supplies
Sterile gloves	Practice supplies

4.5 Pre-Intervention Education

The patient has the right to adequate information about the scope, the chances and the risks of the medical intervention to which he is to consent. This entitlement arises from the right of self-determination over one's person and is derived from a judgement of the German Reichsgericht from 1894 (judgement

of 31.05.1894 RGSt 25, 379ff.) and should protect the patient from the doctor assuming a right of paternalism to which he is not entitled. In addition, it is intended to guarantee the patient's right to knowingly make decisions regarding his body and health which, according to general or at least prevailing medical opinion, are wrong (Neu 2010).

With the entry into force of the **Patients' Rights Act** in 2013 (Sections 630a to 630 h of the German Civil Code), the **duty to inform** (Section 630c of the German Civil Code), the **duty to explain** (Section 630e of the German Civil Code) and the **obtaining of effective consent (**Section 630d of the German Civil Code) are expressly declared to be contractual duties arising from the treatment relationship (New 2017).

The **duties to provide information** are to be distinguished in terms of content from the duties to provide information under Section 630e of the German Civil Code, which are aimed at obtaining the patient's consent. They correspond to the principles developed by case law on therapeutic information and safeguarding information (Section 630c (2) and (3) BGB). Within this framework, the medical history, the diagnosis, the therapy and the necessity of findings investigations are to be discussed. The therapeutic information and advice should also serve to ensure the success of the cure (Neu 2017). Within the scope of the **duty to inform** (§630e BGB), the patient should be given an overview of the type, scope, implementation, dangers, necessity, urgency and suitability of the injection therapy on the spine during the **basic** and **risk information**. Part of the basic information is that the patient also receives an indication of the most serious risk that is specifically associated with the procedure. Therefore, if a periradicular injection is planned for the spine, the patient must be informed about the risk of **paraplegia,** among other things (New 2017). Risk education should provide the patient with an overview of the dangers and risk of failure of injection therapy. Not only general but also typical risks need to be explained. In principle, the patient must be informed irrespective of the frequency and density of the risk, unless alternative interventions with different frequencies of risk and different prospects of success are available. The decisive factor is, above all, whether the risk in question, if realized, would be particularly burdensome to the patient's way of life. This means that, as a matter of principle, information must also be provided about **extremely rare risks.** For injection therapy of the spinal column, for example, anaphylactic shock, meningitis and spondylodiscitis should be mentioned. Safeguarding the patient's right to self-determination requires that the patient be informed of alternative treatment options (Section 630a (1) of the German Civil Code) if several equivalent treatment options are available for a medically reasonable and indicated therapy, each of which leads to different burdens for the patient or offers different risks and chances of success. For injection therapy, for example, **treatment alternatives** (with the respective risk spectra and prospects of success) include physical therapy, physiotherapy, acupuncture, exercise therapy and drug therapy (New 2017).

Information about injection therapy must be provided in a **personal consultation by a physician** who has the necessary medical knowledge and experience to provide appropriate information. In the case of all outpatient spinal injection treatments, **information** on **the day of the procedure is** generally sufficient. In such cases, however, it must be made clear to the patient in connection with the information about the type of intervention and its risks, also in terms of the organizational and temporal sequence, that he or she is left with an independent decision as to whether to have the intervention performed. This is not the case if the patient is given the impression that he or she can no longer extricate himself or herself from a course of events that has already been set in motion (Neu 2017).

In addition to the **personal discussion which is always necessary,** reference can also be made to documents which the patient has received in the form of an information sheet. Necessary information on the injection treatments, including the risks, should be recorded in writing. Such written instructions have the advantage of a precise and comprehensive

description of the subject matter of the information as well as the essential provability for the physician.

4.6 Special Neuroanatomy of the Cervical, Thoracic and Lumbar Spine

There are **7 cervical vertebrae** and **8 cervical spinal cord segments**. Motion and spinal cord segments are not always at the same level as a result of growth displacement. The spinal nerve roots from C4 on down run caudally and laterally, descending to their point of exit, through the intervertebral foramen. Segmental syndromes are named after the spinal nerve root involved. In the cervical spine, the number also identifies the lower vertebral body of the affected segment. In the C6 syndrome, the C5/6 intervertebral disc is affected, and in the C7 syndrome, the C6/7 intervertebral disc is affected. The root C8 passes through the intervertebral foramen C7/Th1 (Fig. 4.1).

The immediate proximity of the vertebral artery and the cervical sympathetic nerve to the uncovertebral region of the lower cervical segments is of particular clinical significance (Fig. 4.2). Studies by Hovelacque (1925), Wrete (1934), Kummer (1984), Kehr and Jung (1985), and Bogduk et al. (1988) have called attention to the interconnections of the cervical sympathetic nerve with the cervical spinal nerves and the vertebral artery. The cervical border cord of the sympathetic nervous system, which is connected to the spinal nerves via the rr. communicantes grisei, denies the

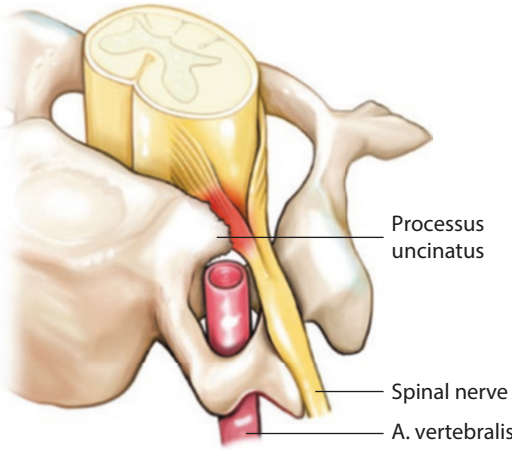


Fig. 4.2 Degenerative changes of the uncinate process can also lead to irritation of the sympathetic nervous system by pressing on the spinal nerve and the vertebral artery

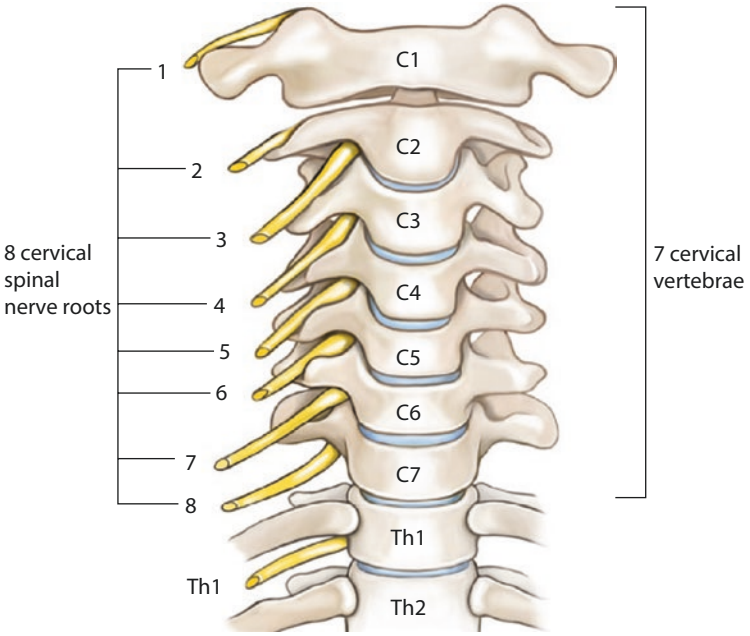


Fig. 4.1 Schematic representation of the cervical vertebrae and the cervicothoracic junction with their outgoing spinal nerve roots

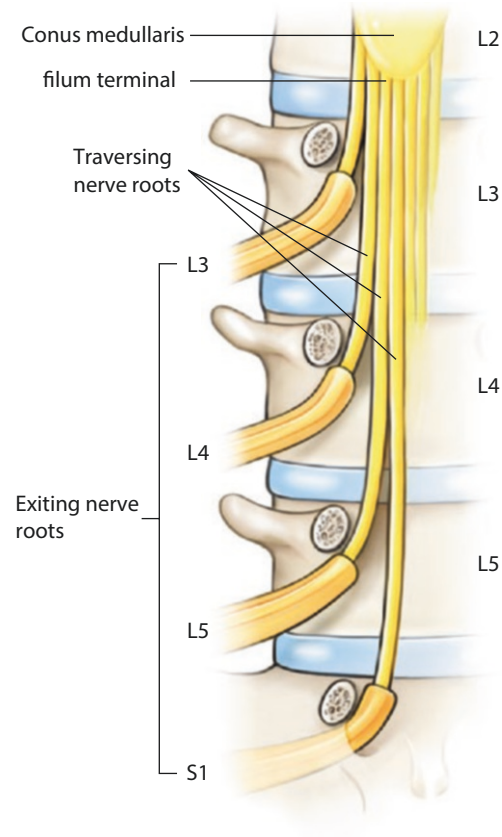
autonomic innervation of the head and neck region and the upper extremities with 3 cervical ganglia. The inferior ganglion, which is fused with the superior thoracic **ganglion** to form the **stellate ganglion, is** of particular importance as a major distribution point, since all efferent and almost all afferent sympathetic fibers from the head, neck, arm, and upper thorax pass through here (Theodoridis and Krämer 2017).

In the **thoracic spine,** the displacement of the spinal cord segments in relation to the associated motion segments described for the cervical spine continues. Between the first and sixth thoracic spines, the displacement is 2 segment heights, and from the seventh to tenth thoracic spines, 3 segment heights. Ventral branches of the thoracic spinal nerve supply the intercostal muscles, the costotransverse joints, the parietal pleura and the thoracic skin as intercostal nerves. Irritation of the thoracic spinal nerves results in so-called intercostal neuralgia.

In the **lumbar spine,** the displacement between the spinal cord segment and the corresponding motion segment is greatest. The lower end of the spinal cord with its tip extends only to the first-second lumbar vertebral body. The spinal nerves run for a longer distance in the subarachnoid space and exit the spinal canal further caudally in their associated intervertebral foramen (◘ Fig. 4.3). The totality of the long caudal spinal nerves, together with the filum terminale, the terminal filament of the spinal cord, which extends to the second coccygeal vertebra, is called the cauda equina.

> The lumbar nerve roots are only tangentially affected by intervertebral discs in the segments L4/L5 and L5/S1, so the risk of disc-related compression is greatest here.

A herniated disc of the **L4/5 intervertebral disc** (◘ Fig. 4.4, blue arrows) primarily compresses



◘ **Fig. 4.3** Emergent and traversing nerve roots in the lower lumbar spinal canal. From the medial pedicle boundary laterally, spinal nerve roots are referred to as exiting roots

the **L5 root**. In the case of a large lateral or cranially displaced prolapse at this level, the **L4 root** can also be compressed, since this runs above the L4/5 intervertebral disc.

The situation is different in the **intervertebral segment L5/S1.** Here, even the **roots L5 and S1** can be compressed at the same time, even in the case of a smaller lateral herniation (◘ Fig. 4.4, red arrows), since the spinal nerve root **L5** in the upper section of the intervertebral foramen rests directly on the outer lamellae of the intervertebral disc.

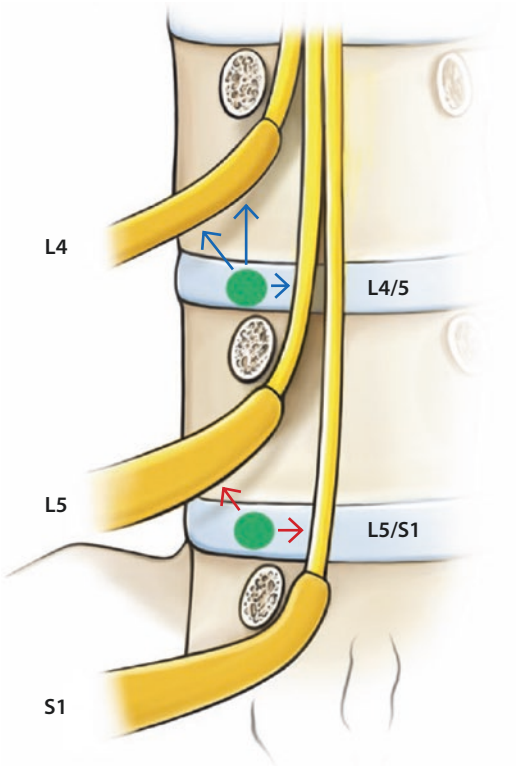


Fig. 4.4 Topography of the exiting and traversing nerve roots L4, L5 and S1 to the intervertebral discs L4/5 and L5/S1

4.7 Implementation of the Interventions

4.7.1 Cervical Spinal Nerve Analgesia (CSPA/Cervical PRT)

Principle

By injecting a local anaesthetic, if necessary mixed with steroids (off-label use), at the exit point of the cervical spinal nerve root from the intervertebral foramen at C5/C6, C6/C7, C7/Th1, one gains influence on discogenic (R. meningeus), arthrogenic (R. dorsalis) and radicular (R. ventralis) pain syndromes in the lower cervical motion segments.

Indication

- Cervical root irritation syndrome C5, C6, C7 and C8,
- pseudoradicular cervical syndrome,
- Cervicocephalic syndrome,
- local cervical syndrome with severe discomfort.

Necessary Instruments

- Disposable cannula 0.60 × 80 mm or 0.60 × 60 mm 23 G (Sterican®) B,
- Mecaine/mepivacaine hydrochloride 0.5% ampoule 5 mL,
- Disposable syringe 5 mL (Luer Solo) B,
- Pulse ox.

Technology

- Sitting position, feet supported (chair, foot step),
- Flexion of the cervical spine approx. 30–40 °,
- X-ray of the cervical spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the spinous process tips C5, C6 and C7.
- The puncture site is 3–4 cm lateral to the midline, halfway between two spinous processes (Fig. 4.5).
- **Landmarks of cervical spinal analgesia (CSPA)** are:
  - **Root C6**: 3.5–4 cm lateral between spinous processes C5 and C6,
  - **Root C7**: 3.5–4 cm lateral between spinous processes C6 and C7,
  - **Root C8**: 3.5–4 cm lateral between spinous processes C7 and Th1.

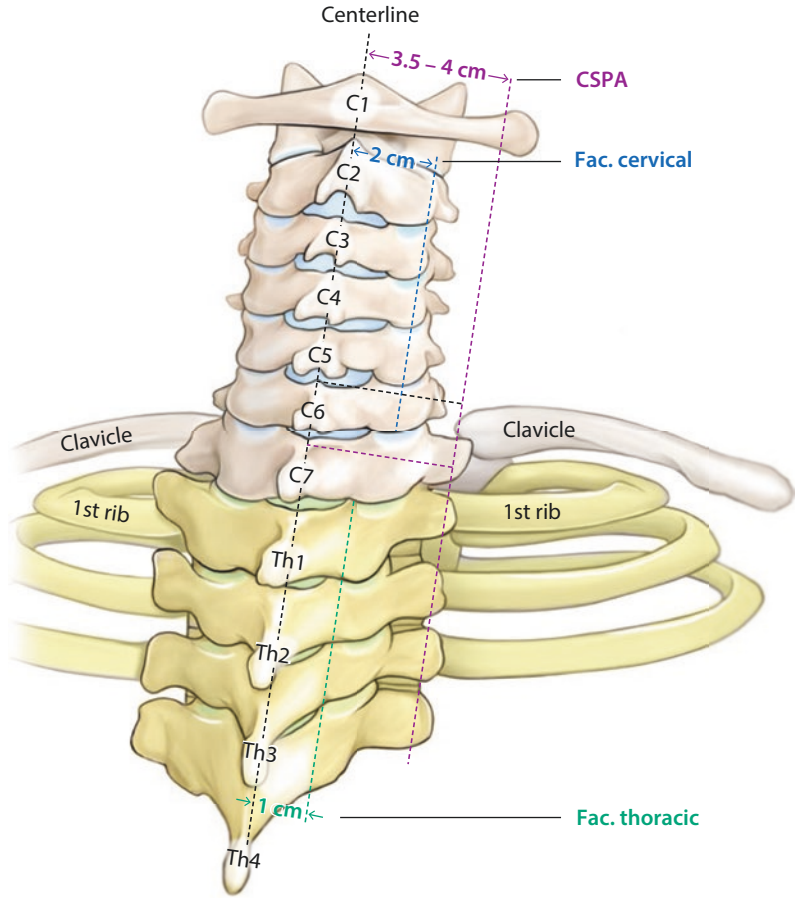


Fig. 4.5 Landmarks during cervical spinal nerve analgesia (CSPA) and cervical and thoracic facet infiltrations

- Insertion of the 6–8 cm long cannula with attached 5 mL syringe perpendicular to the skin surface, up to the edge of the lateral masses of the cervical vertebral arches (Fig. 4.6).
- Craniolateral stabbing direction above the bone boundary with advancement about 1 cm and injection of the local anesthetic.

4.7.2 Cervical Facet Infiltration (Fac. Cervical)

Principle

The injection of a local anaesthetic, possibly mixed with steroids, into the cervical vertebral joint capsules leads to the temporary blockade of irritated nociceptors.

Indication

- Pseudoradicular cervical syndrome,
- Cervicocephalic syndrome,
- localized cervical syndrome.

Necessary Instruments

- Disposable cannula 0.60 × 80 mm or 0.60 × 60 mm 23 G (Sterican®) B,
- Mecaine/mepivacaine hydrochloride 0.5% ampoule 5 mL,
- if necessary, triamcinolone acetonide 10 mg ampoule 1 mL Hexal,
- Disposable syringe 5 mL (Luer Solo) B,
- Pulse ox.

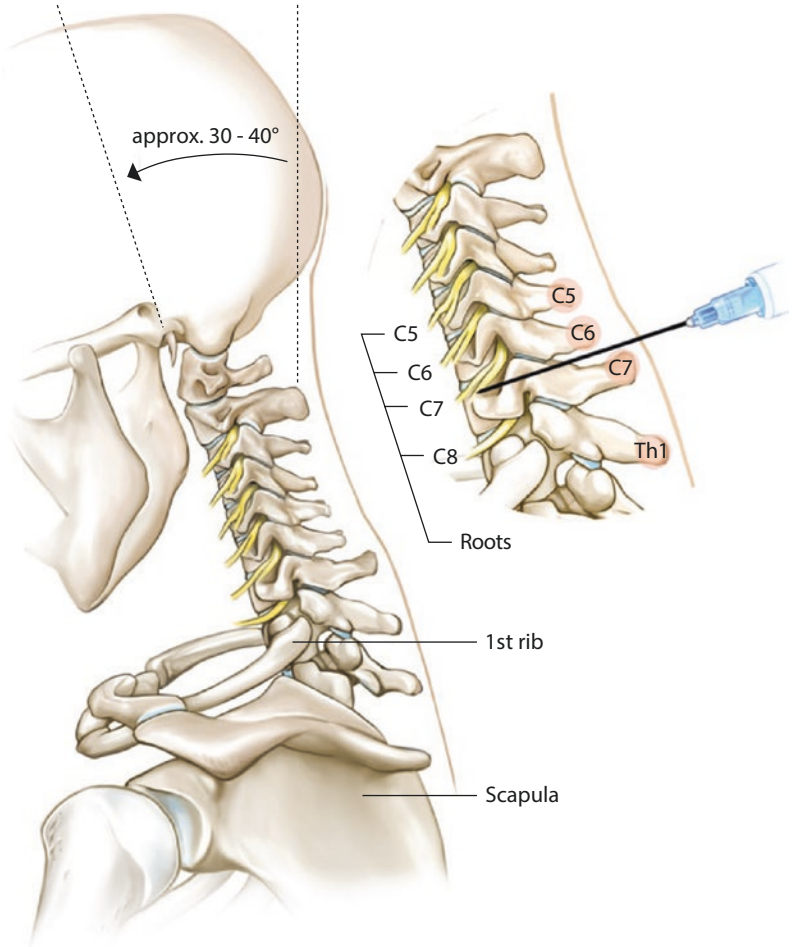


Fig. 4.6 Final needle position for cervical spinal nerve analgesia between C6 and C7 (C7 nerve root) craniolateral to the edge of the lateral vertebral arch portion. A needle length of at least 8 cm is required in most cases

Technology

- Sitting position, feet supported (chair, foot step),
- Flexion of the cervical spine approx. 20°–30°,
- X-ray of the cervical spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the spinous process tips C5, C6 and C7,
- The puncture site is 2 cm lateral to the midline, halfway between two spinous processes (Fig. 4.5).
- **Landmarks of** the **facet joints cervical** are:
  - **FAC C4/5**: 2 cm lateral between spinous processes C4 and C5,
  - **FAC C5/6**: 2 cm lateral between spinous processes C5 and C6,
  - **FAC C6/7**: 2 cm lateral between spinous processes C6 and C7.
- Insertion of the 6–8 cm long cannula with attached 5 mL syringe perpendicular to the skin surface, up to the respective facet joint (bone contact/dorsal capsule),
- Injection of the local anesthetic.

4.7.3 Conclusion and Clinical Relevance of Injection Therapy in the Cervical Spine

Cervical spinal nerve analgesia has a complex local effect on the pain outcome in the cervical spine, since infiltration at the exit point of the intervertebral foramen reaches not only the ventral spinal nerve, but also the dorsal spinal nerve, the meningeal spinal nerve and the sympathetic fibres via the communicating nerves. Injection therapy at the cervical spine focuses on a series of cervical spinal nerve analgesia supplemented by facet infiltrations. Both techniques represent an alternative to costly decompression surgery.

4.7.4 Thoracic Facet Infiltration (Fac. Thoracic)

- **Principle**

The injection of a local anaesthetic, possibly mixed with steroids, into the thoracic vertebral joint capsules leads to a temporary blockade of irritated nociceptors.

- **Indication**

- Thoracic facet syndrome,
- pseudoradicular thoracic syndrome,
- thoracic paravertebral muscle spasm.

- **Necessary Instruments**

- Disposable cannula 0.60 × 60 mm 23 G (Sterican®) B,
- Mecaine/mepivacaine hydrochloride 0.5% ampoule 5 mL,
- if necessary, triamcinolone acetonide 10 mg ampoule 1 mL Hexal,
- Disposable syringe 5 mL (Luer Solo) B,
- Pulse ox.

- **Technology**

- Sitting position, feet supported (chair, foot step),
- kyphosis of the thoracic spine,
- X-ray of the thoracic spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the spinous process apex C7 (vertebra prominens) and subsequently of the underlying spinous process apexes.
- The puncture site is located approximately 1 cm lateral to the upper edge of the spinous process (Fig. 4.5).
- Insertion of the 6 cm long cannula with attached 5 mL syringe perpendicular to the skin surface, up to the respective facet joint (bone contact/dorsal capsule).
- Injection of the local anesthetic.

4.7.5 Conclusion and Clinical Relevance of Injection Therapy in the Thoracic Spine

Degenerative form and function disorders of the dorsal thoracic motion segments can lead to irritation of nociceptors in the facet joints, the costotransverse joints and the thoracic spinal nerves. There is a high risk of pneumothorax with thoracic spine injection therapy. Thoracic facet infiltration is the safest of all thoracic spine injection techniques. The extremely rare thoracic disc herniation cannot be achieved by injections. Overall, it is recommended that injection treatment of the thoracic spine be largely restrained, since local and radicular thoracic syndromes show a benign self-limiting course.

4.7.6 Lumbar Spinal Nerve Analgesia (LSPA/Lumbar PRT)

- **Principle**

Posterolateral injection of a local anaesthetic, if necessary mixed with steroids (off-label use), at the exit site of the lumbar spinal nerve roots from the intervertebral foramen at L3/4, L4/5 and L5/S1.

- **Indication**

- Lumbar root irritation syndrome L3, L4, L5 and S1,
- pseudoradicular lumbar syndrome,
- localized lumbar syndrome.

Necessary Instruments

- Disposable cannula 0.80 × 120 mm 21 G (Sterican®) B,
- Mecaine/mepivacaine hydrochloride 0.5% 2 ampoules 5 mL,
- Disposable syringe 10 mL (Luer Solo) B,
- Pulse ox.

Technology

- Sitting position, feet supported (chair, foot step),
- X-ray of the lumbar spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the iliac crests and the spina iliaca posterior superior bds.,
- Palpation and marking of the spinous process tips L3, L4 and L5 (Fig. 4.7).
- The puncture site is 8 cm lateral to the midline at the level of the iliac crests.
- Starting from the puncture site (needle position initially perpendicular to the skin), the needle is adjusted to 60 ° in the horizontal plane in a lateral direction.
- Insertion of the 12 cm long cannula with 10 mL syringe attached.
- **Landmarks** and corresponding foraminoarticular regions **during lumbar spinal nerve** analgesia **(LSPA):**
  - **Region L3/4**: horizontal puncture to the root L3,
  - **Region L4/5**: Raise the syringe and angle it vertically by 30 ° to the root L4,
  - **Region L5/S1**: Raise the syringe and angle it vertically by 50 ° to the root L5.
- Locate the appropriate foraminoarticular region and inject the local anesthetic.

The main difference to the techniques of Reischauer (1953) and Macnab and Dall (1971) is that a secure bone contact in the posterolateral part of the lumbar vertebra is achieved by the oblique needle direction.

4.7.7 Lumbar Facet Infiltration (Fac. Lumbal)

Principle

The injection of a local anaesthetic, possibly mixed with steroids, into the lumbar vertebral joint capsules leads to a temporary blockade of irritated nociceptors.

Indication

- Pseudoradicular lumbar syndrome,
- localized lumbar syndrome,
- lumbar facet syndrome,
- Hyperlordosis cross pain.

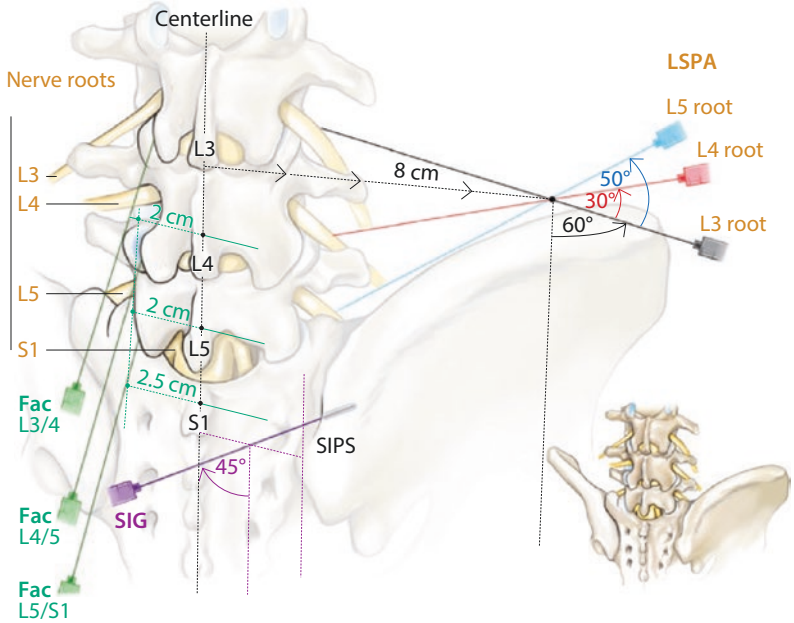


Fig. 4.7 Landmarks and needle locations during lumbar spinal nerve analgesia (LSPA) and lumbar facet infiltrations (*green cannulas*) and SIG infiltration (*purple cannula*). SIG sacroiliac joint, SIPS spina iliaca posterior superior

- **Necessary Instruments**
  - Disposable cannula 0.60 × 80 mm or 0.60 × 60 mm 23 G (Sterican®) B,
  - Mecaine/mepivacaine hydrochloride 0.5% 2 ampoules 5 mL,
  - if necessary, triamcinolone acetonide 10 mg ampoule 1 mL Hexal,
  - Disposable syringe 10 mL (Luer Solo) B,
  - Pulse ox.

- **Technology**
  - Sitting position, feet supported (chair, foot step),
  - X-ray of the lumbar spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
  - Palpation and marking of the iliac crests and the spina iliaca posterior superior bds..,
  - Palpation and marking of the spinous process tips L3, L4 and L5.
  - The puncture site is 2–2.5 cm lateral to the midline, halfway between two spinous processes (Fig. 4.7).
  - **Landmarks of the facet joints lumbar** are:
    - **FAC L3/4**: 2 cm lateral between spinous processes L3 and L4,
    - **FAC L4/5**: 2 cm lateral between spinous processes L4 and L5,
    - **FAC L5/S1**: 2.5 cm lateral between the spinous processes L5 and S1.
  - Insertion of the 6–8 cm long cannula with attached 10 mL syringe perpendicular to the skin surface up to the respective facet joint (bone contact/dorsal capsule).
  - Injection of the local anesthetic.

4.7.8 Ligamentous Infiltration at the Sacroiliac Joint (SIG Block)

- **Principle**

The main target of this injection technique is the region at the transitions from ligament to bone at the dorsal ligamentous apparatus of the sacroiliac joints (SIG) and at the attachments of the iliolumbar ligament.

- **Indication**
  - SIG syndrome,
  - SIG Blockade,
  - localized lumbar syndrome,
  - pseudoradicular lumbar syndrome,
  - if necessary after chirotherapeutic treatment,
  - if necessary in sacroiliitis.

- **Necessary Instruments**
  - Disposable cannula 0.60 × 80 mm or 0.60 × 60 mm 23 G (Sterican®) B,
  - Mecaine/mepivacaine hydrochloride 0.5% 2 ampoules 5 mL,
  - if necessary, triamcinolone acetonide 10 mg ampoule 1 mL Hexal,
  - Disposable syringe 10 mL (Luer Solo) B,
  - Pulse ox.

- **Technology**
  - Sitting position, feet supported (chair, foot step),
  - X-ray of the lumbar spine a.p. and laterally, if necessary also a pelvic overview x-ray, hanging laterally in the direction of the practitioner's gaze,
  - Palpation and marking of the iliac crests and the spina iliaca posterior superior bds..,
  - Palpation and marking of the spinous process tips L3, L4, L5 and S1.
  - The insertion site is located in the midline at the level of the equilateral posterior iliac spine and the S1 spinous process (Fig. 4.7).
  - **Landmarks of the SIG**:
    - 45 ° angle adjustment to the skin,
    - Stitch direction to lateral.
  - Insertion of the 6–8 cm long cannula with attached 10 mL syringe up to the respective SIG joint (bone contact/ligamentous infiltration).
  - Injection of the local anesthetic.

4.7.9 Epidural Dorsal Injection (Epi Dorsal/Epi Straight)

Principle

Injection of a local anaesthetic, if necessary mixed with steroids (off-label use), into the dorsal lumbar epidural space. The aim of orthopaedic pain therapy is to bypass oppressed nerve roots by repeated single injections to reduce pain sensitivity.

Indication

- Polyradicular lumbar root irritation syndrome,
- central spinal stenosis.

Necessary Instruments

- Spinocan cannula 0.70 × 75 mm 21 G (Sterican®) B or coaxial iTP cannula 0.60 × 100 mm 23 G (iTP),
- Mecaine/mepivacaine hydrochloride 0.5% 2 ampoules 5 mL or Naropin 2 mg/mL ampoule 10 mLpoule 10 mL B,
- 2 × disposable syringes (Loss of Resistance)10 mL (Perifix® LOR Luer) B,
- sterile gloves, mouth guard,
- Pulse ox.

Technology

- Sitting position, feet supported (chair, foot step),
- X-ray of the lumbar spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the iliac crests and the spina iliaca posterior superior bds..,
- Palpation and marking of the spinous process tips L3, L4 and L5 (Fig. 4.8).
- The puncture site is located exactly in the midline between the spinous processes, usually between L3 and L4 and L4 and L5.
- Injection of a "loss-of-resistance syringe" filled with physiological saline solution with slow advancement under continuous pressure on the syringe plunger (loss-of-resistance technique).
- When the lig. Flavum is penetrated by the cannula tip, there is an abrupt loss of resistance.
- Replace the NaCl syringe with the LA syringe.
- Injection of the local anesthetic.

4.7.10 Epidural Perineural Injection (Epi Peri)

Principle

Injection of a local anaesthetic, if necessary mixed with steroids (off-label use), into the ventrolateral epidural space in segment L5/

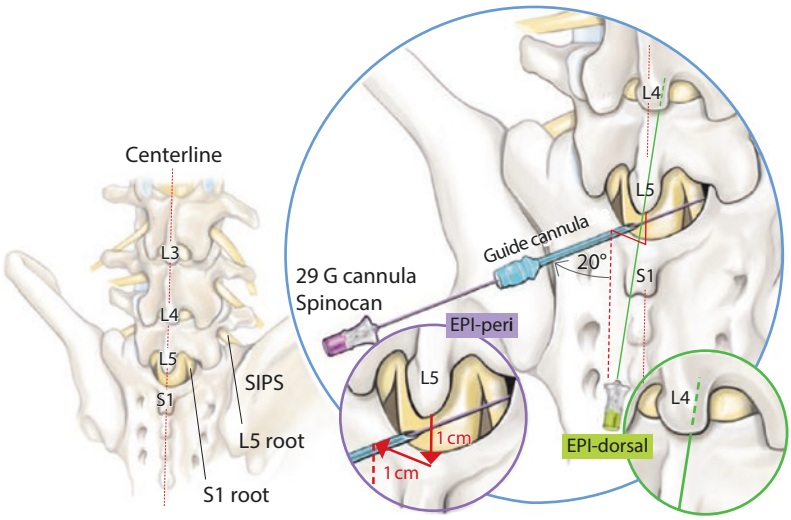


Fig. 4.8 Landmarks and needle positions for epidural dorsal injection (*green cannula*) between L4 and L5 and for epidural perineural injection (*purple cannula*) in segment L5/S1. The 29-G fine cannula is located in the anterolateral epidural space at the superior border of the sacrum between L5 and S1 roots. SIPS Spina iliaca posterior superior

S1 via an oblique contralateral access with a double needle system.

Indication

- Monoradicular root irritation syndrome L5 and S1,
- exacerbated root irritation due to postoperative scars.

Necessary Instruments

- Spinocan cannula 0.35 × 120 mm 29 G (Sterican) B,
- Guide cannula for Spinocan Pencan® 0.70 × 35 mm 22 G B,
- Naropin 2 mg/mL ampoule 10 mL B,
- 2 × disposable syringes 1 mL (Omnifix® -F-Luer Solo) B,
- sterile gloves, mouth guard,
- Pulse ox.

Technology

- Sitting position, feet supported (chair, foot step),
- X-ray of the lumbar spine a.p. and laterally, hanging laterally in the direction of the practitioner's gaze,
- Palpation and marking of the iliac crests and the spina iliaca posterior superior bds..,
- Palpation and marking of the spinous process tips L3, L4, L5 and S1 (Fig. 4.8).
- The puncture site is 1 cm below and 1 cm contralateral to the L5 spinous process.
- Insertion of the guide cannula at an angle of 15–20 ° obliquely (Theodoridis et al. 2009b) to the lig. Flavum.
- Insert the 29 G cannula through the guide cannula. Advance the cannula to the anterolateral epidural space L5/S1 (Figs. 4.8 and 4.9).
- Attach the 1 mL syringe and inject the local anesthetic (Fig. 4.9).

In a study by Teske et al. (2011), volume measurements of the anterolateral epidural space L5/S1 were performed. It was found that even small volumes are sufficient (approx. 1 mL) to flood both nerve roots (L5 and S1).

4.7.11 Conclusion and Clinical Relevance of Injection Therapy in the Lumbar Spine

The main objective of injection therapy in the lumbar spine is the compressed and swollen nerve root, which can best be achieved in the anterolateral epidural space with epidural peri-

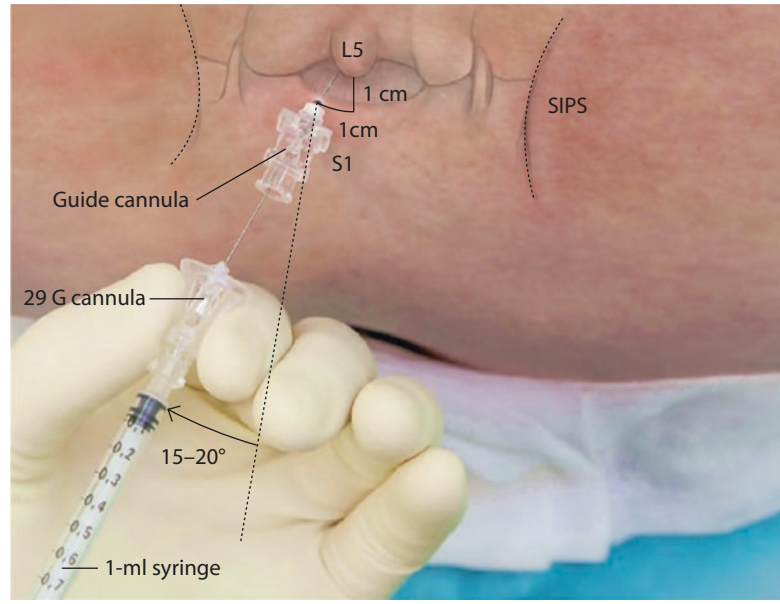


Fig. 4.9 Final needle position of the double needle system on the patient during epidural perineural injection (view from cranial). The needle channel deviates approximately 15–20 ° from the sagittal midline. SIPS Spina ilica posterior superior

neural injection and in the foraminoarticular region with spinal nerve analgesia. In cases of severe pain due to nerve root irritation, lumbar spinal nerve analgesia can even be performed daily for several days. Epidural injections as well as facet and SIG infiltrations may supplement this part of the treatment program. Depending on the severity, injections can be performed on an outpatient or inpatient basis.

4.8 Possible Complications

The **possible complications** include those that can also occur with other injections. However, due to the proximity of the CNS, these can take on a special significance.

- **Orthostatic reactions** are the most common. Symptoms such as pallor, nausea and brief clouding of consciousness are usually harmless and quickly reversible by elevating the legs.
- Signs of **intravascular application** with **cerebral** and **cardiovascular complications** may include vomiting, urge to talk, euphoria, anxiety, agitation, restlessness, dizziness and loss of orientation. Muscle twitching and convulsions (especially clonic) may be followed by coma and central respiratory paralysis. Local anaesthetics have a quinidine-like effect on the heart: decrease in frequency, which may lead to cardiac arrest, prolongation of the conduction time to AV block, decreased excitability, decreased contractility (Theodoridis et al. 2009b).
- Local or general **allergic reactions** up to **anaphylactic shock** can be observed, especially in cases of predisposition (Grifka et al. 1999).
- **Infection**: The proximity to the CNS carries the risk that a spondylitis or spondylodiscitis can develop into an ascending infection up to meningitis. It is particularly problematic that the infection is not always immediately recognizable in depth. An increase in pain with a possible rise in temperature should prompt early laboratory checks and possibly an MRI.
- **Deep hemorrhages** occur as paravertebral hematoma after lumbar or cervical spinal nerve analgesia and facet infiltrations. **Epidural hematomas** from injections are extremely rare. Surgical evacuation is required in cases of compression with neurological symptoms.
- The risk of a **dura or nerve root puncture** with CSF leakage exists with all injections in the vicinity of the CNS. Prolonged loss of cerebrospinal fluid from a persistent dural leak may result in a **postpuncture syndrome.** Typical features are the onset of severe headache after sitting up, associated with one or more accompanying symptoms (neck stiffness, hearing loss, nausea, etc.) and improvement of headache symptoms within minutes of lying down. In 80% of cases, there is a spontaneous remission of symptoms within 5 days (Sirtl et al. 2017).
- In the case of accidental injection of local anaesthetics intrathecally, the local anaesthetic can reach the intracranium and bind to central neuronal structures. The typical symptoms (coma, wide pupils without reaction, central apnoea, arterial hypotension up to cardiovascular arrest) are also called **"total spinal anaesthesia".** Provided that resuscitation measures are carried out swiftly and correctly according to ACLS standards, prevention of complications, hypoventilation and/or hypoxia, central blockade (depending on the dose and type of local anaesthetic) recovers completely with a good prognosis (Theodoridis et al. 2010).
- In the case of injections at the lower cervical spine and at the thoracic spine, accidental puncture of the pleura pulmonalis with subsequent **pneumothorax** is an important complication. Clinical symptoms are a stabbing pain on inhalation and exhalation, shortness of breath and coughing. Treatment depends on the severity of the pneumothorax and ranges from observation to placement of a chest drain.

However, the overall complication rate of spinal injection therapy is low (Theodoridis and Neu 2017), especially when compared to other minimally invasive procedures such as laser therapy, intradiscal procedures, endoscopic and open disc surgery.

4.9 Results in the Literature

4.9.1 Facet/SIG Infiltrations

The importance of the vertebral joints in the development of back and leg pain has been pointed out by numerous investigators (Carrera 1980; Ghormley 1993; Moran et al. 1988; Young and King 1983; Schwarzer et al. 1994; Manchikanti et al. 1999, 2002) in the international literature. Studies using image-guided injections have demonstrated that even small amounts of 0.3–0.5 mL of a local anesthetic are sufficient to safely surround and anesthetize the ramus medialis at the facet joints (Barnsley and Bogduk 1993; Dreyfuss et al. 1997). A comprehensive publication by Manchikanti with another 54 authors (Manchikanti et al. 2013), which also represents the guidelines of the American Association of Interventional Pain Physicians, demonstrates good evidence regarding diagnostic blocks at the facet and SIG joints and satisfactory to good evidence regarding therapeutic blocks. In contrast, there is limited evidence for intra-articular facet injections. In this publication, a total of over 2400 papers from 1966 to 2012 were considered and evaluated. The Cochrane Musculosceletal Review Group criteria and the Newcastle-Ottawa Scale criteria for observational fluoroscopic studies were used as criteria.

4.9.2 Epidural/Periradicular/Transforaminal Injections

There are numerous results from randomized-controlled trials on the efficacy of epidural injections for lumbar root compression syndrome (McQuay and Moore 1998; Watts and Silagy 1995; Carette et al. 1997; Cuckler et al. 1985; Klenerman et al. 1984; Koes et al. 1995, 1999; van Tulder et al. 1997). The aforementioned work by Manchinkanti et al. (2013) found good evidence for epidural and transforaminal injection therapy for the treatment of radiculopathy in disc herniation and satisfactory evidence for spinal stenosis. In contrast, limited evidence was found for diagnostic nerve root blocks.

Specifically on the epidural perineural injection technique with the double-needle system, there are a total of three studies, all with positive evidence. Local anesthetics with steroids were predominantly used (Krämer et al. 1997), but also Orthokine (Becker et al. 2007), a protein produced by the patient's own blood, as an anti-inflammatory or local anesthetic alone (Ng et al. 2005; Teske et al. 2011).

4.10 Reimbursement of Costs

4.10.1 Private Medical Reimbursement (GOÄ)

The most important billing codes in the German Fee Schedule for Physicians (GOÄ) for injection therapy of the spine are summarized in Table 4.5.

4.10.2 Reimbursement by Statutory Health Insurance Physicians (EBM)

The billable services provided by SHI-accredited physicians are assigned to a point value system according to the uniform assessment scale (EBM). An inspection time is also specified for each service item (Table 4.6). The defined inspection times are the basis for the plausibility and billing checks of the panel doctors' association.

Table 4.5 Possible billing codes for injection treatment of the spine in the GOÄ (as of 2013)

Digit no.	Power	1gang (in €)	2.3 times (in €)	3.5 times (in €)
255	Injection intraarticular or perineural	5.54	12.74	19.38
268	Medicinal infiltration treatment in the area of several body regions (also one body region on both sides), per session	7.58	17.43	26.52
470	Induction and monitoring of a single-stage subarachnoid spinal anaesthesia (lumbar anaesthesia) or single-stage peridural (epidural) anaesthesia, up to 1 h duration	23.31	53.62	81.60
476	Induction and monitoring of supraclavicular or axillary arm plexus or paravertebral anaesthesia, up to 1 h	22.15	50.94	77.52
491	Infiltration anaesthesia of large areas, also paracervical anaesthesia	7.05	16.22	24.68

Table 4.6 Billing codes, points and testing times for reimbursement by panel doctors

Digit	Description	Points	Test time (min)
30,721	Sympathetic blockade (injection) at the cervical border cord	212	4
30,722	Sympathetic blockade (injection) at the thoracic or lumbar border cord	186	4
30,731	Plexus, spinal or peridural analgesia, per session	672	5
30,724	Analgesia of one or more spinal nerves and the rr. Communicantes at the foramina intervertebralia, per session	186	3

4.11 Conclusion and Clinical Relevance

- **Injection therapy of** the spine is of **great importance in** the treatment of degenerative spinal diseases, since decongestant and anti-inflammatory drugs are applied **locally** to the point of origin of nociception in the motion segment, thus directly influencing the **primary disorder.**
- The **landmark-guided** techniques are just as effective in the hands of the experienced as the sonography-, image converter- or CT-guided techniques, but can be applied safely and above all radiation-free (for patient and physician) without greater costly equipment and organizational effort. Ultimately, all these procedures have a common end goal and a more or less long learning curve.
- Before the indication for **spinal surgery** is made, it makes sense to check whether one of the **segmental injection procedures** cannot be used.
- **Local, radicular and pseudoradicular spinal syndromes** with a correlation between clinical and imaging findings are usually the **main indications.**

- **Informing patients** requires a **high degree of sensitivity**. Jurisprudence requires comprehensive information even about rare risks.
- Conscientious preparation of the injection treatment helps to avoid mistakes and complications. However, the **complication rate** is **low** overall.
- Direct spinal local anesthetic application is one of the **safest and most effective methods of** orthopedic/casualty surgical pain management.

References

Barnsley L, Bogduk N (1993) Medial branch blocks are specific for the diagnosis of cervical zygapophysial joint pain. Reg Anaesth 18:343–350

Becker C, Heidersdorf S, Drewlo S, Zirke S, Krämer J, Willburger R (2007) Efficacy of epidural perineural injections with autologous contitioned serum for lumbar radicular compression. An investor-initiated, prospective, double-blind, reference-controlled study. Spine 32(17):1803–1808

Bogduk N, Windsor M, Inglis A (1988) The innervation of the cervical intervertebral discs. Spine 13:2–8

Carette S et al (1997) Epidural corticosteroid injections for sciatica due to herniated nucleus pulposus. N Engl J Med 336:1634–1640

Carrera F (1980) Lumbar facet injection in LBP and sciatica. Radiology 137:661–664

Cuckler JM, Bernini PA, Wiesel SW, Booth RE Jr, Rothman RH, Pickens GT (1985) The use of steroids in the treatment of lumbar radicular pain. J Bone Joint Surg Am 67:63–66

Dreyfuss P, Schwarzer AC, Lau P, Bogduk N (1997) Specifity of lumbar medial branch and L5 dorsal ramus blocks: a computed tomographic study. Spine 22:895–902

Ghormley RK (1993) Low back pain with special reference to the art. Facets with presentation of an operative procedure. J Amer Med Ass 101:1773

Grifka J, Broll-Zeitvogel E, Anders S (1999) Injektionstherapie bei Lumbalsyndromen. Orthopade 28: 922–931

Hovelacque A (1925) Le nerf sinu-vertebral. Ann. Anat Pathol 2:435

Kehr R, Jung A (1985) Die Chirurgie der A. vertebralis. In: Gutmann G (ed) Die Halswirbelsäule. Fischer, Stuttgart

Klenerman C, Greenwood R, Davenport HT et al (1984) Lumbar epidural injection in the treatment of sciatica. Brit J Rheumatol 23:35–38

Koes BW et al (1995) Efficacy of epidural steroid injections for low back pain and sciatica: a systematic review of randomised clinical trials. Pain 63:279–288

Koes BW et al (1999) Epidural steroid injections for low back pain and sciatica: an updated systematic review of randomised clinical trials. Pain Digest 9: 241–247

Krämer J, Ludwig J, Bickert U, Owczarek V, Traupe M (1997) Lumbar epidural perineural injection: a new technique. Eur Spine J 6:357–361

Kummer B (1984) Anatomische Grundlagen zum zerviko-zephalen Syndrom. Z Orthop 122:616

Macnab J, Dall D (1971) The blood supply of the lumbar spine and its application to the technique of intertransverse lumbar fusion. J Bone Jt Surg B53:628

Manchikanti L, Pampati VS, Pakanati RR, Fellows B (1999) The prevalence of facet joint pain in chronic low back pain. Pain Physician 2:59–64

Manchikanti L, Singh V, Rivera J, Pampati V (2002) Prevalence of cervical facet joint pain in chronic neck pain. Pain Physician 5:243–249

Manchikanti L et al (2013) An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part II: guidance and recommendations. Pain Physician 16:49–283

McQuay H, Moore A (1998) Epidural corticosteroids for sciatica. In: An evidence-based resource for pain relief. The Bath Press Ltd, Bath, pp 216–218

Moran R, O'Connell D, Walsh MG (1988) The diagnostic value of facet injections. Spine 13:1407–1410

Neu J (2010) Das Aufklärungsgespräch. In: Wirth CJ, Mutschler W, Bischoff HP et al (eds) Komplikationen in Orthopädie und Unfallchirurgie. Thieme, Stuttgart, pp 50–55

Neu J (2017) Allgemeine und spezielle Aspekte der orthopädischen Injektionstherapie. Aufklärung. In: Theodoridis T, Krämer J (eds) Injektionstherapie an der Wirbelsäule Manual und Atlas. Thieme, Stuttgart, pp 94–98

Ng L, Chaudhary N, Sell P (2005) The efficacy of corticosteroids in periradicular infiltration for chronic radicular pain. Spine 30(8):857–862

Reischauer F (1953) Zur Technik der lokalen Novocainbehandlung bei Lumbago/Ischias. Dtsch med Wschr 78:1373

Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N (1994) Clinical features of patients with pain stemming from the lumbar zygapophysial joints. Is the lumbar facet joint syndrome a clinical entity. Spine 19:1132–1137

Sirtl C, Theodoridis T, Nastos I (2017) Postpunktionelles Syndrom. In: Theodoridis T, Krämer J (eds) Injektionstherapie an der Wirbelsäule Manual und Atlas. Thieme, Stuttgart, pp 288–289

Teske W, Zirke S, Nottenkämper J, Lichtinger T, Theodoridis T, Krämer J, Schmidt K (2011) Anatomical and surgical study of volume determination of the anterolateral epidural space nerve root L5/S1 under the aspect of epidural perineural injection in minimal invasive treatment of lumbar nerve root compression. Eur Spine J 20:537–541

Theodoridis T (2007) Injektionstherapie an der Wirbelsäule ohne Bildsteuerung. Orthopade 36:73–86

Theodoridis T (2012) Stellenwert der Injektionstherapie bei degenerativen Erkrankungen der Lendenwirbelsäule. Orthopade 41:94–99

Theodoridis T (2016) Injektionstherapie und Injektionstechniken an der Wirbelsäule. In: Casser H-R, Hasenbring M, Becker A, Baron R (eds) Rückenschmerzen und Nackenschmerzen. Springer, Berlin, pp 312–318

Theodoridis T, Krämer J (2017) Injektionstherapie an der Wirbelsäule. In: Manual und Atlas. Thieme, Stuttgart

Theodoridis T, Neu J (2017) Erkenntnisse über die Injektionstherapie an der Wirbelsäule aus norddeutschen Schlichtungsverfahren. In: Theodoridis T, Krämer J (eds) Injektionstherapie an der Wirbelsäule Manual und Atlas. Thieme, Stuttgart, pp 104–105

Theodoridis T, Ludwig J, Krämer J (2009a) Injektionstherapie an der Lendenwirbelsäule. In: Jerosch J, Steinleitner W (eds) Minimal invasive Wirbelsäulen-Intervention. Deutscher Ärzteverlag, Köln, pp 9–25

Theodoridis T, Mamarvar R, Krämer J, Wiese M, Teske W (2009b) Einstichwinkel bei der epiduralperineuralen Injektion an der Lendenwirbelsäule. Z Orthop Unfall 147(1):65–68

Theodoridis T, Krämer J, Sirtl C (2010) Komplikationen bei Punktion und Injektion. In: Wirth CJ, Mutschler W, Bischoff HP et al (eds) Komplikationen in Orthopädie und Unfallchirurgie. Thieme, Stuttgart, pp 126–132

van Tulder MW, Koes BW, Bouter LM (1997) Conservative treatment of acute and chronic non-specific low back pain: a systematic review of randomised clinical trials of the most common interventions. Spine 22(18):2128–2156

Watts RW, Silagy CA (1995) A meta analysis on the efficacy of epidural corticosteroids in the treatment of sciatica. Anaesth Intensive Care 23:564–569

Wrete M (1934) Über die Verbindung der Cervikalnerven mit den sympathischen Grenzsträngen beim Menschen. Z mikr-anat Forsch 1:425

Young KH, King AI (1983) Mechanism of facet load transmission as a hypothesis for low back pain. Spine 8:327

Radiation Protection and C-Arm Operation

U. Schütz and M. Kraus

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_5

5.1 Introduction

While the natural radiation exposure in Central Europe is 2–2.5 mSV per year, the medically induced radiation exposure of humans is almost the same (0.6–1.8 mSv) and continues to increase (Huda et al. 2008; Wrixon 2008a). The collective dose from medical radiation has experienced a large increase in the last two decades and is mainly due to the significant increase in CT examinations and fluoroscopy-assisted interventional and minimally invasive surgical procedures (Schütz 2010). Not only the patient but also the medical staff is affected by the progressive radiation exposure as a source of danger (Singer 2005). The increasing reduction of visualization of the surgical field conditions that radiographic fluoroscopy (= fluoroscopy, DL) is increasingly used (Yu and Khan 2014). Thus, mobile intraoperative DL (MIODL), especially by means of C-arm technology, has become an indispensable part of modern minimally invasive and interventional spine therapy (Carbone et al. 2003).

In Germany, the handling of radiation sources is regulated by the X-ray Ordinance (RöV), which also sets limits and guidelines on the extent to which occupational exposure can take place, based on data from special expert committees such as the International Commission on Radiological Protection (ICRP) (Wrixon 2008b). These have been amended several times and permitted dose limits have been lowered more and more. The opposing development of an increase in dose-intensive examination methods and simultaneously prescribed reduction of radiation exposure for occupationally exposed persons represents a great challenge for radiation protection in medicine.

In MIODL, the operating room personnel, but especially the surgeons, are exposed to redundant ionizing radiation. The main problem here is scattered radiation.

> Only about 2% of the radiation that can be used for imaging reaches the X-ray detector of the C-arm. The rest is scattered radiation, of which 80–90% is absorbed by the patient and 10–20% is emitted into the environment, potentially exposing the operating room staff (Dresing 2011).

In Germany, in contrast to radiology, no specially trained medical-technical radiology assistants (MTRA) are **used** in **the OR who** are trained in the use of mobile X-ray equipment. Surgeons and OR nurses normally perform MIODL themselves. However, a basic prerequisite for the optimal use of MIODL in terms of image quality and radiation protection is that the operator is familiar with the respective C-arm type and its possible use in the various minimally invasive and interventional situations. Modern DL units can easily generate dose rates in a dimension of 0.2 Gy per min (Schütz 2010). Most units currently in use usually do not provide a way to approximate patient dose other than the crude surrogate parameter "total fluoroscopy time" (DL duration). In order to release as little radiation as possible for optimal intraoperative imaging, an intensive study of the basics of radiation protection is essential, and knowledge of the emission of radiation through the use of the mobile devices is required for this purpose. However, despite compulsory further training, surgeons in particular are often poorly instructed in the operation of MIODL devices, which leads to unnecessarily high radiation exposure of operating theatre staff and patients. **In many of the MIODL procedures performed mainly by non-radiologists, high doses of radiation can** be **delivered to the patient and medical staff,** causing immediate or long-term radiogenic effects. In this regard in particular, reports of radiation-induced skin damage have increased sharply since the early 1990s (Mettler Jr et al. 2002). A case study reports a significant increase in malignant diseases in orthopaedics& trauma surgery (O&U) compared to other departments of a hospital (Mastrangelo et al. 2005). The International Commission on Radiological Protection (ICRP) continues to receive reports of cases in which massively high doses of radiation are applied to patients and staff in non-compliance with these requirements. In some interventional procedures, skin entry

doses (HED) of patients come close to values known from radiotherapy or oncoradiology (Valentin 2000). Radiation damage to physicians and ancillary staff has also been observed in isolated cases. In addition to radiation-induced skin damage, however, a possible induction of future tumors is associated as a problem, especially in younger patients, which only becomes apparent after years of latency.

5.2 Biological Effects of Ionising Radiation

The aim of the limit specifications of the Radiation Protection Ordinance and the ICRP is to avoid radiation damage, which is differentiated into so-called **stochastic**, i.e. random, and **deterministic** effects (Blakely 2000). While the latter clearly have radiation energy threshold doses depending on the cell type affected (minimum approx. 1 Gy) and the severity of the disease is dose-dependent, in radiation protection it is assumed that the stochastic effects do not have threshold doses and that the number of persons affected increases with progedient radiation dose. When assessing these effects, it is important to distinguish between the absorbed dose (Gy), the pure energy transferred to matter by the radiation, and the biologically relevant **equivalent dose (Sv) for the entire body (= effective dose, ED) and the individual organs (= organ dose, OD)**, to which a specific biological weighting factor is added to the absorbed dose. In medical X-rays, the ED is given as between 10 µSv and 20 mSv, depending on the method and procedure (Schütz 2010). In interventional procedures supported by X-ray or CT fluoroscopy, focal acute doses to the patient of 0.1–30 Gy can occur (Mettler Jr et al. 2002).

The threshold doses with regard to deterministic damage are relatively high for most organs and tissues (several Gy), so that for interventional radiological or MIODL procedures "only" acute skin reactions such as erythema and epilation are of importance, which require a cutaneous dose absorption of approx. 2 Gy (ICRP 2000; Selbert 2004). In their review, Mettler et al. (Mettler Jr et al. 2002) report radiation-induced skin damage and eye injury in short- and long-term effects depending on the dose penetrating the skin surface (HED). These focal dose-dependent injuries (Table 5.1) were reported more frequently in the past, but are still reported sporadically, especially for fluoroscopic procedures.

In addition to the deterministic acute damage caused by radiation, however, the possible induction of future tumours (increased cancer risk) is always associated as a problem with radiation exposure (Schütz 2010). To date, the only way to quantitatively assess the extent of such stochastic effects is to perform epidemiological comparisons in the range of intermediate radiation doses (100 mSv to approx. 5 Sv). However, this does not work in the medically interesting range of low radiation doses. It is

Table 5.1 Deterministic early damage in adult patients and medical staff in O&U

Organ	Effect	Threshold dose
Skin	Brief erythema[a]	2 Gy
	Temporary epilation	3 Gy
	Permanent epilation[a]	7 Gy
	Skin necrosis	12–18 Gy
Testes	Temporary sterility	0.15 Gy
	Permanent sterility	3.5 Gy
Ovary	Sterility	2.5–6 Gy
Eye lens	Acute opacification (short-term cataract formation)[a]	0.5–2 Gy
	Cataract long term[a]	4 Gy <3 months 5.5 Gy >3 months
Red bone marrow	Reduced hematogenesis	0.5 Gy

Literature: [a]Valentin (2000)

therefore not yet possible to make quantitative statements on the radiation-induced neoplasia risk below approx. 100 mSv for adults or below 10 mSv for the foetus (Doll and Wakeford 1997).

There is no known threshold below which no tumour induction can occur. At doses <0.05 Gy, the risk of tumor induction is so low that, to date, very large epidemiological studies have not demonstrated any statistically significant new tumor occurrence.

The risk of all solid tumours increases linearly with radiation dose, from the low-dose range (5–100 mSv) up to about 2.5 Sv. Children are much more radiation-sensitive than adults. Radiation appears to cause squamous and basal cell carcinomas in the skin, but not melanomas (Table 5.1). Most tumours show a continuous decrease in radiosensitivity with increasing age (exception: lung carcinoma).

In adults, the tumor risk for the indicated range of X-ray and CT fluoroscopy is comparatively between about 1/1000 and < 1/one million!

In common radiographic examinations, the average ED shows a variation by a factor of 1000 (0.01–10 mSv).

Compared with conventional radiographs, fluoroscopic and CT examinations represent a 10- to 30-fold higher radiation exposure for patients.

The application of the ED to a reference patient is therefore still assessed with an uncertainty of ±40% (Martin 2007). Current studies, mostly model-based, show that the assessment of benefit and risk is hardly possible for the clinician in individual cases and that the risk of morbidity and mortality due to ionizing radiation, especially in CT and X-ray DL, is greatly underestimated. Because the late complication usually occurs years after application (average latency period 10–25 years), its risk is often inadmissibly neglected in everyday clinical practice.

5.3 Dose Guideline Values and Dose Determination

Until a hopefully definitive answer to the question of tumour risk in the low-dose medical range is found at some point, radiation protection has no choice but to estimate the risk in the low range from the known risk coefficient in the medium dose range by means of a reasonable assumption. From Hiroshima and Nagasaki, this is calculated as 10% per Sv. The IRCP calculated a "dose rate reduction factor" of 2 on the basis of its data for loosely ionizing radiation (X-rays, gamma and beta radiation) and therefore assumes a risk coefficient of 5% per Sv in its publication 60 (ICRP 1991).

Thus, a probability of 5%/Sv ED can be derived for the total population of dying from a radiation-induced malignancy (Tables 5.2 and 5.3).

In its publication 103 of 2008, the ICRP defined limits for various organs (OD) and set the ED due to occupational radiation exposure at 20 mSv/year (Table 5.3; ICRP 2008). However, only deterministic damage can be prevented by complying with these limits. The higher the absorbed radiation dose, the greater the potential for inducing neoplasia (Schütz 2010).

Table 5.2 Risk estimates for stochastic late damage (neoplasia) in adult patients and medical staff in O&U

Damage or procedure.	Risk
DNA damage, neoplasia[a]	5%/Sv = 5/100 per Sv = 5/1000 per 100 mSv = 5/100,000 per mSv (children 1.5%/Sv)
DL for vertebroplasty[b]	Patient: 0.17%/procedure operator: 0.025%/year
Skin tumors[b]	DL procedures of 9–10 Gy: Men: 2–11%/Sv; specific mortality risk: 4×10^{-5}–2×10^{-4}/Sv

Literature: [a]International Commission on Radiological Protection (1991); [b] Shore (1990)

Table 5.3 Guideline limits of the effective and organ dose for occupationally exposed personnel according to RöV §31a. (Based on the dose guideline values of the ICRP of 2008)

	Cat. A[a]	Cat. B[a]
ED	20 mSv/year (<18 years.: 1 mSv/year)	6 mSv/year
Gonads, red bone marrow	50 mSv/year	
Uterus	Childbearing age: 2 mSv/Mon, gravidity <1 mSv/Mon	
Eye lens, other torso organs	150 mSv/year (<18 years: 15 mSv/year)	45 mSv/year
Thyroid, skin	300 mSv/year	90 mSv/year
Extremities	500 mSv/year (<18 years: 50 mSv/year)	150 mSv/year
	3-month dose: Max. 50% of the annual dose lifetime working dose: Max. 400 mSv	

[a]In principle, all occupationally exposed persons are classified at least in Cat. B. In addition to intervening personnel in angiography, other personnel are also individually classified in Cat. A if the following conditions are present during an annual examination: Category A: ED >6 mSv/year, OD eye lens >45 mSv/year or OD extremities >150 mSv/year; Category B: ED >1 mSv/year, OD eye lens >15 mSv/year or OD extremities >50 mSv/year

Currently, a limit value of 1 mSv/year applies according to the RöV in Germany for non-occupationally exposed persons. Since 2002, the ED limits for occupationally exposed persons have been reduced to **20 mSv/year (category A)** and **6 mSv/year (category B),** and the OD limits have been adjusted. The annual doses are averaged over a 5-year period.

A major problem in accurately determining radiation in MIODL is the measurement methods. In general, there are several ways to measure radiation exposure: Ionization chambers (rod dosimeter), photoemulsion (film dosimeter), scintillation counter (gamma camera), luminescence detectors: thermoluminescence (TLD), photoluminescence (PLD). The determination of the HED in the skin area of the maximum dose application of patient and operator (hands) is still of importance in MIODL procedures with regard to radiation protection, in order to be able to avoid deterministic early radiation damage to the body surface (Vlietstra et al. 2004). But an accurate evaluation of the maximum HED can be difficult. It depends for the irradiated area on the focus-to-skin distance, tube voltage (kV), tube current (mA) and accumulated DL time. However, these parameters may change during a procedure.

Thus, an automatic method such as HED mapping, in which an instantaneous HED map is generated and plotted on a simulated patient model by measuring changes in tube voltage and current, exposure time, radiation area, and radiation positioning, would of course be desirable (Miller et al. 2002). But such technical capabilities are usually unavailable due to high cost and/or lack of interest (Wagner 2002). The development of normalized skin dose measurements (in Gy per minute) for specific DL systems, focus skin distance, patient volume (e.g., low, medium, high) with the assistance of a medical physicist is desirable. For example, skin dose can be well estimated from accumulated exposure time for each projection using the method of Perisinakis et al. (2004a) for vertebroplasty and kyphoplasty.

For the estimation of the stochastic risk with regard to neoplastic late damage, however, 2 other dose quantities are relevant for the clinician. These are the ED and the dose area product (DFP) for MIODL. Typical ED and gonadal doses to patients during a fluoroscopic procedure are estimated from DFP meters and from conversion tables evaluated and normalized on anthropometric phantoms (Selbert 2004). Roughly speaking, DFP is independent of focus-patient distance, correlates with field size, and depends on the DL technique used. **The risk for stochastic effects (late damage) such as tumor induction and adverse hereditary effects can thus be deter-**

mined in principle. For example, Perisinakis et al. (2004a) calculated a radiogenic tumor induction rate from conventional MIODL-assisted pedicle screw insertion in the lumbar spine of 110 per million procedures (Table 5.2). The evaluation of partial body doses from DFP measurements must also be considered a very crude approach that may substantially underestimate or overestimate the true dose due to varying working conditions (e.g., MIODL equipment/type, radiation protection measurements, type of intervention/surgical procedure, operator experience, etc.).

The ED is currently generally regarded as the most suitable dosimetric parameter for quantifying the stochastic radiation risk (risk of ionizing radiation for the whole organism), since it includes the radiosensitivity of all organs in the dose calculation. However, the ED itself cannot be measured directly, but is calculated from the sum of the measured organ doses multiplied by the respective organ-specific weighting factors (Mountford and Temperton 1992):

$$\mathbf{ED} = \Sigma_{\mathbf{T}}\, \mathbf{w_T} \times \mathbf{OD}.$$

OD is defined as the total energy delivered to a tissue or organ divided by the mass of the tissue: $OD = E_T/m_T$. ED can be determined using anthropomorphic phantoms via patient-attached thermoluminescence (TLD) multiplied by conversion factors for individual body regions. **However, due to time-consuming and computationally intensive simulations and the large uncertainties in the calculations, a patient-specific estimation of the radiation exposure risk is not practicable in everyday clinical practice.**

5.4 C-Arm Technique

Also, the rapid development of MIODL or C-arm technology makes a comparison of the literature with regard to radiation emission and radiation risk increasingly difficult. The classic structure is divided into

- a monitor unit,
- a C-arm stand with DL device (switching device),
- an extension arm (column with cross arm for horizontal movements) and
- the C-arm, which firmly connects the X-ray source (X-ray generator, X-ray source, X-ray tube) and the X-ray detector (analog: image intensifier; since 2006 also digital: flat-panel technology).

The classic C-arm based MIODL units are usually built in such a way that they can be operated from all sides. Due to the C-shaped connection of the two elements, the unit can be moved horizontally, vertically as well as around the swivel axes and produce X-ray images of the patient from almost any angle. DL can be performed as automatic dose rate control or semi-automatic operation. In the first method, the DL data is input by the unit; in the second, the desired mA value is input, and the kV value is controlled independently by the unit. Generally, they are equipped with two monitors. The "live monitor" placed on the left always shows the current DL image, the second "reference image monitor" is used to display images that are stored as a reference. The digital image memory on the one hand provides an image on the monitor for immediate viewing and on the other hand shortens the DL times by holding the last DL image (LIH function, "last image hold"). The progressive dynamics of C-arm use is also reflected in the **permanent improvement and further development of MIODL technology in terms of image quality, ease of use, reduction of radiation exposure and technical sophistication.**

In the last decade, 3D-based C-arm applications have become increasingly established. This (isocentric) 3D C-arm technique offers a useful and technical improvement, as it allows a direct assessment of the spatial conditions of the osseous surgical field (Meier et al. 2011). **The introduction of the so-called C-arm CT (C-arm CT, synonyms: flat detector CT [FD-CT] and "cone-beam CT") in 2004 laid the foundation for a completely new concept of interventional imaging.**[1] A special C-arm,

1 Various product names have been introduced by manufacturers such as XperCT (Philips), InnovaCT (GE), Low Contrast Imaging (LCI, Toshiba), syngoDynaCT (Siemens).

which allows a circular or elliptical orbital movement of the C-arm around the patient, can be used to generate a CT-like volume data set from up to 100 individual images, from which sectional images comparable to CT can subsequently be reconstructed directly intraoperatively and viewed in all planes. With the C-arm CT, for the first time all steps of an intervention, from therapy planning to therapy implementation to immediate therapy monitoring, can be carried out directly with one intervention unit.

This technique opened the way to computer navigation. Computer-assisted surgical (CAS) technologies, in addition to improving surgical precision, can also help reduce radiation emission during spine surgery (Gebhard et al. 2003; Izadpanah et al. 2009). For example, various papers have demonstrated significant ED reduction in 3D MIODL-based spinal fusion surgery at the lumbosacral junction by navigated placement of pedicle screws at the lumbar spine or sacroiliac screws (Gebhard et al. 2003, 2006; Kim et al. 2008; Slomczykowski et al. 1999). Kraus et al. (2010) evaluated **more than 12-fold and nearly five-fold higher ED, respectively, than CAS-3D-MIODL-navigated surgery for** nonnavigated **conventional spinal fusion and SIG screw fixation using TDL** measurements on the phantom (Table 5.4). Other publications also report significant dose reductions using 3D-based MIODL-CAS for both patients and operating room personnel (Smith et al. 2008; Zwingmann et al. 2009) (Table 5.4).

In the literature, so-called 4D X-ray-based image converter systems are also reported, whereby the fourth dimension here is the time

Table 5.4 Patient/personal dose of special radiology-assisted procedures, interventions and operations in O&E (selected literature)

Study, procedure, (measurement methodology), FT	Patient: ED, HED (measurement range) (in mSv)	Doctor: ED, HED (in mSv)
Diagnostic X-ray examinations in O&U[abc]		
– CERVICAL SPINE – LUMBAR SPINE – Pelvis – Hip – Shoulder – Knee	0.2 (0.07–0.3) 1.5 (0.5–1.8) 0.6 (0.2–1.2) 0.7 (0.2–2.7) 0.01 0.005	
Vertebroplasty, Kyphoplasty (MIODL)		
Harstall et al. (2005) (TLD)		Hand: Left 0.11 right 0.05; eye: 0.02; SD: 0.05
FT: 3.4 min/WK		Hand: 0.42[a], 0.12[e]
		1.44[a], 0.004[e] Hand: 2.04[a], 0.074[e]
Fitousi et al. (2006) (phantom), FT: 27.7 min/procedure (TLD).	34.5 82.6 ± 26.2 (MSD)	0.002 mGy[e] Hand: 0.2; eye: 0.33
Mroz et al. (2008) (TLD), FT: 5.7 min/WK	0,47 ± 0.23 Hand: 0.50; eye: 0.48	0.25 ± 0,17 Hand: 1.74[a], <0.01[e]; eye: 0.27
Lumbar spine fusion, pedicle screw placement		
Smith et al. (2008) (film dosimeter)		Basin: 0.043, navigated: 0.003
Jones et al. (2000) (phantom), MIODL, FT: 1.4 min/case.	Under table position: 2.3 Overtable position: 6.9	

(continued)

Table 5.4 (continued)

Study, procedure, (measurement methodology), FT	Patient: ED, HED (measurement range) (in mSv)	Doctor: ED, HED (in mSv)
Slomczykowski et al. (1999) (phantom), MIODL (63 s/screw).	1.0	
Perisinakis et al. (2004b), (phantom), MIODL, FT: 3.3 min/procedure: 4.8 screws	1.5	
Kraus et al. (2010), (phantom). – MIODL, FT: 105 s/procedure: 4 screws – CAS-3D-MIODL, FT: 72 s/procedure: 4 screws	5.0 0.4	
Epidural injections (lumbar spine)		
Botwin et al. (2002) (TLD), MIODL, FT: 15.2 s.		0.003[a], 0.001[e] Ring finger 0.007; eye 0.004
Schmid et al. (2000), MIODL: pulsed/continuous	<0.1/0.84	

FT mean fluoroscopy time; *MSD* maximum surface dose; *WK* vertebral body; *SD* thyroid; *GK* whole body
Literature:[a] Hall and Brenner (2008), [b]Mettler Jr et al. (2008), [c]Tsalafoutas et al. (2007)
(Comparative data: Transatlantic flight: 5–8 mSv; X-ray: 0.4–2 mSv; radiology staff: 1–2 mSv/year)
[a]without specific radiation protection;[e] with optimised radiation protection

axis integrated into the intervention. **However, an additional reduction of radiation emission compared to biplanar and 3D systems could not be shown (Kuntz et al. 2013).**

5.5 Dose Values for Mobile Intraoperative Fluoroscopy

If basic radiation protection measures are observed (lead apron, spacing laws, limitation of DL time), no relevant dose exposure of the personnel is to be expected in simpler procedures, e.g. DL-assisted injection therapy of the spine (Botwin et al. 2002) (Table 5.4). However, there are procedures in DL on the musculoskeletal system that are complex and therefore require increased sensitivity to radiation protection.

In order to understand the problem of radiation risk in MIODL procedures, the dose consideration of vertebroplasty or kyphoplasty can be used as an example. Without radiation protection, patients may experience HED in the vertebroplasty area, for example, which in extreme cases may be in the range of deterministic effect limits (Kruger and Faciszewski 2003; Fitousi et al. 2006). Although the mean ED and HED (8.5–12.7 mSV and 173–233 mGy, respectively) are relatively low relative to an average DL time of 10.1 min, it should not be overlooked that these results of Perisinakis et al. (2004a) were obtained by experienced operators with good medical-physical support. Other authors report DL times of 10–60 min for the same procedures (Mehdizade et al. 2004). These are times which, at the upper limit, may end in high patient risk for deterministic and stochastic radiation effects. In some cases, HEDs of >60 Gy have been measured here (Schütz 2010). Harstall et al. (2005) evaluated significant radiation exposure for the surgeon in a prospective case-control study for MIODL-guided percutaneous vertebroplasty: 8% of the threshold dose (150 mSv) for induction of a cataract and 10% of the annual maximum HED dose limit (ICRP: 500 mSv) are

achieved. The one-year risk for induction of fatal thyroid carcinoma is 0.0025% and for any tumor induction is 0.025%. Fitousi et al. (2006), on the other hand, calculated a neoplasia risk of 0.17% per vertebroplasty for the patient.

In the literature, well over 100 cases of skin radiation and tissue injury, including a large proportion of tissue destruction (dermatonecrosis), have been documented as a result of classic MIODL procedures (Mettler Jr et al. 2002). The true number of radiogenic injuries is undoubtedly much higher. In many of the cases mentioned above, the performing physicians were hardly trained in the topics of radiation protection and radiation consequences, as well as in the assessment of radiation injuries. Almost all of the cases of severe radiation injury mentioned could have been avoided. A literature comparison regarding the ED determined by means of phantom in various conventional and 3D-navigated MIODL-assisted spinal procedures can be found in ◘ Table 5.4.

The immediate questions arise:

- Do the majority of surgeons performing MIODL-assisted spine surgery really know how to optimally use appropriate C-arm equipment to minimize radiation dose?
- In their daily work, are these users aware of the doses of ED, OD and HED acting on the patient as well as the doses to which they themselves are exposed through scattered radiation and targeted positioning of the fingers and/or hands in the radiation path (Selbert 2004)?

According to our empiricism, there is a surprisingly large gap in formal training regarding the physics of DL and radiation safety among nonradiologists who often perform surgical procedures with long DL times, thereby exposing not only patients but also surgical staff to increased risk due to high-dose fluoroscopy.

These radiation injuries can be prevented with optimized radiation protection measures and surgical techniques. Kruger and Faciszewski (2003) indicate optimal techniques for percutaneous vertebroplasty under conventional DL, which can result in a dose reduction of 43–86%. With appropriate hand protection, a surgeon can perform approximately 150 vertebroplasties under MIODL without exceeding the annual dose limits (for the eye it would be 230 and for the ED limits 909). However, with appropriate protective measures, this value can be reduced by approximately 75% (Fitousi et al. 2006). **Other areas of MIODL in O&U also provide relevant reasons for taking radiation protection in the operating room more than very seriously (◘ Table 5.4). In** comparison, the large number of literature references does not lead to a uniform picture and remains unsatisfactory (◘ Table 5.4), since DL time or ED and HED depend on very many influencing factors (Huda et al. 2008; Kron 1994; Moscovitch et al. 2006): inter al. on procedure difficulty, surgical technique, C-arm technique and positioning (Jones et al. 2000), competence of surgical staff (Kraus et al. 2013), patient volume (Miller et al. 2009; Vano et al. 2006) (positive correlation by increasing exposure factors kV and mA for patient and surgical staff), measurement technique and positioning technique. Nevertheless, the ascertainable data show a trend from which substantial recommendations for radiation protection in MIODL for spinal interventions can be derived.

5.6 Radiation Protection

With regard to radiation protection, a distinction can be made between structural measures, equipment measures and personnel-operational measures. When using classic C-arms, more difficult conditions are found with regard to radiation protection compared to the fixed DL facilities of radiological units: Few device-specific shieldings, no spatially limited control area, no structural protective measures for the operating room staff, small distance between examiner and patient, and often long DL times. **Therefore, the personnel-operational measures in particular must be optimized here as the main focus for the prophylaxis of radiation damage.** These have been published in many cases (Schütz 2010),

are partly specified in the Radiation Protection Ordinance (StrlSchV) and can be largely summarized by means of the **5A rule (length of stay, activity, distance, shielding, training):**

For the prophylaxis of radiation damage, the 5A rule applies: residence time, activity, distance, shielding and training.

5.6.1 Residence Time

The radiation dose increases linearly with the length of stay. Despite the complexity of various procedures, **the central principle of all radiological imaging "as little radiation as possible and as much as necessary" (ALARA principle: "as low as reasonably achievable")** must therefore not be neglected in MIODL either. Thus, it is always necessary to use only as much radiation as is absolutely necessary to achieve the operational goal (Kraus et al. 2015). The implementation of the ALARA principle strongly depends on the work processes and the working technique in the OR. **Therefore, practical radiation protection already starts in the work preparation for the OR. Before driving the MIODL unit into the operating room,** the operator (whether OR nurse, assistant physician, or the surgeon himself) should have familiarized himself with the type and method of the procedure or situation and clarified the following questions:

- How should the patient be positioned for surgery?
- Where does anesthesia stand?
- From which side is operated?
- Positioning of the patient with radiation protection?
- Does the monitor display correspond to the patient's position?
- What is the best way to get to the patient with the C-arm?
- Optimal surgical field setting for the surgeon?
- Where is the image monitor located so that the surgeon and fluoroscopist can see it clearly?

The surgeon and fluoroscopist should have a clear view of the monitor. It is recommended that the positioning of the patient and the placement of the C-arm with monitor are in one hand and that the required DL positions are set on a trial basis before sterile draping. In terms of technical options for DL time reduction, **pulsed DL** (interval pulse **DL**) and **LIH techniques** should be used whenever possible for MIODL. In pulsed mode, image series with X-rays of up to 6 frames/s are produced. The pulse duration varies from 200 ms to more than 600 ms, i.e. 170 ms/image at 6 images/s. The advantages of this method are that the short single pulses can have a high dose and the tube load is lower than with continuous radiation. At the same time, the amount of image noise is low; the same applies to the radiation exposure. Thus, sharper and higher contrast images are obtained than with the normal DL technique. Using the LIH function (image memory) as often as possible and a limited use of loops, cine or target shots further helps to keep the DL time low. For example, for cine mode, the dose can vary from 0.4 Gy/min (15 frames/s) to 1 Gy/min (60 frames/s).

5.6.2 Activity

Of course, a technically skilled and experienced surgeon will also keep the DL time lower than a less experienced surgeon. However, the latter should always be aware of doing as little control DL as possible. If the BV is not positioned close to the patient, **the beam angle** should be **changed every now and then** during longer MIODL procedures **to** avoid excessive focal skin exposure, if possible. The goal of rational DL can be achieved by setting and leaving the height and horizontal depth of the C-arm such that the p.-a. or a.-p. and lateral settings can be achieved merely by pivoting the C-arm 90 °. In particular, it may also be helpful to use a **laser aiming device** to locate the desired DL points without beam emission.

5.6.3 Distance

Various studies have shown that, in addition to minimizing the DL time, it is above all a large distance from the radiation source that

provides the most effective protection, since a decisive point of radiation protection is compliance with the quadratic distance law.

> The dose reduces quadratically with the distance from the radiation source.

The relevance of this rule can be clearly demonstrated by the relative dose rate: If this is set at 100% at a distance of 0.5 m, the following regularity results depending on the distance: **1 m: 25%, 2 m: 6.3%, 4 m: 1.6%**. If X-rays are required, the greatest possible distance from the source should therefore be maintained. With regard to the radiation protection of the operating room personnel, the patient is also defined as a (scatter) radiation source in the MIODL: The further away the patient, the lower the scattered radiation dose for the surgical team.

> The surgical team must always be made aware of when the C-arm is emitting X-rays, so that all options for increasing the distance to the radiation source, as well as suitable radiation protection measures, can be used in good time during the surgical procedure.

5.6.4 Shielding (Radiation Protection Material)

As early as 1983, the orthopaedic surgeon Barry determined his own personal dose of 2.27 mSv/year by means of TLD measurement and showed that the highest measured values occurred in the head and neck region. This makes it clear that the upper body is particularly exposed in certain situations and that personal protective measures should be taken here (Barry 1984).

> Good personal protective equipment (PPE) that protects the hull is therefore mandatory and is covered by Directive 89/686/EEC throughout Europe. PPE should be visually inspected for integrity every six months and quality tested annually under DL.

Care must be taken to ensure suitable sizes, sufficient number, proper storage on appropriate holders.

Lead aprons are increasingly being replaced by lighter lead-reduced or even lead-free protective clothing. In Germany, this is regulated by DIN 6857–1 and DIN EN 61331–1. Minimum specifications for the lead equivalent value (PbGw) for PPE according to RöV:

- Sheath apron in the surgical area: front side ≥0.25 mm PbGw (weakening at 75 kV 97%/reduction factor 10–200), back side Pb-free,
- Mantle apron Personal (extending from base of neck to infrapatellar): Anterior ≥0.35 mm PbGw (attenuation at 75 kV 98.5%), posterior ≥0.25 mm,
- Apron Patient: ≥0.5 mm PbGw (attenuation at 75 kV 99.7%),
- Gonad protection patient: testes ≥1 mm PbGw, ovaries, ≥1 mm PbGw,
- Thyroid protection: ≥0.25 mm PbGw (reduction factor approximately 20),
- Eye protection, not obligatory: lead glass goggles with side protection (reduction factor 5–10).

Even if the RöV specifies lower values with regard to the PbGw in the operating theatre, it is recommended that **PPE with a PbGw of 0.5 mm be worn in the anterior or radiation source-facing area** when **wearing** protective clothing for shielding outside the **radiation** field, as the same local dose rates can often occur in modern 3D MIODL procedures as in X-ray diagnostics (Table 5.4). Most importantly, however, PPE must be intact and worn correctly (Fig. 5.1). **Protective goggles to prevent eye damage are still underused**; however, landmark studies are still lacking in this area.

If the focus is to be on radiation protection of the patient, patient positioning in the C-arm close to the detector and far away from the radiation source is preferable (tube-patient distance as large as possible). This also ensures better image quality: larger, sharper, higher contrast (air distance between patient and image intensifier as small as possible). For this reason, the over-the-table position of the radiation source in the OR was considered better for a long time (Beck 2006), especially since this also ensured

Fig. 5.1 Personal protective equipment (PPE) should always be worn to minimize personal exposure. Here, it consists of a lens guard (*1*), a thyroid guard (*2*), and a closed apron (*3*). (From Schütz et al. 2016; with kind permission)

the working height of the surgeons. When the source is positioned below the patient, as opposed to above the table, several authors have measured that although a worse working height results, as the image receiver is more space-consuming than the X-ray tube, there is significantly less exposure for the surgeon in the area of the upper body, head, eyes and thyroid (Dresing 2011; Jones et al. 2000; Lee et al. 2012).

Modern new flat-panel detector imagers can be much more space-saving and thus solve the problem of working height at the under-table position.

However, not only the a.p. orientation of the C-arm plays a crucial role, but also the positioning in the lateral beam path. Rampersaud et al. (2000) evaluated that the dose to the surgeon's torso during spinal surgery can be immensely high when the C-arm is positioned laterally, especially on the side of the X-ray source. In contrast, on the side of the detector, i.e. in the direction of radiation, the dose is exorbitantly lower (53.3 mSv/min vs. 0.022 mSv/min). The hand dose was also significantly reduced by this positioning. The thyroid dose was 3–4 times lower on the side of the detector than on the opposite side (Rampersaud et al. 2000).

Due to the lower exposure to the scattered radiation caused by the patient, the lower table position of the radiation source should therefore always be preferred in the a.p. beam path during MIOLD-assisted spinal intervention (Fig. 5.2) and the surgeon should always stand on the side of the BV, i.e. in the direction of radiation, when setting in the lateral beam path (Fig. 5.3). The operating assistant, who is on the side of the X-ray source, is therefore particularly at risk. For this reason, the assistant must always be able to step away from the table during DL and maintain the greatest possible safety distance.

In the case of the presence of a fluoroscopist who is not surgically involved at the table, the following recommendations apply (Beck 2006): The scattered radiation is so low for the fluoroscopist (DL time 17 h/year) that he can place himself next to the MIODL unit with an apron without hesitation: Radiation exposure 0.01 mSv/a. The advantage here is that a shorter DL time is possible due to the good visibility of the operating field. This results in a lower radiation exposure for patient, surgeon and fluoroscopist.

Consistent tight collimation (fading in) of **the outgoing beam** to the size of the DL image format and the region of interest (ROI)

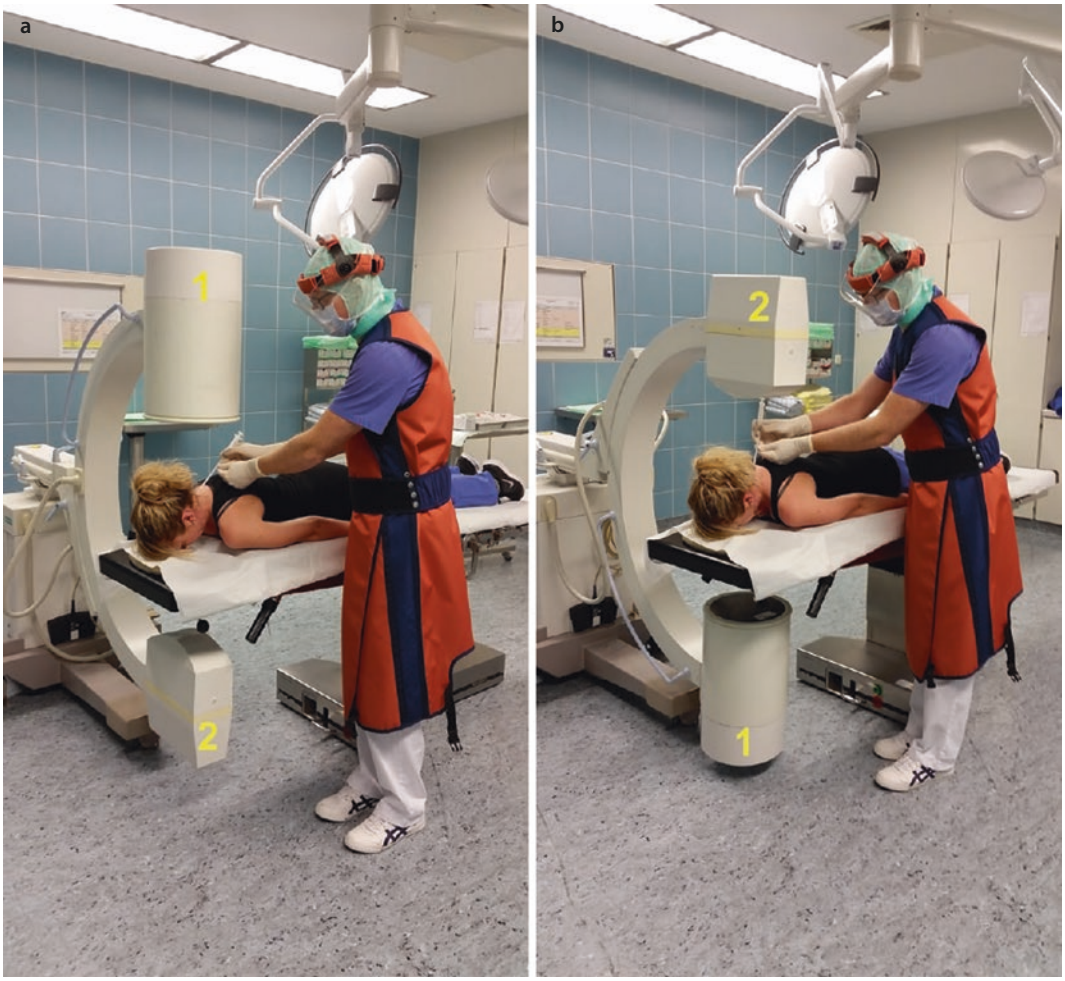


Fig. 5.2 **a** Lower table position: In the a.p. setting, the detector/BV (*1*) is above and the radiation source (*2*) below the table. **b** Upper table position: Although the working height is improved, the disadvantage is the higher radiation exposure of the physician. (From Schütz et al. 2016; with kind permission)

guarantees not only better image sharpness and contrast, but also a reduction of scattered radiation for all. The insertion should be done during the first orientation DL. Lateral superimposition (**slit diaphragm plates**) is used for tubular bones, distal forearms, fingers, etc. (do not forget to rotate the diaphragm). The **iris diaphragm** is used for smaller bones, e.g. patella. Manual DL in particular requires some experience with the classic C-arm. Manual DL means DL without automatic dose rate control. It is necessary when there is too much scattered radiation in the radiation image, when there is a lot of metal in the DL field, when the DL object is easily overradiated, for extremity DL, when the surgeon moves the extremity for orientation, or when a better DL image is to be achieved.

However, the use of collimation for dose reduction is often misunderstood. The various classic MIODL systems proceed differently in their automatic modification mode to compensate for manual or electronic reduction of the "field of view" (FOV; magnification leads to loss of focus) by the user. Quite a few increase the radiation dose relevantly, increasing the HED per unit area (DFP) due to the compensatory dose increase of the system (2–4 times in some cases). **Therefore, besides the mentioned advantages, collima-**

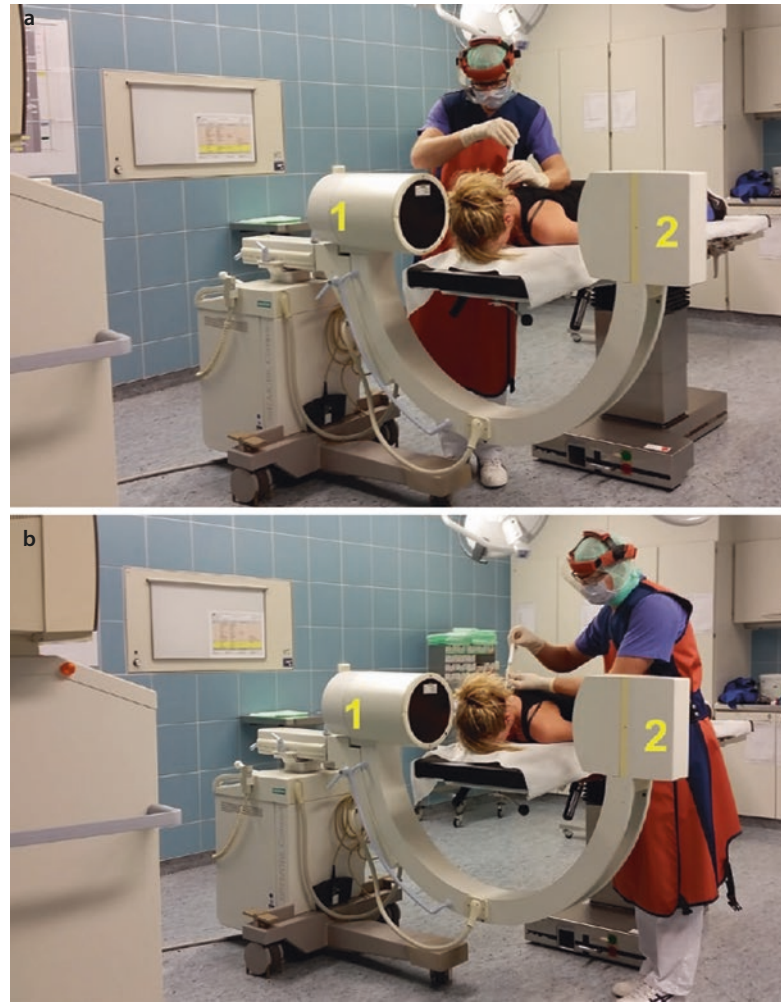


Fig. 5.3 **a** In the lateral beam path, the exposure for the physician is lower on the side of the detector/BV (*1*) than on the side of the radiation source (*2*). **b** If possible, this position should be avoided due to the significantly increased exposure to scattered radiation. (From Schütz et al. 2016; with kind permission)

tion does not necessarily reduce the dose rate of the directly exposed skin (patient), on the contrary, the HED becomes larger than with a larger selected FOV due to compensatory radiation increase by the device. Therefore, with regard to the shielding of the patient, depending on the system, it may also be recommended **to select the smallest possible magnification mode or the largest practicable "field of view" (FOV).**

The use of a scatter radiation grid for scatter radiation reduction is nowadays standard equipment. Depending on the surgical procedure, lead glass walls or table attachments can also significantly reduce radiation exposure. Flexible protective shields against scattered radiation that can be fixed to the C-arm are also being developed, but have not yet been extensively tested with regard to their benefit-application profile in the OR (Mori et al. 2014).

Caution should be exercised when patient volume is increased. This is a major factor influencing HED. The radiation dose is reduced by a factor of 2 for every 4.5–5 cm of tissue depth. **This means that a patient who is 10 cm thicker may receive approximately 4–10 times the radiation dose.** High dose mode settings on the device can generate HEDs of >1 Gy/min if not activated or used properly. As direct consequences, hair loss and cataracts can be induced within a few minutes, and skin necrosis can occur in less than 30 min (Beck 2006).

5.6.5 Training

The above remarks show that, despite optimal equipment, the most important criterion in MIODL is the optimisation of radiation protection to reduce radiation exposure or the stochastic and deterministic radiation risk to the patient and medical staff (Koenig et al. 2001). It is obvious that recommendations and regulations in this regard can only be implemented effectively and optimally if all persons involved in the intervention in the room are trained with regard to operational procedures and radiation protection, have a lot of experience and communicate well with each other. MIODL operators must be competent regarding its use and the applied techniques for dose control with respect to ED and HED of patient and OR staff. There is no doubt that due to inter-individual variation in the experience and habits of the MIODL operator, the applied radiation doses are subject to a variation of 100% or even more (Seidenbusch et al. 2015).

> Intraoperative 3D MIODL imaging must now be required as standard for minimally invasive spine procedures in terms of outcome quality and safety (Kraus et al. 2015).

CAS with 3D navigation is an important option for reducing radiation emission (Kraus et al. 2010), especially when a large patient volume and poor image quality necessitate increased radiation use. In comparison, CAS procedures with CT navigation should be viewed critically for radiation protection reasons, as this significantly increases the procedure-related total ED compared to MIODL procedures due to the preoperative CT scan required for safe navigation (Slomczykowski et al. 1999). It remains to be noted: When speaking of patient radiation risk, a comparison of methods should always compare the total ED required to perform a surgical procedure. If a CT is necessary before a CAS-3D-navigated MIODL procedure for other reasons, the total ED for the patient is again higher than if a CT navigation is performed.

Due to the increase in 3D-navigated MIODL technology with the creation of CT-like image series, which, depending on the intraoperative application, pushes the dose emission more and more into the order of magnitude **of** CT imaging, and due to the wide **range of possible errors in the application and practice, which** cannot be overlooked by the clinician and non-radiologist, it **should be noted that the training of the corresponding users must become a "radiological" one. In addition to the more theoretically oriented, prescribed courses in radiation protection, it would be desirable for mandatory practical instruction and exercises, especially for the personnel who are to operate the C-arm, to be defined in a quality-assuring manner and carried out on a regular basis.** Any CT or CT-like procedure belongs in the hands of a radiologist or certified non-radiologist in order to avoid unnecessary radiation-induced tumor induction. To ensure the best possible reduction of radiation emission during image-guided spinal interventions, O&U and radiology should cooperate more closely in training and radiation protection practice in order to better master the technical challenges together for the benefit of the patient and for self-protection (Kraus et al. 2013; Schütz 2015)!

5.6.6 Quality Assurance

Radiation protection also includes regular controlling of the radiation exposure of all persons in the OR. Since 1.7.2002 (StrlSchV), a DFP measuring device has been required to determine the HED with regard to the patient's radiation exposure. Separate documentation is required for each procedure (cumulative documentation is generally not permitted). For the determination of the personal dose of the surgical team, it should be noted that the use of the official X-ray protection badge (film dosimeter) under the PPE has no relevant significance, which seems logical.

Relevant for the control of the local dose and personal dose, however, is a dosimeter (e.g. rod dosimeter) that can be read at any time outside the protective clothing, preferably above the lead apron on the neck or eye.

Since in some cases annual hand doses above the limit of 500 mSv are measured for surgical-interventional procedures under MIODL (Häusler et al. 2000), every surgeon performing MIODL-assisted procedures is recommended to use a finger dosimeter. Real-time dosimeters with warning function are useful! In general, surgeons should pay constant attention to the exposure of their hands. The arms of the surgeons should never be unnecessarily in the radiation path. Synowitz and Kiwit (2006) were able to demonstrate a reduction in HED for the surgeon's hands when performing vertebroplasty by using a protective glove. However, this is usually accompanied by a reduction in finger sensitivity, which may not be tolerable for many surgeons. After completion of the operation, the DL values must be documented (kV, mA, DL time, number of exposures, DFP).

5.6.7 Hygiene and Sterility

The MIODL device is only to be covered sterilely after a control DL has been completed and the patient has been disinfected and sterilely covered. It is often sufficient to sterilize only the X-ray detector. For hygienic reasons, the device should be moved as little as possible, if necessary then only slowly. Contact with the surgical area must be avoided. In operations where the surgical team comes into contact with the device, e.g. spinal operations, it must be completely sterilized with the help of the surgical team.

When tilting the C-arm, attention must be paid to instrument tables, surgical material, surgical lamps and fittings and equipment standing by or fixed in place. The attention of the surgical team should also be drawn to the swinging or tilting of the C-arm.

For sterile draping, the use of device-specific adapted, preferably tailor-made accessories for draping the C-arm with tube and detector as well as touch screen is recommended. After each DL, the device should not be moved out of the sterile area, if possible, but should remain so that the C-arm is still in the sterile area but does not obstruct the surgeon and assistants. For hygienic reasons, unnecessary movements with the C-arm should be avoided (dust turbulence).

5.6.8 Equipment

In order to guarantee the interests of radiation protection, the minimum equipment of MIODL systems (C-arms) should nowadays include the following elements (see following overview).

Minimum Equipment of MIODL Installations

- Digital imaging
- Automatic Dose Rate Regulation (ADR)
- Limitation of the dose rate
- LIH Technology
- Useful beam limitation to BV diameter
- Pulsed fluoroscopy (DL)
- Warning signal if accumulated dose >2 Gy
- Display of the dose area product (DFP)

However, under the paradigm of dose reduction, modern digital MIODL systems have additional multiple technical features. The user should therefore know his system well in order to be able to use the modern technology adequately. These are mainly

- highly sensitive receiver systems (dose reduction);
- large image intensifier formats;
- a significantly enlarged, square image window and a high image dynamic (approx. 16,000 grey levels);
- Laser aiming devices in the BV and on the tube side (precise alignment with the anatomy for radiation-free positioning of the C-arm);

- Selection of different modes (e.g. half dose, pulsed, pediatric, etc. for anatomical visualization at optimal mA and KV values);
- (virtual) "preview collimators" (positioning of the aperture/iris collimators before the X-ray);
- easy switching between fluoro, cine, subtraction and roadmapping modes;
- Zoom and roaming functions for a better view;
- an advanced noise reduction;
- a modern pulse technique with 8 to 1 pps at constant mA (reduction of a continuous DL with 25 pps by 66–95%);
- variable computer-controlled radiation filter systems;
- a user-friendly touch-screen technology on both sides;
- automatic motorized C-arm positioning from the sterile operating table, controllable via pannel;
- a memory capability of multiple C-arm positions (ensures precision of isocentricity and reproducibility during repositioning);
- an automatic 4-axis movement of the C-arm (detection of any position in the covered space);
- automatic collision protection with the patient or operating table/equipment ("distance control");
- a permanent dose report/indication (DFP: ED of the patient ≈20% of the cumulative DFP, air kerma ≈ HED of the patient) and adjustable dose limit times with all-arm message for dose controlling;
- differentiated image post-processing options;
- a compatibility with common navigation systems for the fully automatic transmission of the image data;
- DICOM-based modern image data archiving, connection and networking solutions (WLAN, USB, CD/DVD, printer etc.);
- custom-made sterile covcers with closed cooling system (independent of the sterile air circulation in the operating field).

5.7 Conclusion

Due to the increase in minimally invasive surgical spinal procedures, the use of mobile C-arm technology continues to grow. In principle, there is a risk that this development will also increase the risk for patients and staff with regard to radiation-induced early and late damage. Due to the parallel further development of the device technology, higher and higher radiation doses can be emitted. Although the improvement of technology also offers the possibility of dose reduction, this can only be used if the user is sufficiently trained in this respect. This chapter is intended to provide information and raise awareness of the causes, extent and risks of intraoperative radiation emission. On the other hand, it is intended to show the positive effects of good competence and understanding as well as consistent implementation and use of modern radiation protection measures on the risk of the individual in dealing with modern C-arm technology in minimally invasive spinal interventions.

References

Barry TP (1984) Radiation exposure to an orthopedic surgeon. Clin Orthop Relat Res 182:160–164

Beck H (2006) C-Bogen und Strahlenschutz im OP. In: Beck H (ed) Intraoperatives Durchleuchten in Orthopädie und Unfallchirurgie. Steinkopf Verlag, Darmstadt, pp 8–13

Blakely EA (2000) Biological effects of cosmic radiation: deterministic and stochastic. Health Phys 79:495–506

Botwin KP, Thomas S, Gruber RD, Torres FM, Bouchlas CC, Rittenberg JJ, Rao S (2002) Radiation exposure of the spinal interventionalist performing fluoroscopically guided lumbar transforaminal epidural steroid injections. Arch Phys Med Rehabil 83(5):697–701

Carbone JJ, Tortolani PJ, Quartararo LG (2003) Fluoroscopically assisted pedicle screw fixation for thoracic and thoracolumbar injuries: technique and short-term complications. Spine (Phila Pa 1976) 28:91–97

Doll R, Wakeford R (1997) Risk of childhood cancer from fetal irradiation. Brit J Radiol 70:130–139

Dresing K (2011) Röntgen in Unfallchirurgie und Orthopädie. Ein Update über physikalische und

biologische Auswirkungen, sinnvolle Anwendung und Strahlenschutz im Operationsaal. Oper Orthop Traumatol 23:70–78
Fitousi NT, Efstathopoulos EP, Delis HB, Kottou S, Kelekis AD, Panayiotakis GS (2006) Patient and staff dosimetry in vertebroplasty. Spine 31(23):E884–E889. discussion E890
Gebhard F, Kraus M, Schneider E, Arand M, Kinzl L, Hebecker A, Bätz L (2003) Strahlendosis im OP – ein Vergleich computerassistierter Verfahren. Unfallchirurg 106(6):492–497
Gebhard FT, Kraus MD, Schneider E, Liener UC, Kinzl L, Arand M (2006) Does computer-assisted spine surgery reduce intraoperative radiation doses? Spine (Phila Pa 1976) 31:2024–2027. discussion 2028
Hall EJ, Brenner DJ (2008) Cancer risks from diagnostic radiology. Br J Radiol 81(965):362–378
Harstall R, Heini PF, Mini RL, Orler R (2005) Radiation exposure to the surgeon during fluoroscopically assisted percutaneous vertebroplasty: a prospective study. Spine 30(16):1893–1898
Häusler U, Czarwinski R, Brix G (2000) Radiation exposure of medical staff from interventional x-ray procedures: a multicentre study. Eur Radiol 19(8):2000–2008
Huda W, Nickoloff EL, Boone JM (2008) Overview of patient dosimetry in diagnostic radiology in the USA for the past 50 years. Med Phys 35:5713–5728
International Commission on Radiological Protection (2008) Publication 103. Recommendations of the ICRP. Ann ICRP 37:2–4
International Commission on Radiological Protection (ICRP) (1991) Publication 60, 1990. Recommendations of the international commission on radiological protection. Pergamon Press, Oxford
International Commission on Radiological Protection (ICRP) (2000) Avoidance of radiation injuries from medical interventional procedures, ICRP publication 85. Ann ICRP 30(2):10–14
Izadpanah K, Konrad G, Sudkamp NP, Oberst M (2009) Computer navigation in balloon kyphoplasty reduces the intraoperative radiation exposure. Spine (Phila Pa 1976) 34:1325–1329
Jones DP, Robertson PA, Lunt B, Jackson SA (2000) Radiation exposure during fluoroscopically assisted pedicle screw insertion in the lumbar spine. Spine (Phila Pa 1976) 25:1538–1541
Kim CW, Lee YP, Taylor W, Oygar A, Kim WK (2008) Use of navigation-assisted fluoroscopy to decrease radiation exposure during minimally invasive spine surgery. Spine J 8:584–590
Koenig TR, Mettler FA, Wagner LK (2001) Skin injuries from fluoroscopically guided procedures: part 2, review of 73 cases and recommendations for minimizing dose delivered to patient. AJR Am J Roentgenol 177:13–20
Kraus M, Krischak G, Keppler P, Gebhard FT, Schuetz UH (2010) Can computer-assisted surgery reduce the effective dose for spinal fusion and sacroiliac screw insertion? Clin Orthop Relat Res 468(9):2419–2429
Kraus M, Röderer G, Max M, Krischak G, Gebhard F, Riepl C (2013) Influence of fracture type and surgeon experience on the emission of radiation in distal radius fractures. Arch Orthop Trauma Surg 133:941–946
Kraus M, Redies M, Richter P (2015) Stahlenschutz im OP. OP-Journal 30(03):138–143
Kron T (1994) Thermoluminescence dosimetry and its applications in medicine. Part 1: physics, materials and equipment. Australas Phys Eng Sci Med 17: 175–199
Kruger R, Faciszewski T (2003) Radiation dose reduction to medical staff during vertebroplasty: a review of techniques and methods to mitigate occupational dose. Spine 28(14):1608–1613
Kuntz J, Gupta R, Schönberg SO, Semmler W, Kachelrieß M, Bartling S (2013) Real-time X-ray-based 4D image guidance of minimally invasive interventions. Eur Radiol 23(6):1669–1677
Lee K, Lee KM, Park MS, Lee B, Kwon DG, Chung CY (2012) Measurements of surgeons' exposure to ionizing radiation dose during intraoperative use of C-arm fluoroscopy. Spine (Phila Pa 1976) 37:1240–1244
Martin CJ (2007) Effective dose: how should it be applied to medical exposures? Br J Radiol 80(956):639–647
Mastrangelo G, Fedeli U, Fadda E, Giovanazzi A, Scoizzato L, Saia B (2005) Increased cancer risk among surgeons in an orthopaedic hospital. Occup Med (Lond) 55:498–500
Mehdizade A, Lovblad KO, Wilhelm KE et al (2004) Radiation dose in vertebroplasty. Neuroradiology 46:243–245
Meier R, Geerling J, Hüfner T, Kfuri M, Krettek C (2011) Isozentrischer C-Bogen. Unfallchirurg 114(7): 587–590
Mettler FA Jr, Koenig TR, Wagner LK, Kelsey CA (2002) Radiation injuries after fluoroscopic procedures. Semin Ultrasound CT MR 23:428–442
Mettler FA Jr, Huda W, Yoshizumi TT, Mahesh M (2008) Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology 248(1):254–263
Miller DL, Balter S, Noonan PT, Georgia JD (2002) Minimizing radiation-induced skin injury in interventional radiology procedures. Radiology 225:329–336
Miller DL, Kwon D, Bonavia GH (2009) Reference levels for patient radiation doses in interventional radiology: proposed initial values for U.S. practice. Radiology 253(3):753–764
Mori H, Koshida K, Ishigamori O, Matsubara K (2014) A novel removable shield attached to C-arm units against scattered X-rays from a patient's side. Eur Radiol 24(8):1794–1799
Moscovitch M, St John TJ, Cassata JR, Blake PK, Rotunda JE, Ramlo M, Velbeck KJ, Luo LZ (2006) The application of LiF:mg,cu,P to large scale personnel dosimetry: current status and future directions. Radiat Prot Dosim 119:248–254
Mountford PJ, Temperton DH (1992) Recommendations of the international commission on radiological protection (ICRP) 1990. Eur J Nucl Med 19:77–79

Mroz TE, Yamashita T, Davros WJ, Lieberman IH (2008) Radiation exposure to the surgeon and the patient during kyphoplasty. J Spinal Disord Tech 21(2): 96–100

Perisinakis K, Damilakis J, Theocharopoulos N, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N (2004a) Patient exposure and associated radiation risks from fluoroscopically guided vertebroplasty or kyphoplasty. Radiology 232:701–707

Perisinakis K, Theocharopoulos N, Damilakis J, Katonis P, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N (2004b) Estimation of patient dose and associated radiogenic risks from fluoroscopically guided pedicle screw insertion. Spine (Phila Pa 1976) 29:1555–1560

Rampersaud YR, Foley KT, Shen AC, Williams S, Solomito M (2000) Radiation exposure to the spine surgeon during fluoroscopically assisted pedicle screw insertion. Spine (Phila Pa 1976) 25:2637–2645

Schmid G, Schmitz A, Borchardt D, Ewen K, von Rothenburg T, Koester O, Jergas M (2000) Effective dose of CT- and fluoroscopy guided perineural/epidural injections of the lumbar spine: a comparative study. Cardio Vascular and Interventional Radiology 29:84–95

Schütz U (2010) Komplikationen bei der bildgebenden Diagnostik. In: Wirth CJ, Mutschler W, Bischoff HP, Püschmann H, Neu J (eds) Komplikationen in Orthopädie und Traumatologie. Vermeiden, erkennen, behandeln. Georg Thieme Verlag, Stuttgart, pp 72–81

Schütz U (2015) Komplikationen bei der bildgebenden Diagnostik. In: Wirth CJ, Mutschler W, Neu J (eds) Komplikationen kompakt: Orthopädie und Unfallchirurgie. Georg Thieme Verlag, Stuttgart, pp 30–39

Schütz U, Beer M, Wild A, Oehler S, Kraus M (2016) Strahlenschutz bei C-Bogen-gestützten Wirbelsäulenprozeduren in Orthopädie und Unfallchirurgie. OUP 4:224–237. https://doi.org/10.3238/oup.2015.0224-237

Seidenbusch M, Krüger-Stollfuß I, Schneider K (2015) Strahlenschutz in der Fluoroskopie im Kindesalter. Fortschr Röntgenstr 187:WS409–WS401

Selbert JA (2004) Vertebroplasty and Kyphoplasty: do fluoroscopy operators know about radiation dose, and should they want to know? Radiology 232: 633–634

Shore RE (1990) Overview of radiation-induced skin cancer in humans. Int J Radiat Biol 57(4):809–827

Singer G (2005) Occupational radiation exposure to the surgeon. J Am Acad Orthop Surg 13:69–76

Slomczykowski M, Roberto M, Schneeberger P, Ozdoba C, Vock P (1999) Radiation dose for pedicle screw insertion: fluoroscopic method versus computer-assisted surgery. Spine (Phila Pa 1976) 24:975–982. discussion 983

Smith HE, Welsch MD, Sasso RC, Vaccaro AR (2008) Comparison of radiation exposure in lumbar pedicle screw placement with fluoroscopy vs computer-assisted image guidance with intraoperative three-dimensional imaging. J Spinal Cord Med 31:532–537

Synowitz M, Kiwit J (2006) Surgeon's radiation exposure during percutaneous vertebroplasty. J Neurosurg Spine 4(2):106–109

Tsalafoutas IA, Tsapaki V, Triantopoulou C, Gorantonaki A, Papailiou J (2007) CT-guided interventional procedures without CT fluoroscopy assistance: patient effective dose and absorbed dose considerations. AJR Am J Roentgenol 188(6):1479–1484

Valentin J (2000) Avoidance of radiation injuries from medical interventional procedures. Ann ICRP 30(2):7–67

Vano E, Gonzalez L, Fernandez JM, Prieto C, Guibelalde E (2006) Influence of patient thickness and operation modes on occupational and patient radiation doses in interventional cardiology. Radiat Prot Dosim 118:325–330

Vlietstra RE, Wagner LK, Koenig T, Mettler F (2004) Radiation burns as a severe complication of fluoroscopically guided cardiological interventions. J Interv Cardiol 17:131–142

Wagner LK (2002) You do not know what you are doing unless you know what you are doing (editorial). Radiology 225:327–328

Wrixon AD (2008a) New ICRP recommendations. J Radiol Prot 28:161–168

Wrixon AD (2008b) New recommendations from the international commission on radiological protection–a review. Phys Med Biol 53:R41–R60

Yu E, Khan SN (2014) Does less invasive spine surgery result in increased radiation exposure? A systematic review. Clin Orthop Relat Res 472:1738–1748

Zwingmann J, Konrad G, Kotter E, Sudkamp NP, Oberst M (2009) Computer-navigated iliosacral screw insertion reduces malposition rate and radiation exposure. Clin Orthop Relat Res 467: 1833–1838

Treatment of Refractory Myofascial Pain of the Neck and Shoulder Girdle with Botulinum Toxin A

S. Grüner, M. Lippert-Grüner, and A. Schulz

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_6

6.1 Introduction

Botulinum toxin is the most potent toxin known. It is formed in various subtypes of the anaerobic rod-shaped bacterium *Clostridium botulinum* (Federal Office of Civil Protection and Disaster Assistance 2007; Holle et al. 2012; Placzek 2006; Schelosky 2016a; Schulz et al. 2016). Some, but not all, subtypes are human pathogenic; symptoms of poisoning also exist in animals such as cattle or ducks. The disease is called botulism. The bacterium itself is a strict anaerobe, the very durable spore form occurs ubiquitously in the soil.

The first systematic descriptions were made in the first half of the 18th century by the physician and poet Julius Kerner. The toxin irreversibly inhibits the release of acetylcholine (ACh) into the synaptic cleft at the motor end plate and also at glandular tissues. It thus leads to chemical denervation for at least about 3 months in transversely striated muscle and about 6–9 months in glandular tissues (Schelosky 2016b; Schulz et al. 2016). The first clinical effects are seen after only a few days, whereas the maximum effect is seen after approx. 6 weeks in the case of muscle and after approx. 12 weeks in the case of glandular tissue.

After this time, re-sprouting of vesicles leads to reinnervation and thus to a renewed release of acetylcholine into the synaptic cleft. In addition to this effect on the efferent limb, evidence has emerged in recent years for an additional mechanism of action in the afferent limb, in which, among other mechanisms, the release of inflammatory mediators such as substance P, glutamate and the calcitonin gene-related peptide (CGRP) can be inhibited, thus reducing peripheral and possibly also central pain sensitization. This effect appears to be more effective in neuropathic than in nociceptive pain. While the effect on the efferent limb can already be considered relatively well researched, the effect on the afferent limb can be clearly demonstrated, but the exact mechanism is still unclear in many areas (Halb et al. 2017; Schulz et al. 2016).

The use of the toxin as a drug in strong dilution began after the Second World War through experiments by the American ophthalmologist Scott for the treatment of strabismus and blepharospasm, these were also the first officially approved indications in 1989 (Schulz et al. 2016). In the following years, more and more indications were added: cervical dystonia, spasm hemifacialis, spasticity of the upper and lower extremities after stroke or infantile cerebral palsy, overactive urinary bladder, axillary hyperhidrosis and also aesthetic indications, for example the treatment of disturbing facial wrinkles. In addition to these indications, clinical studies and off-label therapies have been and are being conducted for other diseases. In the musculoskeletal system, botulinum toxin is used in the treatment of symptomatic, therapy-refractory myofascial trigger points as well as therapy-resistant epicondylitis and plantar fasciitis.

Indications of further mechanisms of action in addition to ACh inhibition emerged from clinical observations and theoretical considerations for approved indications: For example, in the indication of spasticity, pain inhibition in the area of the treated spastic muscle often becomes apparent more quickly than the therapeutic weakening or paralysis becomes clinically manifest. Pain reduction alone has also been demonstrated in studies with dosages below the antispastic effect. The documented effect in the treatment of chronic migraine with the PREEMPT regimen (31 injections in the head and neck area with de facto subcutaneous administration) cannot be adequately explained by the construct of the motor effect of botulinum toxin alone.

Essentially, three different forms of botulinum toxin type A are available as a drug. These do not differ in the structure of the toxin itself, but in the type of envelope proteins (Schelosky 2016b; Schulz et al. 2016; Sommer and Bergfeld 2016):

- Abobotulinumtoxin (trade names Dysport® and Azzalure®),
- Onabotulinumtoxin (trade names Botox® and Vistabel®) and
- Incobotulinumtoxin (trade names Xeomin® and Bocouture®).

Another important difference is the dosage, especially for abobotulinumtoxin compared to the other two types: as a rule of thumb, one

can assume the dose equivalence of approximately 2.4 units of abobotulinumtoxin with 1 unit of the other two types. Another representative of botulinum toxin type A, letibotulinumtoxin, originates from South Korea (Hong et al. 2017).

6.2 Literature Research

A database-supported open-search Internet literature search was performed at the Livivo search portal (► www.livivo.de) in the default setting with the search criteria (a) Botox and (b) Botulinum in combination with the keywords "myofascial", "spine" and "cervical" as well as "myofascial" with "injection" or "saline". Studies from 1998 to the date of the literature search in September 2017 were included, and translations into other languages were automatically considered, supplemented by other literatures known to the authors. Only prospective studies of evidence levels 1–3, corresponding to recommendation grades A and B, were considered.

▪ Study Design, Inclusion and Exclusion Criteria of Studies Focusing on Cervicocephalgia, Cervicalgia, Cervicodorsalgia and Sequelae After So-Called Whiplash Injury

The studies listed examined chronic myofascial pain in the cervical spine and shoulder girdle. In addition to the predefined exclusion criteria due to the drug, such as preparation-related allergies, pregnancy, therapy with aminoglycosides as well as the existence of neuromuscular diseases, more severe local diseases such as radiculopathies in intervertebral disc damage and also coexisting psychological and psychosomatic diseases such as depression and fibromyalgia syndrome were usually excluded. Cases with previous botulinum toxin treatment were generally not included, and current concomitant treatments were also excluded or regimented. Most double-blind randomized controlled trials (RCTs) on this topic use the feature that the botulinum toxin is dissolved in a physiological saline solution and one cannot visually distinguish the therapy solution from a pure saline solution. This is a good basic prerequisite for blinding. The same is true for studies comparing botulinum with local anesthetics. Other studies compare botulinum toxin therapy with other forms of therapy, in which case blinding is usually not possible or only possible with difficulty. In the following, the best-known studies are briefly presented in chronological order.

1. **Botulinum toxin vs. NaCl 0.9%, injection of one site, double-blind RCT study (Wheeler et al. 1998)**

   In this study 33 subjects were divided into 3 groups of 11 and received Botox® in 2 doses of 50 and 100 units vs. NaCl 0.9% by injecting 2 mL each into a trigger point. Approximately 2/3 of the subjects had an accident history. The specific point was selected by local palpation and specification with pressure algometry, and a painless control point was also measured. In parallel, a subjective assessment was performed using the NPAD scale (Neck Pain and Disability Scale; Jorritsma et al. 2012; Wheeler et al. 1999). Follow-ups were performed with pressure measurement and score recording at 1 week, 3 weeks, 6 weeks, 9 weeks, 3 months, and 4 months, respectively. In 11 subjects, a follow-up injection of 100 units in 2 mL NaCl 0.9% was performed on the same side and in two other subjects on the opposite side with a height distance of at least four vertebral bodies. At all control time points, pressure algometry and NPAD scale showed highly significant improvement from baseline in all 3 groups and no significant difference when comparing the three groups with each other.
2. **Botulinum toxin vs. NaCl 0.9%, 5 injection points, double-blind RCT study (Freund and Schwartz 2000)**

   In this study of 30 subjects with a history of accidents and refractory chronic cervical headache symptoms, a comparison was made of 100 units of Botox® in 1 mL NaCl 0.9% with injection of the 5 most pressure painful sites (each with 0.2 mL, i.e. 20 units of Botox® each) vs. 1 mL NaCl 0.9%. 24 of the 30 patients had unilateral cervical spine complaints

and unilateral headaches, these were infiltrated unilaterally, the other six patients had bilateral cervical spine complaints and unilateral headaches, the injections were performed bilaterally. A complete follow-up was performed in 86.7% of the patients after 2 and 4 weeks with recording of headache intensity on a visual analogue scale (VAS) as well as laser-assisted neutral-0 measurement of the cervical spine in all six directions with subsequent summation of the measured deflections from the neutral position (total ROM). Compared to baseline, the verum group showed a tendency to improve the total ROM after 2 weeks and a significant improvement after 4 weeks, as well as a significant pain response on the VAS. In contrast, the placebo group showed no significant difference in either parameter at either time point. A direct statistical analysis of the effects in both parameters comparing verum vs. placebo was not performed; at the time of entry, the medians of the two groups did not differ significantly with regard to total ROM, but in the verum group there was previously a significantly higher median with regard to the values in the VAS.

3. **Botulinum toxin vs. NaCl 0.9%, double-blind RCT study (Wheeler et al. 2001)**

This further study by Wheeler et al. on 50 subjects with chronic neck pain compared a high-dose injection of an average of 230 U Botox® vs. NaCl 0.9%. A history of trauma existed in over half of the subjects. The demographic data of the two groups of 25 subjects each showed a statistically significant difference in 10 parameters only in one area (SF-36 mental, subtest of a questionnaire on physical and psychological well-being; Bullinger and Kirchberger 1998). After the initial examination and the single injection at the most painful site (mainly in the area of the trapezius muscle, here approx. 2/3 of the test persons), control examinations were carried out after 4, 8, 12 and 16 weeks. The NPAD scale and a pressure algometry were carried out at all five time points, in addition to measurement of the GAS (external and self-assessment of parameter changes; Wheeler et al. 2001), measurements of the BDI (depression questionnaire; Jackson-Koku 2016) at the start, after 8 weeks and at the end point after 16 weeks, as well as measurements of the SF-36 in both subscales psychological and physical at the start and end. The drop-out rate was 10% (verum group $n = 4$, placebo group $n = 1$), and their results were excluded from the calculation. Statistical mean analyses revealed significant improvement in NPAD in both groups with no significant differences comparing verum vs. placebo.

4. **Botulinum toxin vs. lidocaine vs. dry needling (Kamanli et al. 2003)**

In this study, a total of 87 trigger points in the cervical spine and shoulder girdle were treated in 29 mostly female subjects with chronic complaints: 32 trigger points in 10 subjects with injection of lidocaine and subsequent dry needling, 33 trigger points in 10 subjects with dry needling only, and 22 trigger points in 9 subjects with injection of botulinum toxin A (manufacturer/preparation not named) and subsequent dry needling. Data collected included pressure algometry in four measurements (pressure intensity until an uncomfortable pressure sensation was reached, pain scale from 0 [no pain] to 3 [significant pain] at a defined pressure intensity, and comparison with the opposite side), the VAS for pain, fatigue, and work ability, the Nottingham Health Profile (NHP; Hunt et al. 1980) quality-of-life scale, and the Hamilton depression and anxiety scales (Hamilton 1959, 1960). Injections used 1 mL of a 0.5% lidocaine solution or 10–20 U of botulinum toxin A in 1–2 mL of 0.9% NaCl solution per point. Analyses of the 3 groups with respect to the number of trigger points, patient age, duration of medical history, and body mass index (BMI) before therapy revealed no significant differences. Results before treatment and 4 weeks after treatment were compared. The lidocaine group showed significant improvements in both categories of pres-

sure algometry with parallel absence of significant change on the opposite side, the visual analogue scale regarding pain, fatigue and work ability and the quality of life score NHP. No significant changes were shown with regard to depression and anxiety according to Hamilton. In the botulinum toxin group there were significant changes analogous to the lidocaine group, additionally a significant increase of the applied pressure force of the pressure algometry also on the opposite side as well as likewise significant changes of the depression and anxiety according to Hamilton. In the group with only dry needling there were no significant changes. Comparing the 3 different treatments, there was a significant change in pressure algometry compared to the previous values, with no significant change on the opposite side. This could be assigned to a specific subgroup, namely a significantly better result of the lidocaine group vs. the dry-needling group, no significant difference of the botulinum toxin group vs. the other two groups. Regarding the pain intensity in pressure algometry, there were no significant differences between the dry-needling group and the botulinum toxin group before and after treatment, significant improvements of the lidocaine group vs. dry-needling group after treatment with lack of significance before, a significant difference between the treatment with lidocaine or botulinum toxin was shown after treatment, but also significant before treatment. On the visual analogue scale regarding pain, there was a significant reduction overall for all 3 groups, although the analysis of the 3 groups among themselves showed no significance. On the visual analogue scale for the assessment of fatigue there was also a significant reduction after treatment, in the subgroup analysis significant advantages for the lidocaine group vs. dry needling, otherwise no differences between the groups. There were no significant differences in the visual analogue scale for the assessment of work ability, no subgroup analysis was performed.

5. Botulinum toxin vs. NaCl 0.9%, injection at up to 5 trigger points, double-blind RCT study (Ferrante et al. 2005)

   Here, 132 subjects with chronic complaints in the cervical spine and shoulder girdle received injections with botulinum toxin type A (no indication of the preparation) in a dose of 10, 25 or 50 units in 0.5 mL NaCl 0.9% into up to five active trigger points. Thus, the maximum doses were 50, 125, or 250 units; physiological saline was injected in the control group. All three therapy groups and the control group were approximately equal in size and demographics. The injection was followed by follow-up with physiotherapy, amitriptyline in ascending doses, ibuprofen in fixed doses, and a combination preparation of a synthetic opioid with acetaminophen as an on-demand medication. Follow-up visits were conducted after 1, 2, 4, 6, 8, and 12 weeks. Outcome measures were pain scores on the VAS, magnitude of taking the on-demand medication, pressure algometry, and the SF36 scale. Both in the analysis placebo vs. verum total (independent of dosage) and in the analysis of the three different dosages of verum among each other, there were no significant differences at all control time points and also at baseline with regard to VAS, intake of the combination drug and pressure algometry: all treatments showed an improvement in symptoms during the course. With regard to the SF-36 scale, only one of the various psychological subscales showed a significant difference placebo vs. verum total.

6. **Botulinum toxin vs. bupivacaine 0.5%, injection 8 sites, double-blind cross-over RCT study (Graboski et al. 2005)**

   This study included 18 subjects with painful trigger points in the cervical spine and shoulder girdle who had previously responded temporarily to bupivacaine injection of the trigger points with a pain reduction of at least half for a minimum of 8 h and a maximum of 1 month, but who then showed symptoms of discomfort again. In each case, nine subjects received injections of 25 U

botulinum toxin A (no indication of the specific preparation) in 0.5 mL solution or 0.5 mL bupivacaine 0.5% per site into an average of approximately 6 and up to 8 painful trigger points. Two weeks after the time at which the subjects reached an average weekly pain level of 75% of the pre-treatment level on a weekly VAS, follow-up injections were made with the other substance at the same pre-treated sites (botulinum toxin-bupivacaine or bupivacaine-botulinum toxin). Following the series of injections, there was an initial statistically significant reduction in pain in both groups. The botulinum toxin group showed a slightly higher pain reduction and slightly longer duration of action than the bupivacaine group, but the differences were not statistically significant.

7. **Botulinum toxin vs. NaCl 0.9%, injection at 10 trigger points, double-blind RCT multicenter study (Göbel et al. 2006)**

The predominantly female subjects with at least 10 trigger points and chronic pain in the area of the neck and shoulder girdle received botulinum toxin A Dysport® or saline. Entry criteria included self-assessment on a pain scale with a weekly score of at least 3 out of 4 (1 = no pain, 4 = severe pain). Injections of 40 units of the preparation were made into each of the 10 most painful trigger points, and three clinical control examinations were performed at 4-week intervals. The 74 subjects in the therapy group and the 70 subjects in the placebo group had comparable demographic data. In the therapy group, complete follow-up occurred in 86.5% of subjects; in the placebo group, this figure was 80%. At the first follow-up after 5 weeks, 51% of the subjects in the verum group reported only mild pain or freedom from pain, compared with 26% of the patients in the placebo group. This significant difference remained over the observation period until the eighth week, after which there were further significant differences, but without statistical significance, until the 12th week.

From the fifth week post injection, there was a constant significant higher number of pain-free days or days with mild pain or freedom from pain in the therapy group vs. the placebo group. No significant difference was observed in the number of painful trigger points and the duration of daily pain between the two groups. From week 5 until the end of the study, there was a significant reduction in pain intensity on a scale of 1–4 in the therapy group vs. the placebo group.

8. **Botulinum toxin vs. NaCl 0.9%, injection at 3–7 sites, double-blind cross-over RCT study (Ojala et al. 2006)**

Here, 31 subjects with comparable demographic data in both groups received onabotulinumtoxin (Botox®) in a low dosage or NaCl 0.9%: first injections of verum (n = 15) or placebo (n = 16) and then injections with the other substance after 4 weeks, followed by a follow-up of another 4 weeks. Injections were given to 3–7 pressure painful sites in the trapezius, levator scapulae, and infraspinatus muscles, each with 5 U botulinum toxin in 0.05 mL saline or with saline alone. The total injection volume was 0.15–0.35 mL NaCl 0.9% per injection series plus 15–35 U botulinum toxin, mean 28 ± 6 units. Approximately 23% of the patients took additional non-steroidal anti-inflammatory drugs (NSAIDs) at times, otherwise no further treatments. Pain (VAS 0–10) and treatment effectiveness (1–5) were recorded, with a score of 1 indicating no effectiveness and a score of 5 indicating very good effectiveness. For each of the maximum of 7 trigger points, a pressure algometry was further used to record the minimum value for pain triggering before treatment, after 4 weeks and after 8 weeks; a point on the right or left deltoid muscle served as a reference value. The follow-up included 100% of the subjects. There were no significant differences in pressure algometry scores, subjective pain scores, and number of trigger points between the two groups. Overall, with regard to pain intensity, there was a decrease of approximately

24% after 4 weeks and a further decrease of another 17–19% after the eighth week, this also in both groups (botulinum toxin followed by NaCl and NaCl followed by botulinum toxin). Statistically significant differences could not be shown, not even in pressure algometry, which experienced slight improvements overall and in both groups. In the subjective evaluation of efficiency, the botulinum toxin group achieved a significantly better result than the saline group with the first injection, and after the second injection the saline group showed diametrically better, but statistically non-significant results.

9. **Botulinum toxin dose-finding study, injection at 8 points, single-blinded multicenter phase II study (Jerosch et al. 2012)**

This study, conducted in 2003–2005 and republished in 2012, evaluated the therapeutic effect of the botulinum toxin A preparation Dysport® at two doses in 119 fully enrolled subjects with chronic myofascial complaints of the shoulder and neck region with pain intensity of at least 3–4 on a scale of 0–4 (0 = pain-free, 4 = severe pain). Pain scores were recorded daily over a period of 13 weeks. After 1 week, randomized injections of either 200 U (n = 69) or 320 U (n = 70) Dysport® were administered to 8 trigger points (25 or 40 U/point, respectively). The 4 most painful points on both sides were injected, in this case either all 4 points in the trapezius muscle or 3 points and one point in the splenius muscle. Clinical follow-up was performed after 2, 6 and 12 weeks. The patients, most of whom were female, were comparable in their baseline data. At 7 weeks, approximately 45% in the low-dose group and approximately 51% in the higher-dose group showed a mean decrease in pain of at least 2 points for at least 1 week; at the conclusion at 12 weeks, these values increased to approximately 67% and 81%, respectively, but the differences between the selected doses were not statistically significant. Mean pain intensity decreased in both groups from an average of 3.3/4 to 2.4/4 (Dysport 200) and 2.3/4 (Dysport 360) points at 6 weeks, with a further slight decrease to an average of 2.3/4 (Dysport 200) and 2.0/4 (Dysport 360) points. The SF-36 physical score increased in both groups from an initial average of about 33 points to an average of 39 points at 6 weeks and an average of 43 points at 12 weeks.

10. **Botulinum toxin vs. NaCl 0.9%, injection at 1–2 points, double-blind RCT study (Kwanchuay et al. 2015)**

This study included 33 patients with 48 trigger points in the upper trapezius muscle with complaints for at least 3 months and a pain intensity of at least 3 out of 4 points. Subjects were randomized to receive either 20 U Botox® in 0.2 mL 0.9% NaCl solution or 0.2 mL 0.9% NaCl solution per trigger point. 24 trigger points were treated per group in a total of 33 patients: The 18 patients with unilateral findings were divided between both groups and received 1 injection (verum to placebo 8:10); the 15 patients with bilateral findings received either verum on both sides (n = 4), placebo on both sides (n = 3), or verum on one side and placebo on the other (n = 8). The follow-up rate was 100%. Documentation of pain on the VAS and pressure algometry were performed before the injection, after 3 weeks and after 6 weeks. Demographic data including pain history duration, VAS and pressure algometry scores were comparable in both groups. Both groups showed a significant reduction in pain intensity and significant improvement in pressure algometry compared to baseline values. Comparing both groups with each other, there were no significant differences in pain intensity at both control time points and no significant difference in pressure measurement at the first control, but the values in pressure measurement in the botulinum toxin group were significantly higher at the second control.

6.3 Discussion of the Study Results

In the last 20 years or so, a large number of publications have appeared dealing in various forms with the treatment of botulinum toxin in relation to the spine. This review article summarizes the results of the treatment of myofascial trigger points in the cervical spine and shoulder girdle. Publications dealing primarily with the treatment of headache or complaints in the lumbar-pelvic-hip region and the pelvis were not included here for reasons of scope.

The results of the botulinum toxin treatment of myofascial pain in the neck and shoulder girdle are diametrically opposed, a clear tendency cannot be identified. This circumstance might also be a reason for the fact that the preparations – as of today – are not approved for this indication.

In the publications with a direct comparison of botulinum toxin A vs. saline solution, the question remains whether the therapy with NaCl 0.9% is actually a placebo therapy: Especially with providers of alternative therapies one regularly finds variants of neural therapy which also offer injections with physiological saline solution instead of procaine or lidocaine. However, this is not a newer therapy; rather, it was already listed as a possible form of therapy in the standard work by Simons et al. (1998) on myofascial trigger points.

All studies comparing botulinum toxin vs. NaCl 0.9%, with the exception of the work by Freund and Schwartz (2000), also showed an improvement with saline treatment. Dry needling and also acupuncture treatment also lead to positive therapeutic effects. The studies listed showed partially comparable results for the injection with botulinum toxin as well as for NaCl 0.9%, further also comparable results for the injection with botulinum toxin as well as for local anesthetics. The analyzed studies rather point to the logical conclusion that all therapies have a similar efficacy.

Considering the studies botulinum toxin vs. physiological saline solution, some comments arise: In the Wheeler study from 1998 (Wheeler et al. 1998), improvement was demonstrated in both groups with no significant difference. Although the study had a longer observation period, the number of cases was small, numerous subjects underwent follow-up injections, and subjects with and without a history of trauma were included; no differentiation in this regard is apparent. The publication by Freund and Schwartz (2000) had both a small number of cases, a short follow-up and a lack of comparability between the two groups, the significance therefore appears reduced. The second study by Wheeler et al. (2001) also found improvement in both groups with no significant difference. The study design had fewer deficits than the first study. The publication by Ferrante et al. (2005) showed a higher number of cases and longer observation period, significant differences could not be found even over the longer observation period. Overall, however, this study appears more significant than the three previous studies. The work of the group around Göbel et al. (2006) was also carried out with a higher number of cases and longer observation period, the result here was diametrical with advantages for the botulinum toxin group. The work of Ojala et al. (2006) published in the same year showed an interesting study design with a cross-over approach, but the results were not constant, moreover, the work had only a shorter observation time and smaller number of cases. The work of Jerosch et al. (2012) is methodologically weaker compared to the other studies, as there was no control group, but the long observation time and high number of cases are to be noted positively. From this work it can at least be concluded that a higher number of patients could be successfully treated in previously refractory cases. The most recent work by Kwanchuay et al. (2015) is methodologically weaker due to the shorter observation period and low number of cases; significant differences in the treatment groups were not found. The work of Kamanli et al. (2003) shows as a positive circumstance that three different procedures (botulinum toxin with dry needling, local anesthetics with dry needling, dry needling alone) were directly compared with each other, but also only over a short period of time and with small case numbers: Efficacy

was shown for all three forms of therapy with no significant differences between them. The work of Graboski et al. (2005) examined botulinum toxin vs. local anesthetic and showed slight advantages for botulinum toxin, but without statistical significance with a small number of cases in the treatment groups.

6.4 Practical Conclusions and Overall Therapy Concept

The available clinical studies currently do not allow a positive assessment regarding a superior efficacy of botulinum toxin compared to other substances or therapies. The methodologically best clinical studies show contradictory results, whereby this may also be related to the number of trigger points treated. Nevertheless, clinically relevant efficacy of therapy with botulinum toxin can be derived from the studies without clear advantages or disadvantages compared to local anesthetics.

From our own practical experience, it must be emphasized that no botulinum toxin treatment should be carried out in clinical practice if a chronic pain disorder with psychological and somatic factors or a fibromyalgia syndrome is present (at least coexistently). The results here are usually sobering.

Furthermore, a test infiltration with a local anaesthetic should be carried out before the injection with botulinum toxin in order to be able to select patients for botulinum toxin therapy. If a local anaesthetic infiltration does not result in at least a short-term pain reduction of at least 50%, treatment with botulinum toxin should not be carried out.

Therapy with botulinum toxin alone is often insufficient. This therapy should be embedded in a multi-stage concept with optional drug treatment (NSAIDs, analgesics, myotonolytics, anticonvulsants, if necessary antidepressants), physiotherapeutic treatment, independent gymnastic exercises and sports activities, shock wave therapy, acupuncture and dry needling as well as physical therapy measures. From clinical experience, there is no evidence that the selection of one or the other botulinum toxin preparation seems more appropriate.

Botulinum toxin therapy is another therapeutic procedure that can be used as a "therapeutic reserve" in previously refractory cases. However, it must be emphasized that this is a very cost-intensive and unapproved procedure, which then also requires an intensive "off-label explanation"—including economic reasons. Furthermore, it must be considered that in the case of off-label use, the liability for possible later and perhaps not yet known side effects is transferred from the manufacturer or distributor to the user. It has to be explicitly pointed out that according to the product information of the manufacturer only trained physicians are allowed to perform the injections, this requires special attention especially in case of off-label use. Injectors should also check the liability coverage.

At the time of writing this chapter, the treatment of myofascial trigger points with botulinum toxin is not a service provided by the statutory health insurance funds and is therefore excluded from billing under this system; it is paid for under the physicians' fee schedule. Whether and to what extent other cost units pay for this partially or completely has to be clarified in the individual case. According to the Patients' Rights Act, effective information also includes prior economic information, especially since the costs for the preparations represent a not inconsiderable share of a GOÄ settlement.

References

Bullinger M, Kirchberger I (1998) SF-36-Fragebogen zum Gesundheitszustand (PSYNDEX Tests Review). https://www.zpid.de/retrieval/PSYNDEXTests.php?id=9003482. Accessed on 30.07.2018

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2007) Biologische Gefahren II, Entscheidungshilfen zu medizinisch angemessenen Vorgehensweisen in einer B-Gefahrenlage. Bonn, S 204–216. http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/PublikationenForschung/Bio-Gefahren-II-MedVers.pdf?__blob=publicationFile. Accessed on 30.07.2018

Ferrante F, Bearn L, Rothrock R, King L (2005) Evidence against trigger point injection technique for the treatment of cervicothoracic myofascial pain with botulinum toxin type a. Anesthesiology 103:377–383

Freund B, Schwartz M (2000) Treatment of chronic cervical-associated headache with botulinum toxin type a: a pilot study. Headache 40:231–236

Göbel H, Heinze A, Reichel G, Hefter H, Benecke R et al (2006) Efficacy and safety of a single botulinum type a toxin complex treatment (Dysport) for the relief of upper back myofascial pain syndrome. Pain 125: 82–88

Graboski C, Gray D, Burnham R (2005) Botulinum toxin a versus bupivacaine trigger point injections for the treatment of myofascial pain syndrome. Pain 118:170–175

Halb L, Amann B, Bornemann-Cimenti H (2017) Einsatz intra- bzw. subkutaner Botulinumtoxine bei Post-Zoster-Neuralgie. Nervenarzt 88:408–414

Hamilton M (1959) The assessment on anxiety states by rating. Br J Med Psychol 32:50–55

Hamilton M (1960) A rating scale for depression. J Neurol Neurosurg Psychiatry 23:56–62

Holle D, Rabe K, Obermann M, Straube A, Gerwig M, Diener C (2012) Botulinumtoxin bei Kopfschmerzen. Akt Neurol 39:546–552

Hong B, Chang H, Lee S, Park J, Kwon J (2017) Efficacy of repeated botulinum toxin type a injections for spastic equinus in children with cerebral palsy-a secondary analysis of the randomized clinical trial. Toxins 9(8):253

Hunt S, Mc Kenna S, Mc Ewen J, Backett E, Williams J, Papp E (1980) A quantitative approach to perceived health status: a validation study. J Epidemiol Community Health 34:281–286

Jackson-Koku G (2016) Beck depression inventory. Occup Med 66:174–175

Jerosch J, Söhling M et al (2012) Open-label, multicenter, randomized study investigating the efficacy and safety of botulinum toxin type a in the treatment of myofascial pain syndrome in the neck and shoulder girdle. J Musculoskelet Pain 2:95–99

Jorritsma W, de Vries G, Dijkstra P, Geertzen J, Reneman M (2012) Neck pain and disability scale and neck disability index: validity of Dutch language versions. Eur Spine J 12(1):93–100

Kamanli A, Kaya A, Ardicoglu O, Ozgocmen S, Ozkurt Zengin F, Bayik A (2003) Comparison of lidocaine injection, botulinum toxin injection, and dry needling to trigger points in myofascial pain syndrome. Rheumatol Int 25:604–611

Kwanchuay P, Petchnumsin T, Yiemsiri P, Pasuk N, Srikanok W, Hathaiareerug C (2015) Efficacy and safety of single botulinum toxin type a (Botox®) injection for relief of upper trapeziusMyofascial trigger point: a randomized, double-blind, placebo-controlled study. J Med Assoc Thail 98(12):1231–1236

Ojala T, Arokoski J, Partanen J (2006) The effect of small doses of botulinumtoxin toxin a on neck-shoulder myofascial pain syndrome. Clin J Pain 22(1):90–96

Placzek R (Hrsg) (2006) Botulinumtoxin in Orthopädie und Sportmedizin—Evaluation eines neuen Wirkstoffes zur klinischen Anwendung im Fachgebiet Orthopädie. Habilitationsschrift, Medizinische Fakultät der Charité, Universitätsmedizin Berlin

Schelosky L (2016a) Klinische Anwendung von Botulinumtoxin Typ A. In: Sommer B, Bergfeld D, Sattler G (Hrsg) Botulinumtoxin in der ästhetischen Medizin. Thieme, Stuttgart, S 10–11

Schelosky L (2016b) Pharmakologie des Botulinumtoxins. In: Sommer B, Bergfeld D, Sattler G (Hrsg) Botulinumtoxin in der ästhetischen Medizin. Thieme, Stuttgart, S 18–22

Schulz A, Grüner S, Lippert-Grüner M (2016) Botulinumtoxin – mögliche Indikationen in O & U. OUP 4:218–221

Simons D, Travell J, Simons L (1998) Myofascial pain and dysfunction: the trigger point manual volume I upper half of body. Lippincott Williams Wilkins, Philadelphia

Sommer B, Bergfeld D (2016) Präparate und Dosierungen. In: Sommer B, Bergfeld D, Sattler G (Hrsg) Botulinumtoxin in der ästhetischen Medizin. Thieme, Stuttgart, S 23–25

Wheeler A, Goolkasian P, Gretz S (1998) A randomized, double-blind, prospective pilot study of botulinum toxin injection for refractory, unilateral, cercicothoracic, paraspinal, myofascial pain syndrome. Spine 23(15):1662–1667

Wheeler AH, Goolkasian P, Baird AC, Darden B (1999) Development of the neck pain and disability scale. Spine 24(13):1290–1294

Wheeler A, Goolkasian P, Gretz S (2001) Botulinum toxin a for the treatment of chronic neck pain. Pain 94:255–260

Lumbar Facet Joint Injection and Radiofrequency Denervation

M. Schneider

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_7

Historically, it was first postulated by Goldthwaith in 1911 that the facet joints were responsible for some of the non-radicular pain originating in the lumbar spine (Goldthwait 1911). In 1933, Ghormley introduced the term facet syndrome. He saw the facet syndrome as a symptom complex in its own right and recommended spondylodesis for its treatment (Ghormley 1933). It was not until 40 years later, in the 1970s, that treatment methods for pain induced by facet joints improved. Rees (1971) introduced percutaneous cutting of the joint nerves with a scalpel and Shealy (1975) established percutaneous radiofrequency denervation.

Nevertheless, doubts were still widespread in the 1980s–1990s as to whether the facet joints could even be considered a source of pain. Therefore, numerous studies were developed during this time that were able to prove this. Bogduk in particular was able to provide clarity through the precise anatomical description of the medial branch (ramus medialis) of the dorsal spinal nerve (Bogduk 1983; Bogduk and Long 1979; Bogduk et al. 1982) (Fig. 7.1).

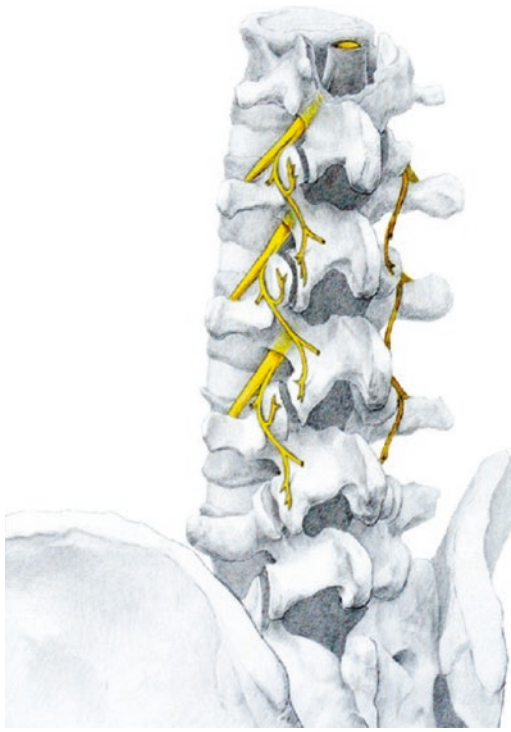


Fig. 7.1 Innervation of lumbar facet joints

7.1 Indication

A distinction must be made between the indications for lumbar facet joint injections and lumbar radiofrequency denervation of facet joints. Some authors regard lumbar facet joint injections merely as a diagnostic measure (Van Zundert et al. 2011).

The indication for facet joint injection exists when it is assumed that the facet joints are the pain generator. Consistently, several authors have shown that there is no valid manual examination method for diagnosing facet joint syndromes (Manchikanti et al. 2000). Schwarzer in particular has shown this well in his work (Schwarzer et al. 1994, 1995).

Schwarzer was also able to demonstrate that typical radiations occur when certain lumbar facet joints are irritated. McCall et al. (1979) were able to demonstrate that, contrary to the assumption that pseudoradicular pain only extends to knee level, it can indeed radiate to the outer ankle (Fig. 7.2).

Indirect radiological indications of a facet joint syndrome can be joint space narrowing at the facet joints or a narrowing of the intervertebral space, since a decrease in the intervertebral space often leads to increased intraarticular joint pressure and subsequent arthrosis. Nevertheless, imaging is also not considered to be directional in various studies and can only contribute to the indication to a very limited extent (Manchikanti et al. 2000).

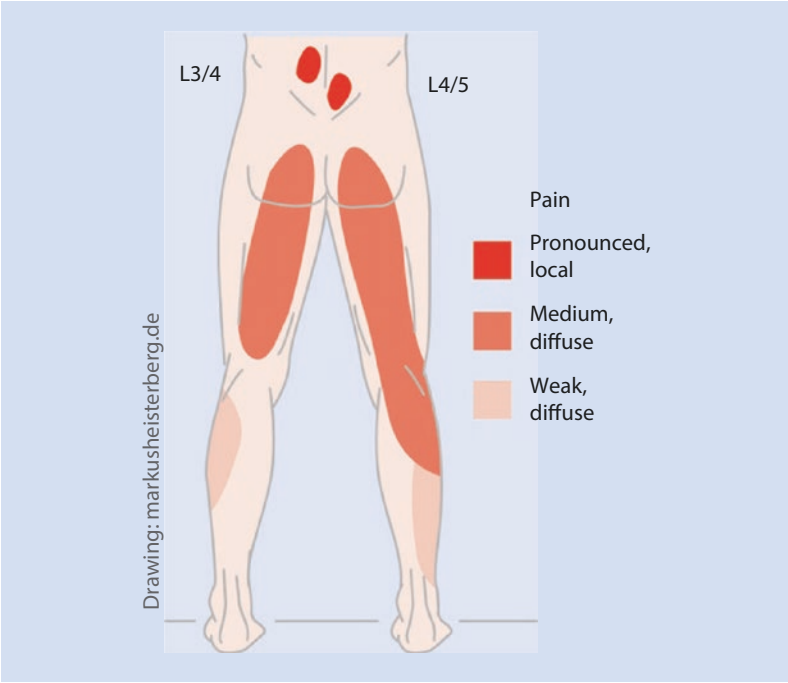


Fig. 7.2 Localization of pain induced by the facet joints L3/4 (*left*) and L4/5 (*right*)

7.2 Preinterventional Diagnostics

After it was shown in ▶ Sect. 7.1 that conventional diagnostics are only possible to a very limited extent before performing facet infiltration, this section refers to the preinterventional diagnostics for lumbar radiofrequency denervation.

As with the large joints, historically an intra-articular injection was initially attempted as a diagnostic criterion for radiofrequency denervation. However, Bogduk showed early on that diagnostics in the form of a blockade of the ramus medialis is the better option, on the one hand because of the bisegmental innervation of the facet joints and on the other hand because of the comprehensible course of the ramus medialis. Furthermore, the studies conducted in the 1980s and 1990s on the therapeutic effects of intra-articular injection often did not produce good long-term results (Carette et al. 1991).

These facts led to the fact that, also under the influence of the Spine Intervention Society (SIS), pain diagnostics should be carried out where, according to anatomical findings, nociception is concentrated and, as a common nerve, can also be addressed well by intervention: the rami mediales of the dorsal branch of the spinal nerves L1–L4 or the dorsal branch at the processus articularis at L5.

In summary, the SIS has justified the advantages of diagnostics with a blockade of the ramus medialis in its guidelines in this way (Bogduk 2013):

- Blockages on the medial branch are easy to perform.
- These blockades are safer and more expedient.
- Blocks on the medial branch are easier to perform in repeated form.
- Intraarticular injections have no therapeutic benefit because no intraarticular treatment techniques exist for facet joints.
- In contrast, a radiofrequency neurotomy of the medial branch can be performed after a positive diagnosis.

Even if cross-sectional imaging does not provide a directional diagnosis, it is nevertheless recommended that both a native X-ray (due to better comparability with fluoroscopy) and a magnetic resonance tomogram be obtained before the injection so that any inflammatory

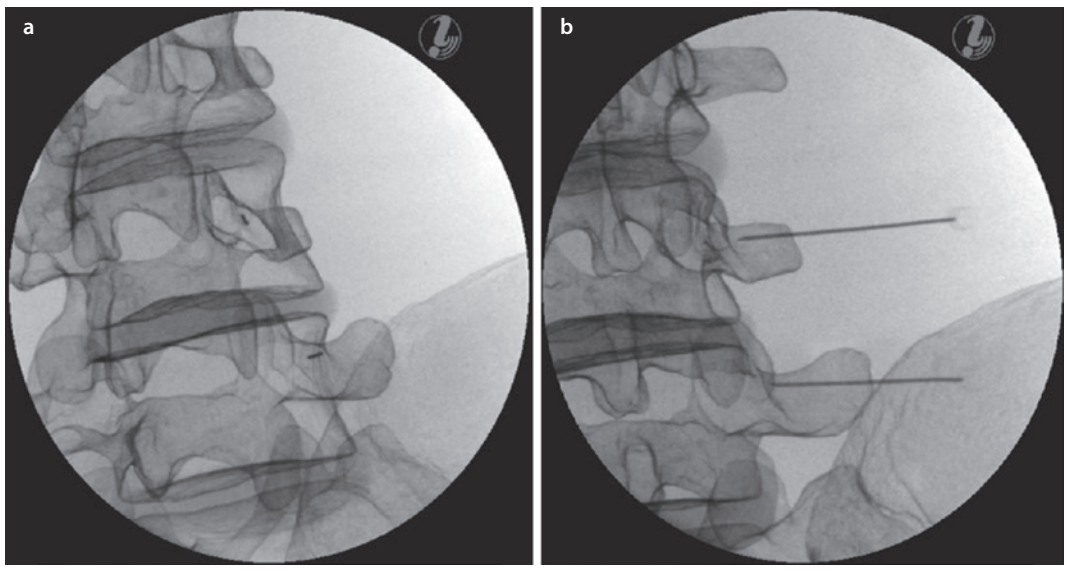
conditions or abnormalities (joint cysts, synovial cyst, etc.) can be detected before the procedure.

In the early days of facet joint injection, it was considered problematic that single diagnostic blocks lumbar showed an unacceptably high rate of 25–38% false positives (Manchikanti et al. 2000; Schwarzer et al. 1994). They share this fate with most peripheral diagnostic nerve blocks. For this reason, positive blocks must be controlled, as also demonstrated in the studies cited previously.

Here we distinguish two alternatives: on the one hand the comparative blockade and on the other hand the double block.

In comparative blockade, a long-acting local anaesthetic is injected and then compared with a short-acting one. This significantly reduces the risk of a false positive blockade and is referred to as a concordant dual blockade (Barnsley and Bogduk 1993). The result is described as concordant if the duration of action of the blockade corresponds to that of the applied local anaesthetic. In the placebo-controlled test trial—albeit cervical—this resulted in a sensitivity of 86% and a specificity of 65% (Lord et al. 1995). In clinical practice, however, this procedure has not proved to be reliably feasible. Therefore, double blockade with injection of the same local anesthetic twice at the same dose on different treatment days has become established. The clinical improvement on the VAS scale should be at least 50%, preferably 75%, of the initial value. In the vast majority of the studies described, the blockades are performed using an image intensifier (fluoroscopically guided). Due to the anatomical conditions, the location to be addressed at the transition from the proc. articularis to the proc. transversus can be optimally displayed by adjusting the C-arm at an angle (◘ Fig. 7.3).

The use of a C-arm has two advantages, also with regard to patient safety. On the one hand, the distribution of the contrast medium can already be seen before the local anaesthetic is administered and the needle position can still be corrected accordingly; on the other hand, an intravascular needle position would also be seen. The amount of contrast medium usually does not exceed 1 mL.



◘ **Fig. 7.3** From facet joints block ramus medialis L3 and L4. (**a**) oblique (**b**) ap (lumbar injection trainer company 3B Scientific, Hamburg)

7.3 Necessary Instruments

An image intensifier, also called a C-arm, which has a double screen system, is indispensable for performing fluoroscopically controlled facet injections and also radiofrequency denervation. The double screen has the advantage that the last image is always saved on the right screen in case of smallest corrections of the needle position. In addition, it is also indispensable for legal reasons to ensure image recording. Optimal quality is offered here by a so-called DICOM connection ("digital imaging and communications in medicine"), which not only transmits the patient data, but also the area dose product and other physical values.

The best proven needles are 9 cm or 12 cm long 25 G spinal needles, which on the one hand allow good radiological imaging and on the other hand are so flexible that the tip can be bent slightly if necessary and thus better controlled. In very obese patients, it may be necessary to use a thicker diameter needle, as the contrast in the imaging deteriorates and the thin needles are otherwise difficult to see.

A list of the materials and drugs used is shown in Table 7.1.

Table 7.1 Materials and drugs for injection at the medial branch lumbar (proposal)

Drug or material	Dose or details	Application
Scandicaine 2%	5 mL	Anesthesia of the skin
Ropivacaine 2 mg/dL	2 mL	Anesthesia medial branch
Dexamethasone 8 mg	2 mL	Additive for therapeutic block
z. E.g. Solutrast	0.5–1 mL	Contrast medium to exclude intravascular needle position
Injection cannula 23 G	0.6 × 80 mm	Skin quad
Spinal cannula, if necessary with Quincke cut 25 G or 22 G	0.5(0.7) × 80 mm or 120 mm	For injection at the medial branch
Radiofrequency cannula 18 G 10 mm active tip, curved	50 mm, 100 mm or 150 mm	To set the radio frequency lesion

To perform a radiofrequency neurotomy, an appropriate generator is used with a non-insulated end of the electrode (usually 10 mm long), which achieves molecular vibration of the proteins by a high-frequency current, heating the nearby tissue and creating temperatures of 45–85 °C. This denatures the protein of the nerve fibers and coagulates the tissue. It should be noted that the isotherm of the coagulation needle spreads radially in an oval shape on the needle. The width of the lesion zone correlates significantly with the thickness of the electrode, so that today, in contrast to the 1990s and 2000s, an 18-G needle is generally used (formerly 20–22 G). Radiofrequency generators are offered by various companies. Most of these have different operating modes, such as bipolar coagulation, whereby two or even more electrodes can be connected in parallel and the lesion zone is then located between the two electrodes.

A special form concerns the radiofrequency generator of the Halyard company, which, in addition to a conventional radiofrequency, as described above, can effect water cooling of the electrode by means of a special, separately available pump. This considerably enlarges the lesion zone, which is primarily important in radiofrequency neurotomy of the sacroiliac joint (Chap. ► 12).

Nowadays, lesion cannulas that are slightly curved at their end are mostly used, as they can better adapt to the nerve course at the base of the transverse process.

7.4 Pre-Intervention Education

In the meantime, standardized patient information sheets reviewed by legal experts are available for both lumbar facet injection on the medial branch and lumbar radiofrequency denervation (Perimed-Verlag, ▶ www.perimed.de; Thieme Compliance, ▶ www.thieme-compliance.de). In any case, a sketch showing the anatomical conditions and the needle position should additionally be added or prepared. It is also essential nowadays in the German legal system to discuss an alternative treatment option with the patient. The patient's allergies to medications, intolerance of contrast media, medication with anticoagulants and previous illnesses should also be asked about in the patient information questionnaire. The possible complications of the intervention, as described in ▶ Sect. 7.6, should be explicitly listed. The author also strongly recommends recording the explanation on the model.

As a general rule, education must not take place on the day of the injection. Since all pain therapy interventions are elective procedures, it is strongly recommended to conduct a separate diagnostic and educational discussion with the patient and to schedule the intervention on a second day. This procedure applies analogously to major surgical interventions.

7.5 Implementation of the Intervention

7.5.1 Spatial Requirements

Pain therapy procedures on both the nerve roots and the facet joints can be performed in an easy-to-clean procedure room. The same requirements as for an aseptic operating room in which open joints are operated on do not have to be met. Care should be taken to provide appropriate X-ray shielding. Wearing a dosimeter and appropriate protective clothing (X-ray apron, thyroid shield) is a matter of course. The use of lead goggles is advisable, at least for the surgeon.

Fig. 7.4 Intervention area

Conventional operating tables are not recommended for performing facet joint injection and radiofrequency denervation because they usually have radiopaque metal bars at the ends. A radiolucent table that is adjustable in height should be used. Since moving the image converter parallel to the table usually adjusts the focus, the author recommends making sure that the table is also electrically adjustable in the horizontal plane. There should be a resuscitation facility in the room, and oxygen should also be available. As many storage places as possible should be paid attention to. It is advantageous to be able to dim the lighting in order to achieve better contrast on the monitors. In summer, air conditioning is advantageous due to the longer time the X-ray aprons are worn (Fig. 7.4).

7.5.2 Preliminary Anatomical Remarks

First of all, one must be clear about how the innervation of the facet joints L1-S1 runs. The medial branch of L1-L4 arises from the dorsal ramus before the spinal nerve root reaches the transverse process. Then the ramus dorsalis runs caudally and moves into the pit between the proc. transversus and the proc. articularis. It then passes under the mamillo accessory ligament and enters the multifidus muscle. Here it gives off articular branches both above and below. In this way, each medial branch sup-

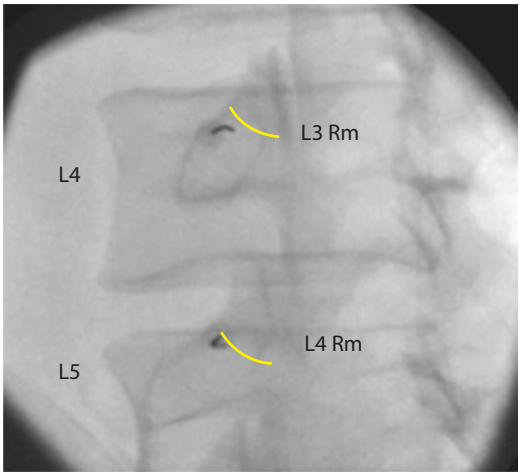


Fig. 7.5 Location of the lesion zones for the facet joint L4/5. The *yellow lines* correspond to the respective course of the ramus medialis (*Rm*). (Courtesy of Dr. Kniesel, Hamburg)

plies half of each of 2 facet joints (Bogduk and Long 1979; Bogduk et al. 1982).

This implies that in the case of a blockage of a facet joint, 2 medial branches (special case facet joint L5/S1) must always be anesthetized. The segmental designation ("numbering") can be irritating here, since the respective facet joint, consisting of the upper and lower joint parts of the adjacent vertebral bodies, has a lower number than the nervous supply. Thus, the facet joint L4/5 is supplied by the medial branches of L3 and L4, etc. (Fig. 7.5). The facet joint L5/S1 is a special form, since here the dorsal branch and not the medial branch runs over the wing of the sacrum, which corresponds to the transverse process of the fused sacral vertebral body. So here, both in diagnostics and in radiofrequency, the pit between the articular process at L5 and the massa lateralis is the target point for the lower joint portion.

7.5.3 Technical Execution of the Injection at the Ramus Medialis

After appropriate preparation of the medication and sterile preparation of the skin, the segment to be treated is now located. Here, care must first be taken to ensure that the top plate and bottom plate of the respective adjacent vertebrae are directly hit in the central beam and that no asymmetries are created in the image. The C-arm is then lowered 15–25 ° to the side to be treated. The so-called Scotty Dog appears in the oblique image, the radiological structure that appears in the oblique lateral position of the central beam when the joint with the joint space is projected onto half of the corresponding vertebral body. The target of the intervention is then the point behind or above the eye of the Scotty Dog.

For reasons of radiation protection, one should prepare a longer metal pointing stick, e.g. a Kirschner wire, and mark the entry point on the skin. The author recommends applying a wheal subcutaneously; further anaesthesia in the course of the puncture channel is usually not necessary. The puncture needle is then passed down the central jet to the center of the target point on the Scotty dog's eye. In case of bone contact, a contrast medium of (approx. 0.5 mL) is administered and, if the contrast medium spreads well, the local anaesthetic is injected in case of purely diagnostic infiltration, if necessary with the addition of a steroid in case of therapeutic injection.

If an intra-articular injection is planned, the joint space should be targeted in this exact position instead of the Scotty Dog's eye. After reaching the capsule, one usually feels a short resistance. It should be noted that the volume for intra-articular injection is very limited. Studies have shown that no more than 1.5 mL will fit into a non-degeneratively altered joint. Thus, one should inject a maximum of 0.5 mL of contrast medium in order to then be able to inject another 1 mL of local anesthetic and/or steroid.

When blocking the dorsal branch of L5, the C-arm is tilted laterally only a few degrees. If the iliac crest overlaps the target region, it is helpful to tilt a few degrees caudally. The target point is the confluence of the proc. articularis with the wing of the sacrum. After bone contact, analogous procedure as for anesthesia of the medial branches.

7.5.4 Technical Implementation of Radiofrequency Denervation

Basically, the preparation is identical to that of the anesthesia of the lumbar branch. In addition, a larger quantity of the local anaesthetic has to be provided, since due to the thickness of the radiofrequency cannula a complete injection around the expected puncture canal is recommended. Another peculiarity is that, in contrast to injection, care must be taken to ensure that the radiofrequency needle is positioned as parallel as possible to the nerve because of the ellipsoidal lesion zone of the cannulae (Bogduk 2013). To achieve this optimal parallel position, the cannula must be guided from significantly further dorsal to the target.

It is helpful to slightly de-lordoticize the lumbar spine by placing a cushion underneath abdominally. First, the top and bottom plates are aligned parallel in fluoroscopy, as in facet joint injection, then the angle is swivelled laterally until the target point of the injection can be seen at the confluence of the proc. articularis and proc. transversus. The C-arm is now lowered in a caudocranial direction by 20–30°: a fluoroscopic shadow is often seen, which resembles the shape of a boomerang at the inner border. The slight lateral swing is necessary to place the electrode in front of the mamillo-accessory ligament, as this can otherwise deflect the electrode from the target. Marking with the Kirschner wire is further performed and local anesthesia is administered in the stab canal until bone contact dorsal to the superior edge of the proc. transversus. The electrode is then carefully advanced in this caudocranial ray canal until the bone contact is reached approximately 1–2 mm lower than the target point. The contact at the periosteum can be painful, in this case 0.5–1 mL local anaesthetic should be injected. The curved electrode is then advanced dorsally in a cranial direction with its bend, constantly changing the fluoroscopic planes a.p., obliquely and laterally (Fig. 7.6a, b).

The optimal position is reached at the ramus medialis L1–L4 when the electrode tip ends in the middle of the neck of the facet joint in the lateral beam path and does not cross the line of the cover plate in the a.p. beam path.

The coagulation time varies between 60 s and 90 s and between 80 °C and 85 °C, depending on the operator and the device. Usually, several lesions on one medial ramus are necessary.

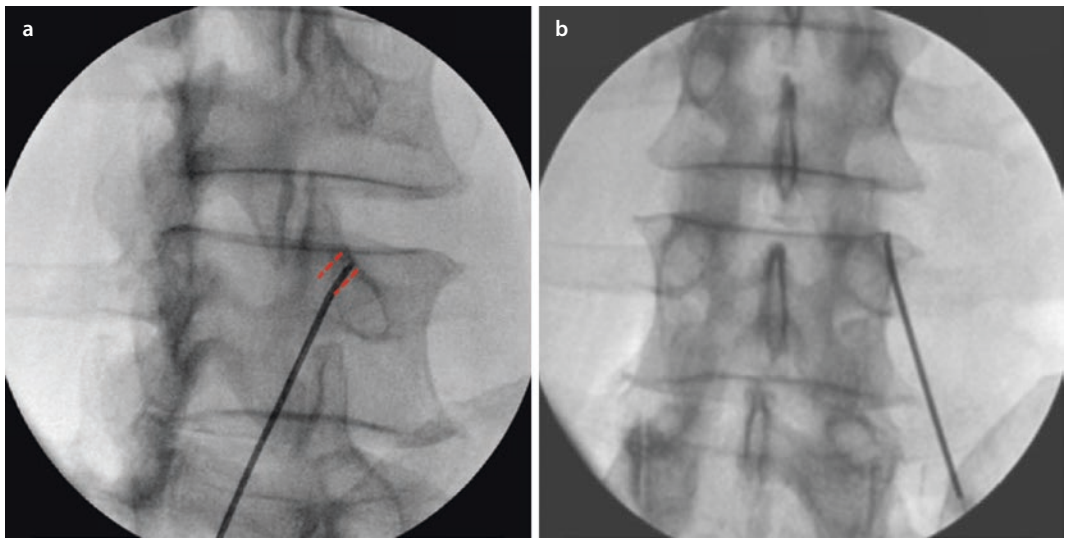


Fig. 7.6 Position of the radiofrequency cannula at L4 in the oblique image **a** and in the a.p. image **b**. (Courtesy of Dr. Kniesel, Hamburg)

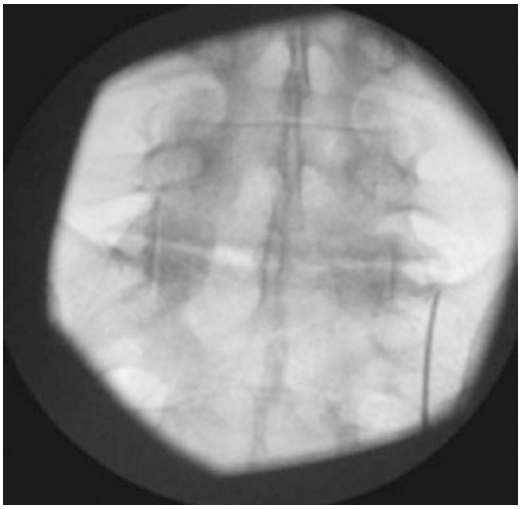


Fig. 7.7 Position of the radiofrequency cannula at L5 in the a.p. image. (Courtesy of Dr. Kniesel, Hamburg)

The procedure for coagulation of the dorsal branch at L5 differs from the procedure outlined in that lateral pivoting of the C-arm is not helpful from an imaging point of view because of the overlap with the iliac crest. The nerve here runs in a predetermined pit and in the a.p. image the needle should not overhang the cover plate of S1. Also, the fluoroscopic axis must be displaced less in the caudocranial direction because of the angle from the sacrum to LWK5 (Fig. 7.7).

The need for sensitive or motor testing has been considered differently in the recent past. While in the early days until about 2013 sensitive testing with 50 Hz to 1.5 V and motor testing with 5 Hz to 0.5 V was obligatory, according to the SIS guidelines this is currently no longer necessary if all radiological-anatomical conditions are taken into account. This should be decided individually by the surgeon depending on experience.

Once the cannula position has been secured in all planes, the automatic program of the radiofrequency generator is usually started, in which a temperature increase of up to 80 °C is achieved within approx. 20 s. Unpleasant sensations are often experienced at 50–60 °C. In this case, it should be specifically asked whether these are in the area of the intervention or further distally; under no circumstances should a sensation be felt along the associated spinal nerve. In such a case, the procedure should be aborted and the needle repositioned. If the pain directly at the lesion site becomes too severe, local anesthetic can be injected again. In unproblematic cases, the lesion can be continued for a period of 60–90 s and at a temperature of 80–85 °C. For each medial branch, 2–3 lesions are recommended at intervals of one lesion width (depending on the thickness of the cannula). In the special case of the dorsal branch at L5, retraction of the cannula by lesion length is sufficient, as the branch runs in a pit and is thus coagulated 2 times along its length.

7.6 Possible Complications

Both lumbar injections at the medial branch and lumbar radiofrequency treatment have a very low complication rate. In particular, injection at the medial branch appears very safe. A theoretical minimal mechanical risk is penetration into the intervertebral foramen, which could result in anesthesia or injury to the spinal nerve root. As with all injections, there is a risk of pharmacologic reaction such as allergy, contrast intolerance, or reaction to the local anesthetic with accidental intravascular administration.

In a prospective evaluation of 1433 injections, 6.1% showed intravascular contrast uptake, which, however, usually did not lead to complications (Lee et al. 2008).

In general, the following risks exist:

- Formation of a hematoma, secondary bleeding,
- Infection,
- allergic reaction to drugs or contrast media,
- vasovagal syncope,
- epidural subdural injection,
- Nerve Traumatization,
- radicular pain post injection,
- intra-arterial or intravenous injection,
- Radiation Exposure.

The patient should be informed about all these risks.

7.7 Results in the Literature

With the increase in the number of facet joint injections and radiofrequency denervation procedures performed, corresponding review articles have been published that deal with the evidence of the methods. In recent years, two publications stand out.

The first are the ASIPP (American Society of Interventional Pain Physicians) guidelines published in Pain Physician (Falco et al. 2012). They consider the literature from 1966 to 2012 and describe appropriate levels of evidence, divided into good, satisfactory and limited. The guidelines are 283 pages long, cite 2424 references, and were written by 51 authors.

The other is a comprehensive book entitled *Evidence-Based Interventional Pain Medicine According to Clinical Diagnoses,* edited by Van Zundert et al. (2011), originated from a Dutch manual.

According to the evidence base, the recommendations were divided into the grades listed in Table 7.2. Table 7.3 shows the evidence-based recommendations for medial branch injection, intra-articular facet injection and radiofrequency of the medial branch lumbar. With a $1B^+$ recommendation in the Dutch publication, the repeatedly expressed opinion that radiofrequency denervation of the medial branch in the lumbar region is one of the best scientifically evaluated procedures in pain therapy is confirmed.

Table 7.2 Graduation of the recommendation. (According to Van Zundert et al. 2011)

Level of recommendation	Description
$1A^+$, $1B^+$, $2B^+ \rightarrow$	Positive recommendation
$2B^{\pm}$, $2C^+ \rightarrow$	To be considered, preferably in a controlled situation (in the context of a study)
0	To be used only in a controlled situation (in the context of a study)
$2C^-$, $2B^-$, $2A^- \rightarrow$	Negative recommendation

Table 7.3 Evidence-based recommendations of interventional treatments lumbar

Therapy method	ASIPP Guidelines (Falco et al. 2012)	Van Zundert et al. (2013)
Infiltration of the medial branch	Good	Not available
Facet infiltration intraarticularly	Limited	$2B^{\pm}$
Radiofrequency denervation of the medial branch	Good	$1B^+$

7.7.1 Impact on the Latest Guidelines

These publications have recently led to the first recommendation of facet infiltration at the medial branch and radiofrequency denervation lumbar in the guidelines of the British National Institute for Health and Care Excellence (NICE) in November 2016 by an institution that is independent of a pain therapy society and is responsible for health care guidelines in the UK (NICE 2016). A year later, the German guidelines on specific back pain were published. Here, the British guideline was followed and, on the one hand, a prevalence for facet-dependent pain of between 20% and 40% was mentioned and, on the other hand, facet infiltration on the medial branch and the resulting radiofrequency denervation were also recommended in special cases (AWMF 2017).

7.8 Conclusion and Clinical Relevance

In contrast to the root irritation syndromes with their unambiguous clinic, the problem with pain conditions due to changes in the facet joint is that clinical diagnostics and imaging have no evident significance here. One has to rely on the anesthesia of the facet joint

as a valid diagnostic criterion. In the present chapter, the necessity of the double block and the superiority of anesthesia of the medial branch compared to intra-articular injection were discussed. If a double block is performed on the medial branch at lumbar facet joints using clean standardized technique and the patient benefits, lumbar radiofrequency denervation at the facet joint has been established as one of the best evaluated procedures over the last 25 years. The procedure is low risk compared to other minimally invasive procedures. Due to the good evidence base, both procedures have now also been included in national guidelines in Europe. Appropriate training and adherence to standardized techniques in accordance with the guidelines are indispensable.

References

Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF) (2017) S2k-Leitlinie: Spezifischer Kreuzschmerz. AWMF-Registernummer 033-051. https://www.awmf.org/uploads/tx_szleitlinien/033-051l_S2k_Spezifischer_Kreuzschmerz_2018-02.pdf. Accessed on 24.07.2018

Barnsley L, Bogduk N (1993) Medial branch blocks are specific for the diagnosis of cervical zygapophyseal joint pain. Reg Anesth 18:343–350

Bogduk N (1983) The innervation of the lumbar spine. Spine 8:286–293

Bogduk N (2013) Practice guidelines for spinal diagnostic and treatment procedures, 2. Aufl. International Spine Intervention Society, Illinois

Bogduk N, Long DM (1979) The anatomy of the so-called "articular nerves" and their relationship to facet denervation in the treatment of low-back pain. J Neurosurg 51:172–177

Bogduk N, Wilson AS, Tynan W (1982) The human lumbar dorsal rami. J Anat 134:383

Carette S, Marcoux S, Truchon R, Grondin C, Gagnon J, Allard Y, Latulippe M (1991) A controlled trial of corticosteroid injections into facet joints for chronic low back pain. NEJM 325:1002–1007

Falco FJ, Manchikanti L, Datta S, Sehgal N, Geffert S, Onyewu O, Zhu J, Coubarous S, Hameed M, Ward SP (2012) An update of the effectiveness of therapeutic lumbar facet joint interventions. Pain Physician 15:E909–E953

Ghormley RK (1933) Low back pain: with special reference to the articular facets, with presentation of an operative procedure. JAMA 101:1773–1777

Goldthwait JE (1911) The lumbo-sacral articulation: an explanation of many cases of lumbago, sciatica and paraplegia. Boston Med Surg J 164:365–372

Lee CJ, Kim YC, Shin JH, Nahm FS, Lee HM, Choi YS, Lee SC, Ko JS, Kim TH, Sim WS (2008) Intravascular injection in lumbar medial branch block: a prospective evaluation of 1433 injections. Anesth Analg 106:1274–1278

Lord SM, Barnsley L, Bogduk N (1995) The utility of comparative local anesthetic blocks versus placebo-controlled blocks for the diagnosis of cervical zygapophysial joint pain. Clin J Pain 11(3):208–213

Manchikanti L, Pampati V, Fellows B, Bakhit CE (2000) The diagnostic validity and therapeutic value of lumbar facet joint nerve blocks with or without adjuvant agents. Curr Rev Pain 4:337–344

McCall IW, Park WM, O'Brien JP (1979) Induced pain referral from posterior lumbar elements in normal subjects. Spine 4(5):441–446

National Institute for Health and Care Excellence (NICE) (2016) NICE Guideline (NG 59) Low back pain and sciatica in over 16s: assessment and management. https://www.nice.org.uk/guidance/ng59. Accessed on 24.07.2018

Rees WE (1971) Multiple bilarteral subcutaneous rhizolysis of segmental nerves in the treatment of the intervertebral disc syndrome. Ann Gen Pract 26:126–127

Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N (1994) The false-positive rate of uncontrolled diagnostic blocks of the lumbar zygapophysial joints. Pain 58:195–200

Schwarzer AC, Wang SC, Bogduk N, McNaught PJ, Laurent R (1995) Prevalence and clinical features of lumbar zygapophysial joint pain: a study in an Australian population with chronic low back pain. Ann Rheum Dis 54:100–106

Shealy CN (1975) Percutaneous radiofrequency denervation of spinal facets: treatment for chronic back pain and sciatica. J Neurosurg 43:448–451

Van Zundert JV, Hartrick C, Patijn J, Huygen F, Mekhail N, van Kleef M (2011) Evidence-based interventional pain medicine according to clinical diagnoses. Pain Pract 11:423–429. https://doi.org/10.1111/j.1533--2500.2011.00490.x

Van Zundert AA, Reina MA, Lee RA (2013) Prevention of post-dural puncture headache (PDPH) in parturients. Contributions from experimental research. Acta Anaesthesiol Scand 57(7):947–949. https://doi.org/10.1111/aas.12132

Cervical Radiofrequency Therapy

M. Legat

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_8

8.1 Indication

The indication for radiofrequency therapy on the cervical spine can only be made on the basis of several selection criteria. The following pain patterns are found in the literature: Significant for complaints in the area of the facet joints at level C2/3 are side-emphasized pains in the area of the occiput. In the area C3/4, partly at the level of C4/5, complaints or pseudoradicular radiation into the upper part of the M. trapezius are to be expected, for the facet joint C5/6 rather pain in the transversus area or at the upper edge of the M. trapezius are significant. Concerning the joint at the level of C6/7, the complaints are localized in the area of the dorsal part of the shoulder or the scapula.

Clinically, the patients experience movement-dependent complaints, especially during lateral rotation and lateral inclination of the cervical spine. Manual diagnosis reveals swelling (multifidii muscle) above the relevant irritation points of the facet joints and corresponding painful insertion points at the nuchal line. The absence of neurological deficits is to be required.

Only repeated blockade of the medial artery using local anesthetics (according to the criteria of the Spine Intervention Society [SIS]; ▶ Sect. 8.2) provides a clear diagnostic statement.

In principle, all conservative treatment options should be exhausted before cervical radiofrequency therapy is performed. The pain should be present for more than 3 months and painkiller abuse should be excluded.

8.2 Preinterventional Diagnostics

The same prerequisites or inferences apply to the clinical examination and imaging procedures as mentioned for facet coagulation in the lumbar spine (▶ Chap. 7).

In the cervical spine, too, the **local anesthetic** diagnostic **blockade of the R. medialis** and thus of the facet joint innervation under image intensifier control offers the greatest **diagnostic** significance. This diagnostic procedure should be performed strictly according to the guidelines of the Spine Intervention Society. It is obligatory to perform the procedure at least two times with local anesthetics of different duration. A pain reduction of at least 50% should be achieved. This pain reduction should correspond to both the referred pain area of the facet joint in question and the duration of action of the local anaesthetic.

One speaks then of so-called comparative or concordant blockade. These have a high specificity of 88%, but a relatively low sensitivity of 54%. If the duration of action of the local anaesthetic is not taken into account, the sensitivity (100%) increases at the expense of the specificity (65%). If the nerve blocks are to be used for diagnostic purposes prior to further invasive procedures, such as radiofrequency ablation, a higher specificity is to be preferred (Van Kleef et al. 1999).

▪ Material

A 90 mm long 25 G needle is considered optimal. Contrast medium is not necessary for the blockade of the medial rr. Local anesthetics that can be used include bupivacaine 0.5% as a long-acting local anesthetic and lidocaine 2% as a short-acting local anesthetic. No more than 0.3–0.5 mL should be applied to the nerve in question in order to prevent the local anaesthetic from spreading and thus infiltrating other nerve structures.

▪ Rec

Before placing the diagnostic block, the patient should be informed that this is only a diagnostic procedure and not a therapeutic one. He should be informed about the normal risks of an injection—such as bleeding or allergic reactions and, especially in the case of diagnostics on the upper cervical spine, about ataxia.

▪ Storage

Regarding the positioning of the patient, the author prefers the prone position. The forehead is placed in a gel ring on the head of the operating table, the mouth and neck area remain free. The arms are fixed close to the body with the shoulders pulled down.

Disinfection of the intervention area and access from the side are then performed.

Image Intensifier Setting

A direct lateral adjustment must be ensured in the image intensifier. This is achieved by directly superimposing the silhouettes of the vertebral arch in question and forming the shape of a trapezium. For the facet joints C3/4 to C6/7, the target point is in the center of the trapezium (Figs. 8.1 and 8.2). For the R. medialis C7, which supplies the facet joint C7/8, this is located at the anterior upper quadrant of the trapezium. For the third occipital nerve, the connecting line that intersects the C2/3 joint perpendicularly in the middle is visited in the lateral approach and infiltrated at 3 points.

8.2.1 Diagnostic Blockade of the Medial Ramus

For the Rr. mediales C3–C6, the needle is advanced slowly under image intensifier control to the bone contact and then 0.5–0.5 mL local anaesthetic is applied. For the R. medialis C7, the needle is advanced carefully and slowly under constant image intensifier control (Bogduk 2004). Before application of the local anaesthetic, a control is performed in a.p. setting to avoid neuroforaminal injection of C8. The application of 0.3 mL local anesthetic is then performed. In the area of the third occipital nerve, the lower target point is visited first and 0.3 mL of local anesthetic is injected. At the middle target point, which is exactly at the level of the joint space, the needle is slightly withdrawn to avoid an intra-articular injection, then 0.3 mL of local anaesthetic is injected. Infiltration is then performed at the cranial target point (Bogduk 2004). After removing the needle, the skin is cleaned again briefly, then a plaster bandage is applied.

Documentation is required in both the lateral and anterior-posterior light paths.

Throughout the procedure, constant monitoring is performed via pulse oximeter, blood pressure monitor and ECG.

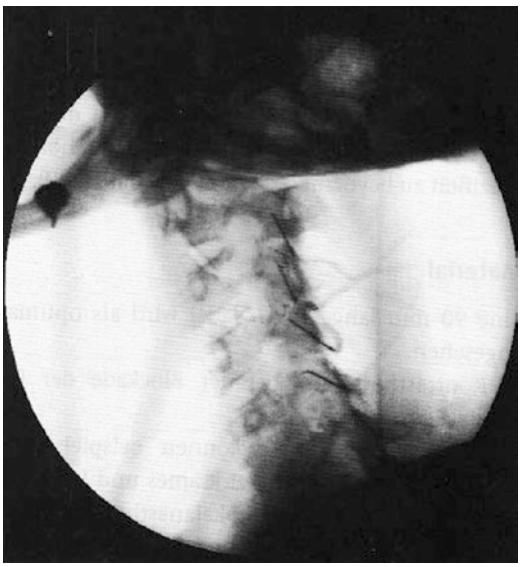


Fig. 8.1 Diagnostic blocks of the rami mediales C3–C6 on lateral fluoroscopy. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

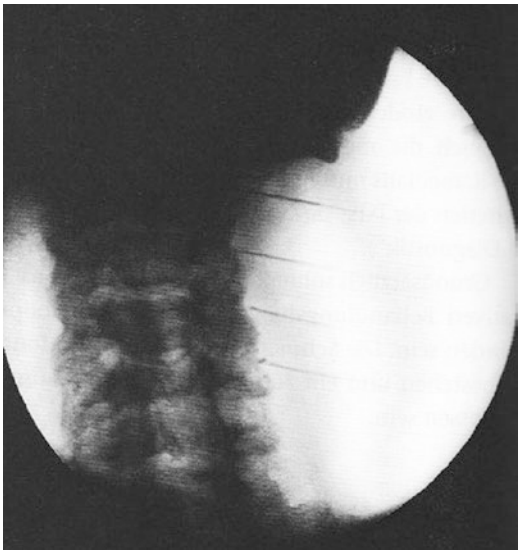


Fig. 8.2 Diagnostic blocks of the rami mediales C3–C6 in a.p. fluoroscopy. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

8.3 Necessary Instruments

We refer to the previous article concerning lumbar facet coagulation (▶ Chap. 7).

For the 2-needle technique, we use a radiofrequency cannula with a length of 90 mm, 22 G at the cervical spine, with the active needle tip being 5 mm long.

For the newer 1-needle technique, a so-called Sharped Needle 20 G, 100 mm with a curved active tip of 10 mm is used.

8.4 Pre-Intervention Education

The following is a summary of the minimum requirements for information prior to cervical radiofrequency therapy. This is essentially divided into the presentation of the indication, the implementation and the complications.

Chronic cervical spine-related pain conditions, which have their main cause in the small vertebral joints, should be indicated.

Procedure: The patient is in the prone position. The respective pain nerves supplying the joints are coked by inserting appropriate needles and probes. A total of between 4 and 6 needles are required. This is done under fluoroscopic control for better control. Anesthesia is not necessary, but a sedative may be injected. The coking itself is done under local anaesthesia. Blood pressure, pulse and oxygen content of the blood are constantly checked.

Complications: Overall, radiofrequency denervation can be considered very low risk in the hands of an experienced surgeon. Even with this method, there is no absolute guarantee of success. Despite prior testing, it can happen that only insufficient pain relief occurs or that the pain reappears after a longer period of time. Then this method can be used again.

Possible complications of cervical radiofrequency therapy include:

- Pain in the course of the puncture sites with bruising,
- Development of an inflammatory focus along the puncture sites (very rare),
- Development of partial paralysis or loss of sensation (very rare), with burning pain in the affected skin area (very rare).

8.5 Implementation of the Intervention

8.5.1 Storage

The positioning of the patient is the same as when performing the diagnostic blockade. Sedation is only performed in anxious and agitated patients with Dormicum (1–5 mg) and possibly Propofol. Careful titration should be used here, as the patient's feedback is important for the entire procedure.

8.5.2 General Procedure

Neurotomy of the medial cervical artery is a 2-step procedure. A needle is inserted in the oblique position and a second needle in the parasagittal direction. This ensures a longer coagulation distance of the affected nerve (Fig. 8.3).

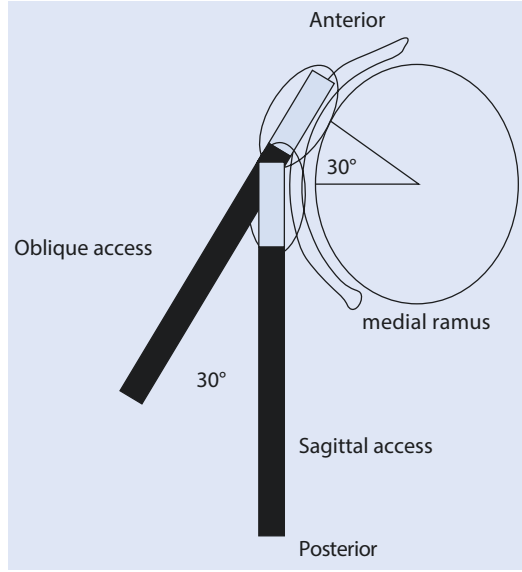


Fig. 8.3 Drawing in the transverse plane showing the lateral articular pillar. The course of the R. medialis and the sagittal and oblique approaches are shown. These two approaches are necessary to ensure a long coagulation distance. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

We prefer the approach in oblique position as the first step, as this is the more difficult step in terms of recognizing the necessary landmarks. Then the sagittal insertion is performed.

8.5.3 Procedure for C3–C6

See Bogduk (2004).

Insertion in Oblique Position

When proceeding in the oblique position, the target point in lateral fluoroscopy is the anterior third of the upper joint pillar. Three individual lesions are placed from cranial to caudal (Fig. 8.4).

Before the actual coagulation procedure, a local anaesthetic should be administered here, as described above for the diagnostic blockade. Not only the nerve itself should be anaesthetised, but also the small muscles lying on it, as strong pain can be triggered especially on these during coagulation. A total injection volume of 0.5–1 mL is used.

The needle used can be left as a target marker for the actual thermocoagulation. In a 30 ° oblique view of the marker needle, the electrode cannula is then inserted (Fig. 8.5). The tip of the marker needle serves as the aiming point. Once the direction is set, the view is changed to the lateral view and the needle is advanced to the bone contact under constant image intensifier control (Fig. 8.6). The first placement of the needle tip should be at the dorsocaudal edge of the neuroforamen. Once this position is reached, documentation is performed using both lateral and a.p. fluoroscopy. Here, the lateral view ensures that the cannulae do not advance too far and the a.p. view ensures that the electrode is in contact with the articular post.

Prior to the lesion, the marker needle should be retracted by approximately 5–10 mm to avoid contact with the electrode.

The coagulation itself is carried out at a temperature of 80–85 °C for 90 s. The coagulation process is then repeated.

If the patient describes any symptoms during coagulation, this should be interrupted and a precise diagnosis of the symptoms should be made. If there are sensations of pain or heat, local anaesthetic should be injected again via the marker needle. If other symptoms occur, the position of the electrode should be checked.

By gently withdrawing the electrode cannula and advancing it either cranially or caudally, additional points can be coagulated. A total of at least 3 coagulations should be performed.

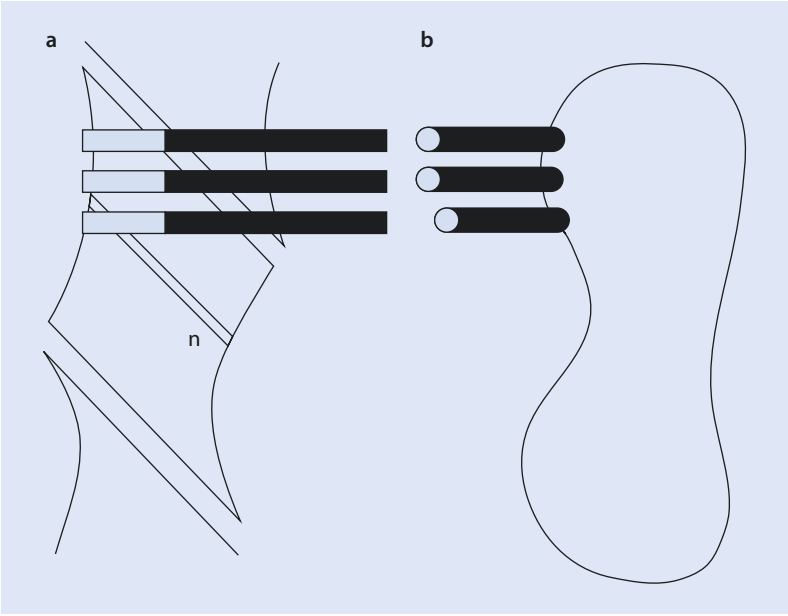


Fig. 8.4 Location of radiofrequency electrodes in oblique approach, segments C3-C6. **a** 3 consecutive electrodes in lateral projection; **b** in a.p. projection at the relevant medial ramus. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

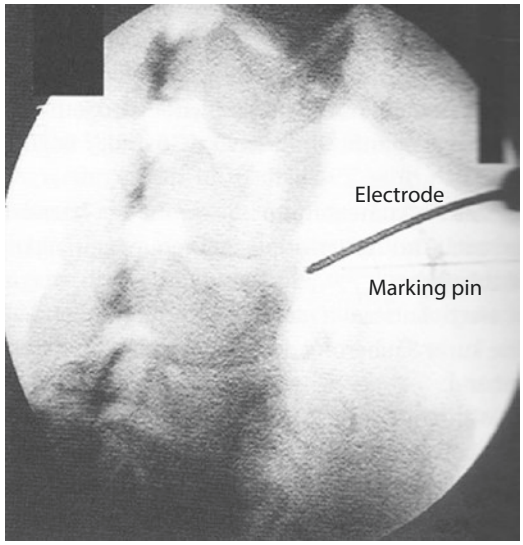


Fig. 8.5 Image intensifier setting in oblique position; electrode position oblique to lateral articular post of C5; target approximately 3 mm medial to marker needle tip. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

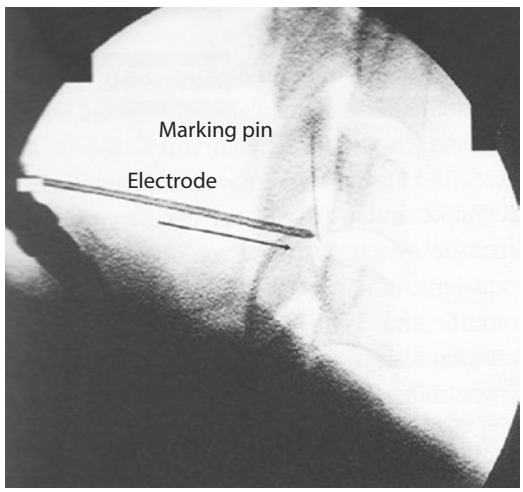


Fig. 8.6 Lateral image intensifier setting; Oblique electrode position at the lateral joint post of C5. The target is the marker needle tip. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

Insertion Sagittal

Using the sagittal approach, the more dorsolateral portion of the nerve can be coagulated on the lateral joint post (Fig. 8.7). Here, at the level of C5, the middle two-quarters form the target region; for C3, C4 and C6, it is located cranially.

The marker needle used for the oblique approach can also serve as a target point here.

The electrode insertion is performed in a.p. view (Fig. 8.8). The tip of the marker needle serves as the aiming point. Here, too, the needle should graze the articular process slightly medial to the marker needle. This prevents the electrode from being advanced too far initially. Once the bone is reached, the electrode can be corrected more easily and slide along the lateral articular post. Further advancement then takes place under the lateral image intensifier setting (Fig. 8.9). The needle is advanced until it covers the middle third of the articular abutment. Again, the a.p. setting ensures contact with the articular process. The corrections are then made accordingly.

Coagulation is then carried out again at a temperature of 80–85 °C for 90 s. The coagulation is then repeated. Again, 3 coagulations are performed at different heights. The rest of the procedure is the same as for oblique access.

8.5.4 Procedure for C7

See Bogduk (2004).

The procedure for the medial cervical artery at C7 is similar to that for C3-C6 (Figs. 8.10 and 8.11). The marker needle also serves as a target point here and is placed in the same way as for the diagnostic blockade. Since, as described above, this is positioned more cranially and closer to the neuroforamen, even closer-meshed image intensifier controls are necessary when advancing the radiofrequency cannulae, particularly in

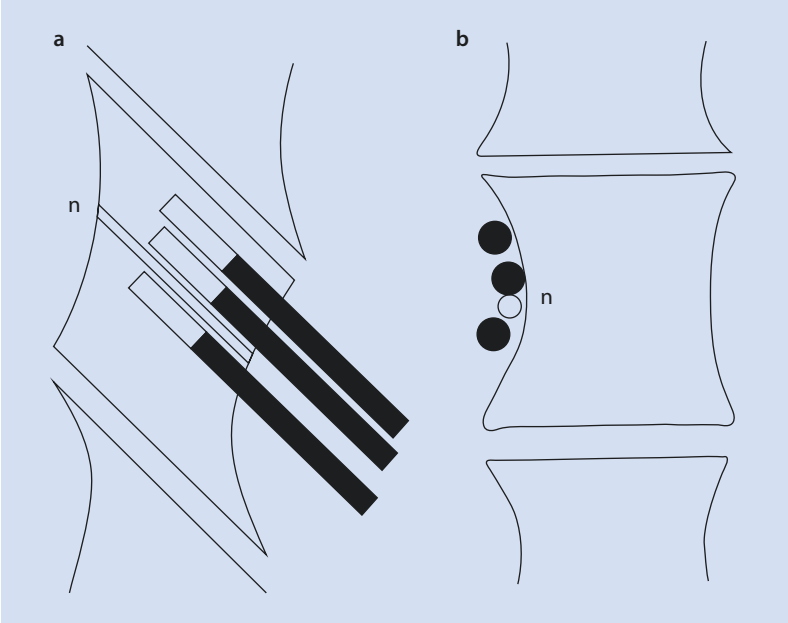


Fig. 8.7 Location of radiofrequency electrodes in sagittal approach, segments C3–C6. **a** 3 consecutive electrodes in lateral projection; **b** in a.p. projection at the relevant medial ramus. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

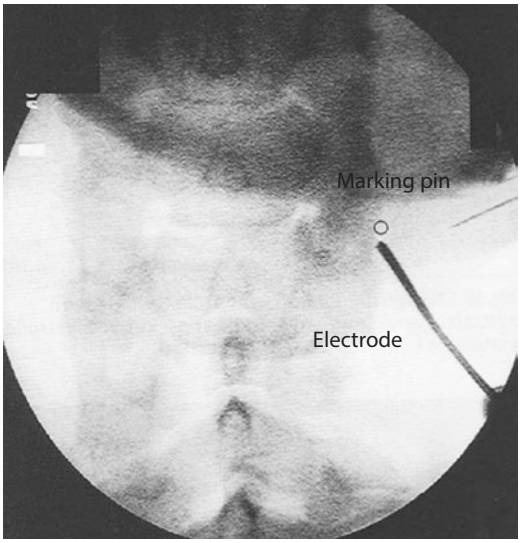


Fig. 8.8 a.p.-Image intensifier setting: Sagittal electrode position at the lateral joint pillar of C5 in the lower coagulation position. The circle marks the higher coagulation site. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

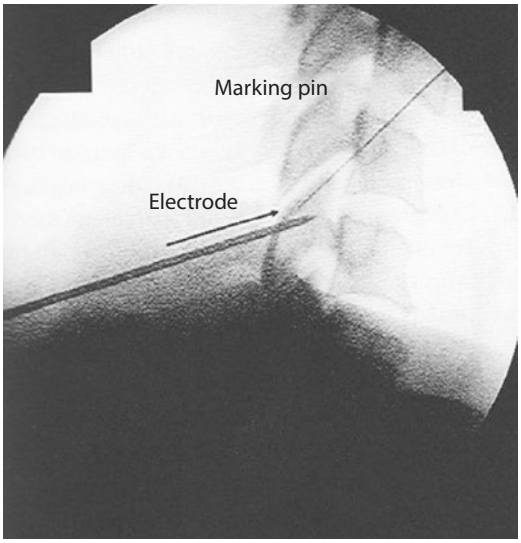


Fig. 8.9 Lateral image intensifier setting: Sagittal electrode position at the lateral joint pillar of C5 in the lower coagulation position. The arrow marks the higher coagulation site. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

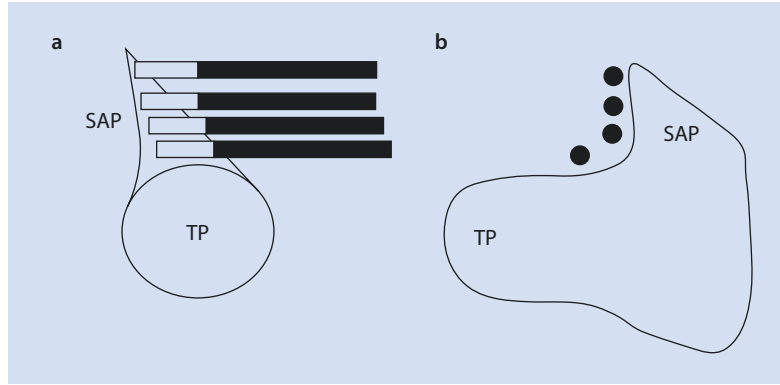


Fig. 8.10 Position of radiofrequency electrodes in sagittal approach, segment C7. **a** Consecutive electrodes in lateral projection; **b** in a.p. projection. *TP* processus transversus; *SAP* proc. articularis superior. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

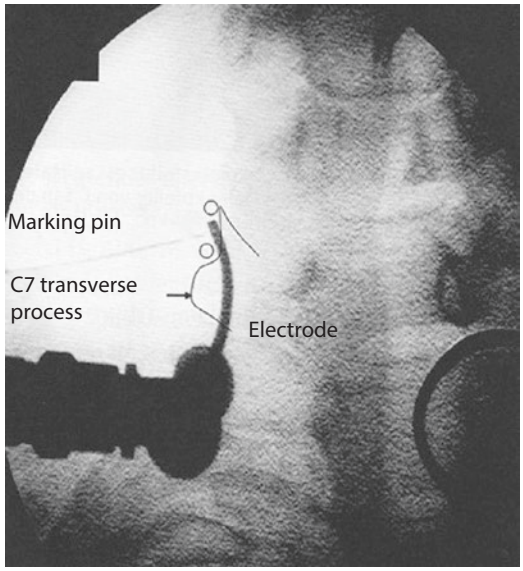


Fig. 8.11 a.p. image intensifier setting: Sagittal electrode position at the lateral superior articular process of C7 in the middle coagulation position. The circles mark the cranial and caudal coagulation sites. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

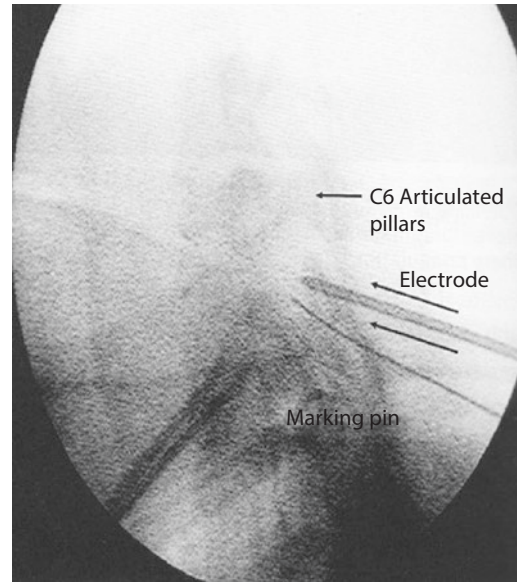


Fig. 8.12 Lateral image intensifier setting: Sagittal electrode position at the lateral superior articular process of C7 in the mid-coagulation position. The arrows mark the cranial and caudal coagulation sites. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

the lateral beam path (Fig. 8.12). This is the main difference compared to the C3-C6 heights. Otherwise, the procedure is identical.

8.5.5 Procedure for the Third Occipital Nerve

See Bogduk (2004).

The same principles are applied in the region of the third occipital nerve as in the region of C3-C6. The only differences are in the target points (Fig. 8.13). For the oblique approach, these are located in the anterolateral surface of the superior articular process of C3, from the apex to the base opposite the floor of the neuroforamen C2/3 (Figs. 8.14 and 8.15). For the sagittal approach, the direct posterior-anterior approach is best, since the target nerve runs transversely through the lateral portion of the C2/3 facet joint (Fig. 8.16). Here, in the lateral control, the tip of the electrode should lie over the middle third of the C2/3 joint; in the

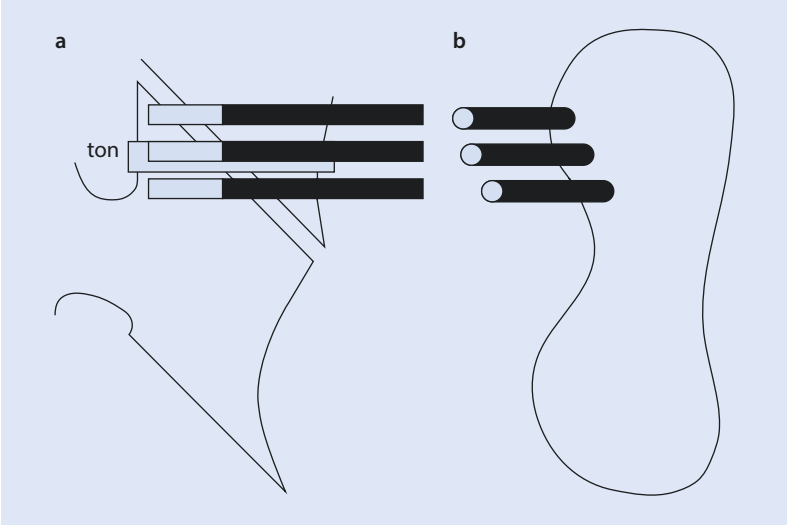


Fig. 8.13 Location of radiofrequency electrodes in oblique approach, third occipital nerve (*ton*). **a** 3 consecutive electrodes in lateral projection; **b** in a.p. projection. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

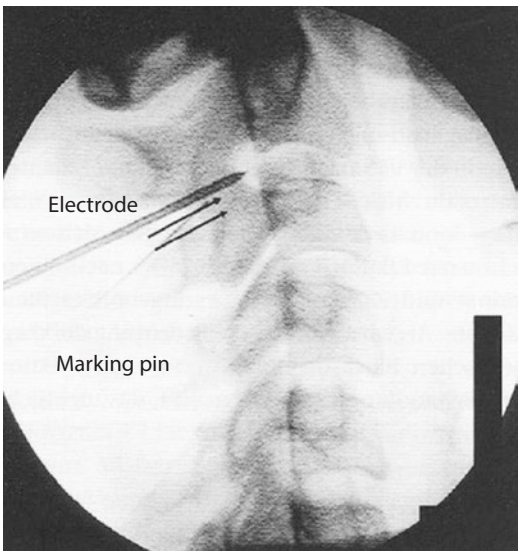


Fig. 8.14 Lateral image intensifier setting: Oblique electrode position at the posterior edge of neuroforamen C2/3 in the upper coagulation position for the third occipital nerve. The arrows mark the caudal coagulation sites, which are necessary to ensure coagulation for positional variations of the nerve course. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

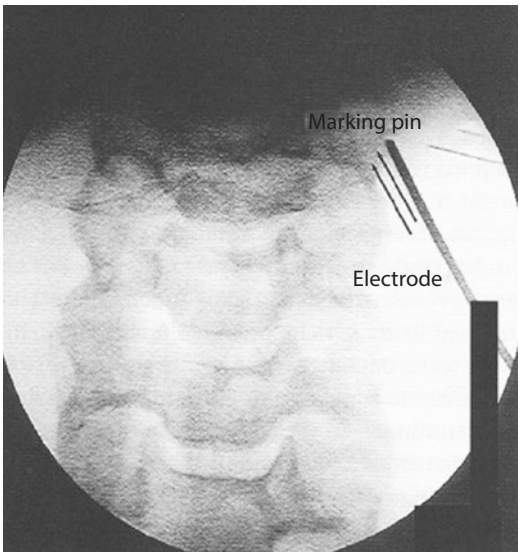


Fig. 8.15 a.p. image intensifier setting: Oblique electrode position slightly medial to the lateral cervical silhouette in the upper coagulation position for the third occipital nerve. The arrows mark the caudal coagulation sites. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

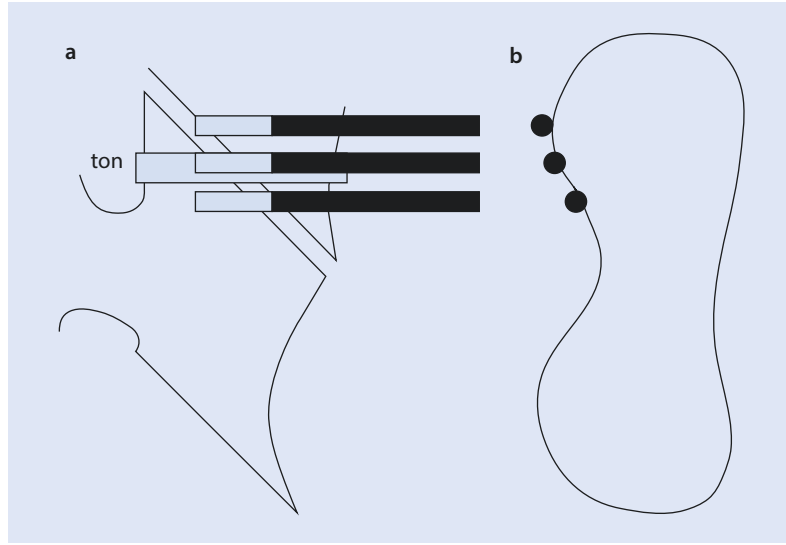


Fig. 8.16 Location of radiofrequency electrodes in sagittal approach, third occipital nerve (*ton*). **a** 3 consecutive electrodes in lateral projection; **b** in a.p. projection. (From Bogduk 2004; courtesy of the International Spine Intervention Society, San Francisco)

a.p. view, the electrode should be in contact with the lateral convexity of the joint.

Postoperatively, the wound surface is sterilely cleaned again and then a small plaster bandage is applied.

Vasovagal reactions can occur, especially with coagulation at the level of C2/3; therefore, caution is advised when repositioning the patient after the procedure (▶ Sect. 8.6).

8.5.6 Procedure in New Technology

Since the course of the ramus medialis around the lateral joint pillar can be well covered with a so-called sharped needle, the sagittal access is sufficient. This is further improved by an increased needle diameter (20 G) and a longer active tip (10 mm). At the level of C5, the middle two-quarters of the massa lateralis form the target region; for C3, C4 and C6, the target region is cranial.

The marker needle is recommended for local anaesthesia, as in the above method. The electrode insertion is performed in a.p. view (Fig. 8.8). The tip of the marker needle serves as the aiming point. The needle lightly touches the articular process with the needle tip oriented medially (Fig. 8.17). The Sharped Needle is then rotated with the tip pointing laterally. Further advancement

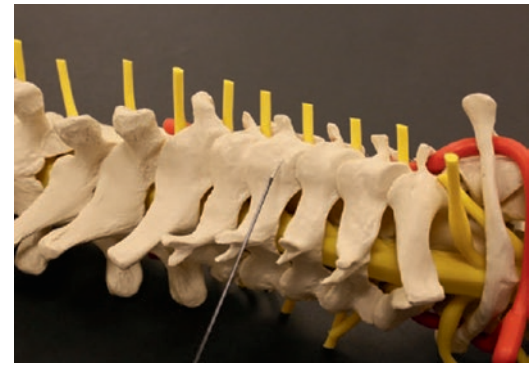


Fig. 8.17 Position of the radiofrequency electrode on the anatomical model with the new technique: At the level of C5 on the dorsolateral joint post with medialized electrode tip (sharped needle), ventralized by 1 cm. (Courtesy of © M. Legat. All Rights Reserved)

is then performed under the lateral image intensifier setting (Fig. 8.18). The needle is advanced until it covers the middle third of the articular abutment (Figs. 8.19 and 8.20). Here, too, the a.p. setting ensures contact with the articular process. The corrections are then made accordingly.

Coagulation is also performed at a temperature of 80–85 °C for 90 s. Due to the larger lesion area, usually only 2 lesions are necessary. To avoid complications (▶ Sect. 8.6), precise work is necessary with larger lesion areas.

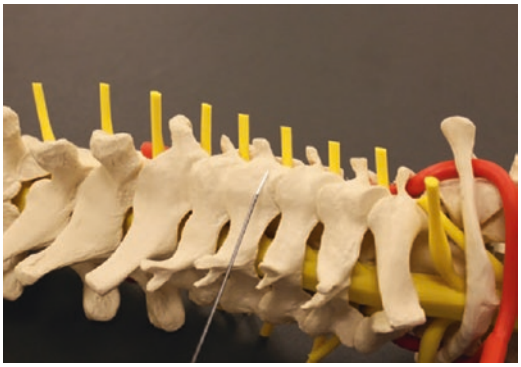


Fig. 8.18 Position of the radiofrequency electrode on the anatomical model using the new technique: At the level of C5 on the dorsolateral joint post with lateralized needle tip (sharped needle), ventralized by 1 cm. (Courtesy of © M. Legat. All Rights Reserved)

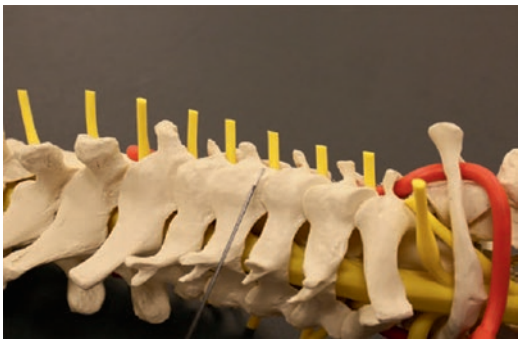


Fig. 8.19 Position of the radiofrequency electrode on the anatomical model using the new technique: At the level of C5 on the dorsolateral joint post with medialized electrode tip (sharped needle), ventralized by 1.5 cm. (Courtesy of © M. Legat. All Rights Reserved)

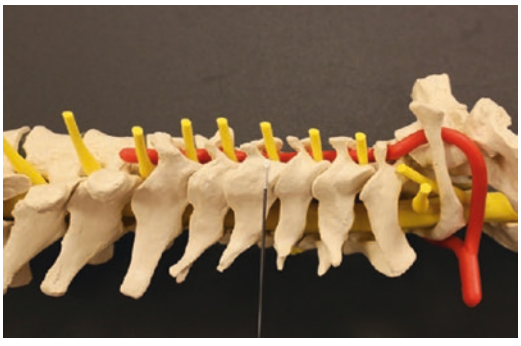


Fig. 8.20 Position of the radiofrequency electrode on the anatomical model: At the level of C5 on the dorsolateral joint post with medialized electrode tip (sharped needle), in final position. (Courtesy of © M. Legat. All Rights Reserved)

8.6 Possible Complications

General complications can occur during radiofrequency therapy on the cervical spine, but these are observed only very rarely. These are hematomas or infections as well as allergic reactions to local anesthetics.

Since the electrodes normally penetrate only the dorsal skin and dorsal cervical muscles, well away from the vertebral artery, spinal nerve and radicular arteries, which are located more anteriorly, serious injury to these structures is avoided.

As the patient is not under general anaesthesia and feedback can always be obtained from him, incorrect positions, as reported in the literature for accidental access through the interlaminar space, are not possible.

Care should be taken to ensure that the neutral electrode is applied over as wide a surface area as possible to avoid burns.

Side effects reported in the literature with radiofrequency therapy concerning the C3–C7 medial ridge are:

- vasovagal syncope (2%),
- Dermoid cyst (1%),
- Kobner's phenomenon (1%),
- Neuritis (2%),
- Numbness in the skin area of the coagulated nerves (29%),
- Dysesthesias in the skin supply area of one of the coagulated nerves(19%).

None of the neurological side effects persisted or required intervention (Bogduk 2004).

Specifically for coagulation at the level of the third occipital nerve, ataxia (95%), numbness (97%), dysesthesias (55%), and hypersensitivity (15%) may occur (Bogduk 2004).

8.7 Results in the Literature

In the following, the recent literature concerning radiofrequency treatment of the lumbar and cervical spine is presented. Three studies are explained in detail. All relevant studies are listed in a table at the end of this section (Table 8.3).

Since 1994, there have been 3 double-blind, randomized, controlled studies on radiofrequency denervation concerning the lumbar spine. These studies were presented by Gallagher et al. (1994), Van Kleef et al. (1999) and Leclaire et al. (2001).

Gallagher et al. (1994) included 60 patients in their study. These had to meet the following criteria: Back pain for longer than 3 months, age between 25 and 55 years, and typical criteria for facet joint pain. All patients who met these criteria received an injection of 0.5 mL of bupivacaine 0.5% in and around the painful facet joints. Patients who did not experience pain relief after the injections were excluded from the study. The other patients were divided into a group with clear pain relief and a group with questionable pain relief. These two groups were then randomized to either denervation or placebo lesioning. Radiofrequency coagulation was usually performed at 80 °C for 90 s. Outcomes were evaluated using the visual analog scale (VAS) and an abbreviated form of the McGill Pain Questionnaire. Analysis revealed significant differences between the thermocoagulation group and the placebo lesion group, each with positive diagnostic blockade. This was particularly evident in the VAS after one and after 6 months and in the McGill pain questionnaire after 1 month. This showed a pain reduction of almost 50% after 1 month and a continuation of the result after 6 months. In conclusion, the importance of the diagnostic blockade with regard to the prediction of the treatment outcome and the significantly longer duration of the effect in the lesion group compared to the placebo group, which had only received the facet injection, were highlighted.

In the study by Van Kleef et al. (1999), patients were included in the study who had already seen several physicians and had undergone an extensive diagnostic assessment. All patients had already received physical therapy, manipulation, TENS and analgesics with unsatisfactory results. These patients had to meet the following additional criteria: Age between 20 and 60 years, chronic back pain for more than 12 months, a mean pain level of at least 4 (VAS) or a maximum pain level of at least 7 (VAS), and no neurologic deficits. Patients with spinal surgery and specific causes of back pain—such as discus prolapse, spondylolisthesis, ankylosing spondylitis, spinal stenosis, infection or trauma—were excluded, as were patients with diabetes mellitus and multilocular pain syndrome. Patients who met the above criteria underwent diagnostic blockade. In this procedure, 0.75 mL of lidocaine 1% was injected at each target point (R. medialis of the R. dorsalis). The Likert scale was used to evaluate a positive result. Patients who showed pain attenuation of at least 50% were included in the study. Of 92 patients who met the above criteria, 31 experienced >50% pain reduction and were entered into the final study. This involved randomly assigning 15 patients to the lesion group and 16 patients to the placebo group. The lesion group received radiofrequency therapy of the R. medialis at a temperature of 80 °C for a duration of 60 s. The placebo group received radiofrequency therapy of the R. medialis at a temperature of 80 °C for a duration of 60 s. The placebo group received the same procedure without current application. The criterion of double-blindness was achieved by the surgeon leaving the room after placing the electrode and applying local anesthesia. The usual diagnostics concerning sensory and motor function as well as the actual lesion were performed by an independent examiner. The patients were not informed about the actual procedure.

The evaluation took place daily by means of VAS, the treatment success was assessed by the patients on a 7-point scale (−3: very bad; 0: no change; +3: no more pain). Physical impairment was recorded on the 7-point scale according to Waddell and Main. Limitations in activities of daily living ("disabilities") were assessed according to the Oswestry score. The Coop-Wonca chart was used to assess quality of life.

The assessment took place immediately before and 8 weeks after treatment (◘ Table 8.1). Only patients with a minimum reduction of 2 points on the VAS and at least a 50% reduction in pain were considered to have received successful treatment; all poorer results were considered to be failures. The

Table 8.1 Lumbar facet denervation in the treatment of chronic lumbar back pain: 8-week results of the study by Van Kleef et al. (1999)

	Average placebo group	Average lesion group	Variance, unadjusted (90% confidence interval)	Deviation, adjusted (90% confidence interval)
Changes VAS, mean	−0.43	−2.37	1.94[a] (0.24–3.64)	2.46[a] (0.72–4.20)
Changes VAS, peak value	−1.02	−3.64	2.62[b] (0.92–4.32	3.39[b] (1.55–5.22)
Changes VAS, lowest value	0.48	−1.85	2.33[b] (0.87–3.79)	2.42[b] (0.91–3.92)
Effect achieved globally	0.37	1.33	−0.96[a] (−1.70–0.22)	−1.10[a] (−1.89–0.30)
Changes in impairment (7-point scale according to Wadell and Main)	− 0.07	−0.33	0.27 (−0.69–1.22)	0.31 (−0.74–1.35)
Change in analgesic intake over 4 days	1.75	−2.13	3.88[a] (1.19–6.57)	3.24 (−0.13–6.60)
Changes on the Oswestry disability scale	1.69	−11.07	15.75[b] (4.16–21.35)	10.90[a] (1.76–20.0)
Changes in the coop Wonca quality of life chart	−1.62	−3.13	1.51 (−1.85–4.97)	2.27 (−1.77–6.30)

VAS visual analogue scale; [a]$p < 0.05$; [b]$p < 0.01$

assessment was repeated at the third, sixth and 12th month.

The statistical analysis considers the treatment success after 8 weeks as the primary outcome variable. This was compared between the lesion and placebo groups. Secondary outcome data were the differences in changes on the VAS, the Oswestry Disability Scale, and the Coop-Wonca Quality-of-Life Chart. Results showed a significant reduction in pain peaks on the VAS in the lesion group compared to the placebo group, as well as the success rate was significantly higher in the lesion group. Additionally, the results showed that freedom from pain after diagnostic nerve block predicted a higher success rate. Similarly, the actual differences in VAS scores, global achieved effect, and Oswestry Disability Scale scores between the two groups were significant. At 3, 6, and 12 months, there was a clearly significant difference between the lesion and placebo groups in terms of the number of successes.

In summary, there was a significant reduction in pain (VAS); this was particularly true for the peak values and less pronounced for the average values. A reduction in the use of analgesics and an improvement in disability status were also observed. The impairment variables (according to Waddell and Main) showed no significant change.

Van Kleef explained a recurrence of pain symptoms by nerve regeneration.

According to Van Kleef, the extent of pain reduction achieved is highly variable. He attributes this mainly to the problem of defining the lumbar "facet syndrome". However, a good prediction of the treatment result can be made by means of the preceding diagnostic blockade.

A double-blind randomized study was published by Leclaire et al. (2001). The study was conducted between 10/1993 and 12/1996 at the Hospital Notre-Dame in Montreal/Canada.

In this study, patients were primarily evaluated by practicing physicians in Montreal. Seventy patients were selected who had lumbar back pain for 3 months and experienced a significant reduction in their symptoms for at least 24 h by intra-articular facet injection with the contrast agent Omnipac (0.3 mL),

lidocaine 2% (0.5 mL), and triamcinolone 40 mg (0.5 mL). Exclusion criteria were allergy to local anesthetics, blood clotting disorder, pacemaker, ischialgiform pain with neurological deficit, structural changes—such as bone injury and spondylitis—and condition after back surgery.

An a priori Roland-Morris questionnaire 12 weeks after injection was chosen as the primary outcome criterion. In addition, the Oswestry score, VAS, degree of spinal mobility and strength, and frequency of return to work were used.

The treatment was then performed after randomization into groups of 4 patients each. Radiofrequency therapy was performed according to the technique of Lazorthes and Verdie, modified according to Shealy. After the usual stimulation sequence, thermocoagulation was performed under local anesthesia with lidocaine for 90 s at a temperature of 80 °C. The choice of segments was made after the facet injections were performed. At least 2 facet joints, usually L4/5 and L5/S1, were coagulated unilaterally or bilaterally.

A detailed medical history and physical examination were performed as a baseline assessment. The patient's previous therapies in relation to his back pain were also recorded. A Roland-Morris and an Oswestry questionnaire were completed for each patient, as well as a VAS scale. An examination of the lumbar spine was performed for flexion, extension, lateral tilt, and rotation. In addition, triaxial dynamometry was used to check the force against resistance and the angular velocity at 25% of the maximum resistance.

The questionnaires, the VAS, the triaxial dynamometry and the frequency of return to work were evaluated after 4 and 12 weeks. The patients, the examination assistant as well as the physicians who were responsible for the patient's return to work were blinded to the treatment.

A total of 70 patients underwent the therapy, 36 received lesion treatment and 34 placebo treatment. Regarding the functional improvements, the Roland-Morris score showed a significant positive result after 4 weeks, whereas the Oswestry score did not. Both scores were not significant with regard to the treatment effect after 12 weeks. The VAS scale showed no significant improvement after 12 weeks (Table 8.2). The secondary outcome criteria (triaxial dynamometry, return to work, and analysis of medication, physiotherapy, and chiropractic treatment frequency) showed no significant difference between the two groups over time.

Table 8.2 Lumbar radiofrequency denervation of the facet joints in the treatment of lumbar back pain: 12-week results of the study by Leclaire et al. (2001)

Outcome measurement	12 weeks after therapy		Change from original value		Treatment effect (95% confidence interval)
	Neurotomy (n = 35)	Placebo treatment (n = 31)	Neurotomy (n = 35)	Placebo treatment (n = 31)	
Disability score (0–100)					
Roland-Morris	43.1	44.4	9.8 (±19.5)	7.2 (±17.0)	2.6 (−6.2–11.4)
Oswestry	33.6	33.7	4.7 (±12.0)	2.7 (±9.1)	1.9 (−3.2–7.0)
Pain					
Visual analogue scale (0–100)	52.3	44.4	−0.5 (±25.0)	7.2 (±27.3)	−7.6 (−20.3–5.1)

The Roland-Morris score and the Oswestry Low Back Pain Disability questionnaires range from 0 to 100, with higher scores indicating poorer functional status
The visual analogue scale (VAS) ranges from 0 ("no pain") to 100 ("most severe pain")

Leclaire et al. concluded from the results that radiofrequency therapy of the R. posterior did not show a positive effect after 12 weeks, neither in the primary outcome data (Roland-Morris score, Oswestry score) nor in the secondary outcome data (dynamometry, return to work).

Overall, Leclaire et al. conclude that radiofrequency denervation has only short-term effects within 4 weeks on functionality and no effect at all on pain behavior after 4 and 12 weeks.

Regarding the cervical spine, the controlled, randomized, double-blind study by Lord et al. (1999) should be mentioned. In this study, the therapeutic effect of thermocoagulation of the medial branch of the R. dorsalis of the cervical root of a painful cervical spine segment was investigated in patients with chronic neck pain after cervical whiplash. Patients with posttraumatic neck pain after cervical spine distortion lasting longer than 3 months and associated with painful zygagophyseal joints of segments C3/4 to C 6/7 were included. In the majority of patients, the pain was unilateral and unisegmental. The pain had been confirmed with placebo-controlled local root infiltrations performed before thermocoagulation. Twelve patients underwent thermocoagulation. The control group was also 12 patients who underwent the identical invasive procedure with application of the coagulation needle to the cervical R. dorsalis of the painful zygapophyseal joint; only no heating of the needle was performed for coagulation. Neck pain was scaled on a visual analog scale before coagulation and described using the McGill Pain Questionnaire. Follow-up examinations were performed 3–5 days, 2–3 weeks, and 3 months after the pain management procedure. Thermocoagulation showed a significant effect on pain relief or analgesia. Thus, postoperative remitted pain in the treated group reached a level of 50% of preoperative pain intensity only after 263 days compared to the placebo group, which showed a transient pain improvement of only 8 days. From the results it was concluded that in patients with neck pain after cervical spine distortion a longer lasting pain relief or pain reduction can be achieved with thermocoagulation. This is true at least for patients in whom the facet pain was secured preoperatively by diagnostic infiltration blocks with a local anesthetic. The method is not suitable for patients in whom the pain cannot be suppressed with local test infiltration, nor for patients who report pain remission with placebo blockade with saline.

Table 8.3 Overview of the evidence for radiofrequency denervation in the literature up to 2014[a]

Localization	Medial branch injection	Medial branch radiofrequency denervation
Cervical	Moderate 2 trials (1 r, 1 nr)	Moderate 6 trials (1 r, 5 nr)
Thoracic	Moderate 2 trials (1 r, 1 nr)	Moderate to poor 2 trials (2 nr)
Lumbar	Long-term: Good, short-term: Good 2 trials (2 r): – Positive for LA + St, only LA: 1 r LZ (5–6 procedures/a), 1 r KZ	Good to moderate (Cochrane) (pulsed limited, only 1 nr) 15 trials (7 r, 8 nr): – 13 positive: 6 r LZ (none + diag. Blocks), 7 nr LZ – 2 negative: 1 r, 1 nr

r Randomised; *nr* not randomised; *LA* local anaesthetic; *St* steroid; *LZ* long-term; *KZ* short-term

[a]Literature: Falco et al. (2012a, b); Boswell et al. (2007), Manchikanti et al. (2002, 2008, 2012), McDonald et al. (1999), Datta et al. (2009), Staal et al. (2009), Chou et al. (2011)

Table 8.3 summarizes the evidence for radiofrequency denervation of the facet joints, divided into cervical, thoracic, and lumbar spinal regions, based on the relevant literature up to 2014.

8.8 Reimbursement of Costs

Reference is made here to ► Chap. 7.

8.9 Conclusion and Clinical Relevance

At the present time, radiofrequency therapy, especially in the cervical spine, is the only surgical and minimally invasive procedure that has been evaluated in a double-blind randomized study and shown to be significantly effective. In the literature, the incidence of facet syndrome in the cervical spine is described as between 25% and 35%, in some cases 40%. Radiofrequency therapy is the treatment of choice after unsuccessful conservative treatment, particularly in cases of prolonged complaints, i.e. chronic facet symptoms. A detailed diagnosis, as described in ► Sect. 8.2, is a prerequisite.

References

Bogduk N (Hrsg) (2004) Practice guidelines for spinal diagnostic and treatment procedures, 1. Aufl. International Spine Intervention Society, San Francisco

Boswell et al (2007) A systematic review of therapeutic facet joint interventions in chronic spinal pain. Pain Physician 10:229–253

Chou et al (2011) Guideline warfare over interventional therapies for low back pain: can we raise the level of discourse? J Pain 12:833–839

Datta et al (2009) Systematic assessment of diagnostic accuracy and therapeutic utility of lumbar facet joint interventions. Pain Physician 12:437–460

Falco et al (2012a) Systematic review of the therapeutic effectiveness of cervical facet joint interventions: an update. Pain Physician 15:E839–E868

Falco et al (2012b) An update of the effectiveness of therapeutic lumbar facet joint interventions. Pain Physician 15:E909–E953

Gallagher J et al (1994) Radiofrequency facet joint denervation in the treatment of low back pain: a prospective controlled doubleblin studie to assess ist efficacy. Pain Clin 7:193–198

Leclaire R et al (2001) Radiofrequency facet joint denervation in the treatment of low back pain. Spine 26:1411–1417

Lord SM et al (1999) Percutaneous radiofrequency neurotomy for chronic cervical zygapophyseal joint pain. Clin J Pain 11:208–213

Manchikanti et al (2002) Medial branch neurotomy in management of chronic spinal pain: systematic review of the evidence. Pain Physician 5:405–418

Manchikanti et al (2008) Cervical medial branch blocks for chronic cervical facet joint pain: a randomized double-blind, controlled trial. Spine (Phila Pa 1976) 33:1813–1820

Manchikanti et al (2012) An update of evaluation of therapeutic thoracic facet joint interventions. Pain Physician 15:E463–E481

McDonald et al (1999) Longterm follow-up of patients treated with cervical radiofrequency neurotomy for chronic spinal pain. Neurosurgery 45:61–67

Staal et al (2009) Injection therapy for subacute and chronic low back pain: an updated Cochrane review. Spine (Phila Pa 1976) 34:49–59

Van Kleef M et al (1999) Randomized trial of radiofrequency lumbar facet denervation for chronic low back pain. Spine 24:1937–1942

Cervical Epidural Injection

M. Legat

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_9

9.1 Introduction and Indication

For the introduction and definition, please refer to ▶ Chap. 10 on lumbar epidural injection. In the last 5 years, interlaminar injections have also been used internationally for the cervical spine.

The dorsal epidural space in particular can be reached interlaminarily. In a so-called intervention in the lateral recessus, it is possible to infiltrate several nerve roots.

Indications for cervical **transforaminal** and **interlaminar** injection are:

1. Radicular pain is detected anamnestically, clinically and possibly also with electrophysiological findings. It must be acknowledged that electrophysiology may not be able to provide evidence in some cases.
2. A failure to respond to conservative treatment with appropriate medications, physical measures, and physical therapy.

The following contraindications arise:

- Absolute contraindications:
  - The patient is unable or unwilling to consent to the intervention.
  - The patient cannot cooperate under the measure.
  - History of anaphylactic reaction to contrast media.
  - An untreated local infection in the area of the intervention.
  - Coagulopathy.
  - Pregnancy.
- Relative contraindications:
  - Drug allergy,
  - Treatment with anticoagulants,
  - Systemic infection,
  - massive cardiovascular or respiratory impairment,
  - Immunosuppression.

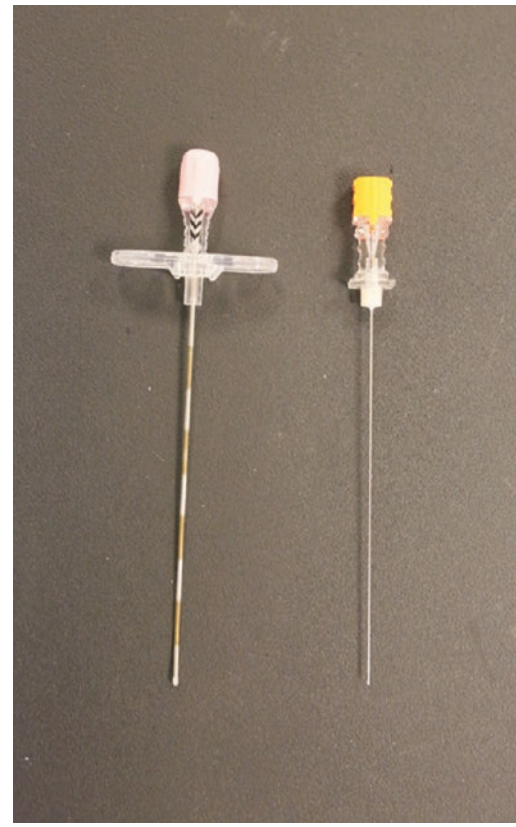
9.2 Necessary Instruments

Fluoroscopy with C-arm is required, optimal is the equipment with an additional digital subtraction angiography.

The necessary emergency equipment for resuscitation as well as the necessary monitoring with blood pressure monitoring, pulse oximetry and ECG are a matter of course.

The **materials** needed are:

- Needles:
  - Transforaminal: Needles with a small gauge (23 G–26 G) are recommended, which should ideally be equipped with a mandrain, length 60–88 mm.
  - Interlaminar: Tuohy cannula 18 G, length 90 mm (◘ Fig. 9.1).
- Skin disinfectant, without iodine.
- Sterile gloves.
- At least 2 syringes with 2 mL or 5 mL, interlaminar additionally LOR (Loss of Resistance) syringe.
- Connecting tube to ensure immobile position of the needle.
- Venous indwelling cannula.



◘ **Fig. 9.1** Tuohy cannula (*left*) and spinal cannula (*right* with yellow head). (Courtesy of © M. Legat 2018. All Rights Reserved)

Medications used for injection are:
- Local anesthetics:
  - Ropivacaine, 0.2% and
  - Lidocaine, 1–2%.
- Water-soluble steroids:
  - z. E.g. betamethasone, 6–18 mg,
  - z. E.g. Triamcinolone, 20–80 mg,
  - z. For example, dexamethasone, 8 mg.
- NaCl 0.9% interlaminar for LOR testing.

Preinterventional documentation should include collection of the following baseline data:
- Pain documentation using the NRS (Numerous Rating Scale).
- Documentation of Activities of Daily Living (ADL) that are impaired by pain.

9.3 Pre-Intervention Education

The patient needs to understand why the intervention is being performed and what both the potential risks and benefits are.

The patient must be informed about infection, allergic reaction, hematoma, unchanged pain symptoms or increase in pain, puncture of the dural sac with spinal headache and arachnoiditis, as well as potential injury to the spinal cord. In addition, the patient should be informed of any short-term weakness or numbness in the upper extremities. Alternative treatment options must be discussed.

9.4 Implementation of the Intervention

Premedication

This is necessary if i.v. sedation is to be performed. Likewise, if the patient is known to be allergic to contrast media, he should be pretreated with H1 or H2 blockers. The author recommends that intravenous access should always be established in order to be able to act quickly in an emergency.

Storage

For transforaminal nerve root block, the patient is positioned supine with slight dorsal extension in the cervical spine. For epidural interlaminar injections including catheter application, the patient is in the prone position, the cervical spine is slightly flexed. The respective target point (▶ Sect. 9.4.1) is then marked. Disinfection is then performed 3 times. The author usually prefers a colored disinfectant; in the cervical spine area, a colorless disinfectant is used for cosmetic reasons.

Intervention Techniques

The transforaminal nerve block will be described first. It should be mentioned here that this technique is now critically assessed (▶ Sect. 9.5; Manchikanti et al. 2008). Complications are rare, but when they do occur, considerable lesions result. For example, embolization of the spinal arteries, which form end arteries between C4 and C6, can cause infarction of the spinal cord. Embolization of the vertebral artery is likely to cause cerebellar infarction.

9.4.1 Transforaminal Injection

Target identification: First, an a.p. fluoroscopy of the cervical spine is performed. The segment in question is identified and the corresponding cover and base plates are adjusted orthogradely. Then the view is changed to oblique view, which is approx. 40 ° from ventral. In this view, the neuroforamen in question is displayed in a circular shape. In this setting, the target point on the posterior neuroforamen lies directly on the superior process of the lower vertebra. The target point is marked and, after appropriate disinfection, local anesthetic is applied.

A 25 G needle is then used to puncture and advance it in the direction of the superior articular process of the facet joint until it contacts the bone (◘ Fig. 9.2). Advancement is performed stepwise in 5-mm increments under constant fluoroscopy. The target view must be strictly adhered to.

When a bony resistance is reached, the needle is then first discreetly retracted. Then switch to the p.a. view. In this view, the needle

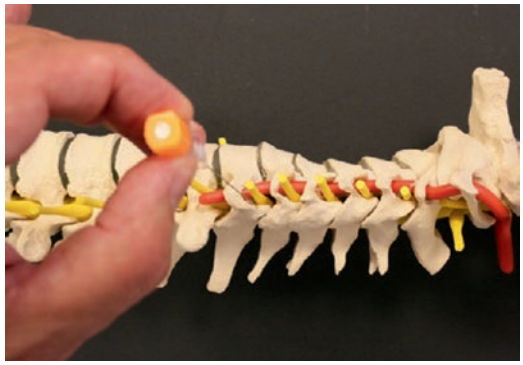


Fig. 9.2 Spinal needle at the processus superius with bone contact in oblique view. (Courtesy of © M. Legat 2018. All Rights Reserved)

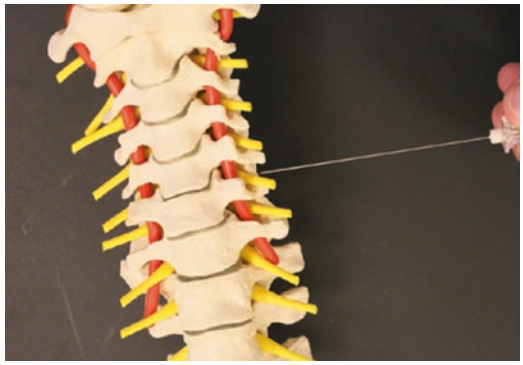


Fig. 9.3 Spinal needle at the processus superius with bone contact in a.p.-view, the massa lateralis is not crossed. (Courtesy of © M. Legat 2018. All Rights Reserved)

should not exceed the lateral edge of the massa lateralis (Fig. 9.3). Older techniques called for penetration by approximately 1/3 of the massa lateralis diameter. For the above reasons of accidental puncture of the spinal artery with corresponding complications, the author recommends remaining more lateral.

If the patient reports nerve sensations in this setting, the needle must be corrected immediately. As long as these sensations persist, the intervention must be interrupted and terminated if persistent.

To ensure an immobile needle, the author prefers a transfer tube.

A small amount of contrast medium up to 0.8 mL is injected directly under real-time fluoroscopy. The contrast medium should represent the spinal nerve and form a good enhancement. If this is not the case, the outflow of the contrast medium must be visualized under continuous fluoroscopy, possibly there is an intra-arterial injection. This can be clearly visualized by a downstream DSA mode. If intra-arterial puncture is suspected, the procedure must be stopped immediately. In the case of a venous puncture, a slower outflow to the caudal is evident here. If a vascular injection has been ruled out with certainty, contrast medium can be injected until good enhancement is also seen in the epidural space and at the dorsal root ganglion. The patient may report sensations in the affected arm with further administration of contrast, which may resemble radicular pain. Images in both the p.a. view and oblique view are documented. Slow injection of the therapeutic solution (local anesthetic and steroid) can then be given. Small volumes are recommended. The dosages of the individual drugs are, for example, ropivacaine 0.2% 1–2 mL, plus a steroid e.g. dexamethasone 4–8 mg.

9.4.2 Interlaminar Injection

Taget identification: The patient is in prone position, first an a.p. fluoroscopy of the cervicothoracic junction is performed. The base plate of C7 and the cover plate of Th1 are orthograded in the C7/Th1 segment. The puncture is generally performed at this level, since the dorsal epidural space is largest here. With an interlaminar medial injection, the lower cervical spine region can be easily reached up to the level of the C6 nerve root. Higher nerve root involvement requires a more lateral puncture of the epidural space, so that the C5 nerve root can also be reached via the lateral recessus. The nerve roots C5–C8, which are mostly affected, can be treated well in this way.

In this setting, the optimal aiming point on the side in question is on the upper edge of the lamina Th1. The aiming point is marked and disinfected.

The skin insertion of the Tuohy needle takes place after appropriate local anesthesia over the selected target. The insertion direction

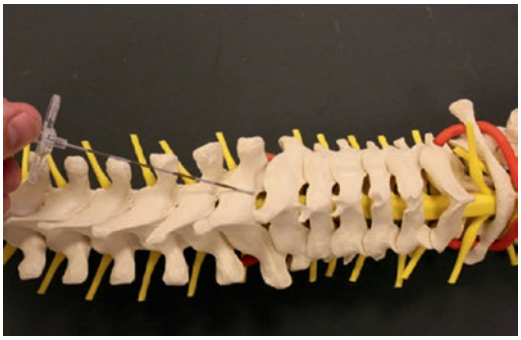


Fig. 9.4 Location of the Tuohy needle tip at the Th1 lamina on the left in the p.a. view. (Courtesy of © M. Legat 2018. All Rights Reserved)

is initially directed towards the target point. As soon as this is touched with bony contact (Fig. 9.4), the needle is discreetly withdrawn and slightly corrected cranially. The loss-of-resistance syringe is applied.

The lamina is then passed through with light pressure on the syringe plunger. In most cases, a tough resistance through the ligamentum flavum is now visible. The lateral view should now be used (Fig. 9.5a). As a rule, good visualization can be achieved when the X-ray beam is faded in. The syringe is now slowly advanced under constant fluoroscopy, finally the syringe plunger subsides and the loss of resistance is reached (Fig. 9.5b). Deep insertion and thus injury to the spinal cord can thus be safely avoided. Further advancement is not necessary.

In this position, the injection of the contrast medium is performed in real-tim fluoroscopy. The procedure for puncturing an artery, the dural sac or a vein is the same as for the transforaminal technique. If these artificial punctures are excluded, contrast medium is further injected. If the Tuohy syringe is correctly positioned in the lateral recess (Fig. 9.6a), the contrast medium is now distributed in the peridural space. If this is the case, switch to p.a. fluoroscopy. The lateral recess is now visualized; as a rule, the C6-Th1 nerve roots (Fig. 9.6b), and in some cases also C5, can be easily reached with this interlaminar technique. The total volume of contrast medium is noted and the therapeutic medium (usually local anesthetic and steroid) is now injected. Usually about 3 mL of 0.2%

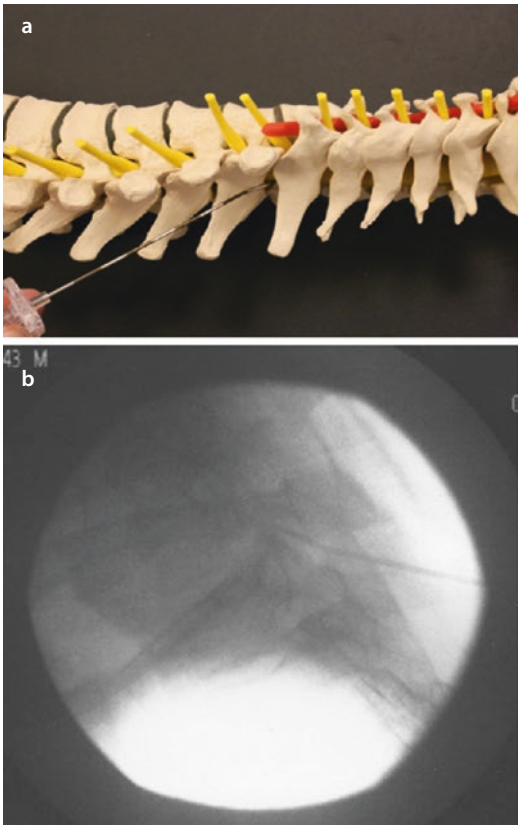


Fig. 9.5 **a, b** Position of the Tuohy needle tip at the passage through the ligamentum flavum on the left, level C7/TH1. **a** In lateral view on the model; **b** in lateral view under BV. (Courtesy of © M. Legat 2018. All Rights Reserved)

ropivacaine and 8 mg of dexamethasone are used by the author. This is followed by removal of the puncture cannula.

9.4.3 Performance Parameters

The intervention should require only one skin puncture. Correction of the direction of the needle should be no more than 8 times, the total fluoroscopy time should not exceed 30 s.

9.4.4 Post-Intervention Observation and Instruction

After application of a sterile plaster dressing, the patient is observed for a further 30 min under monitoring (blood pressure monitor-

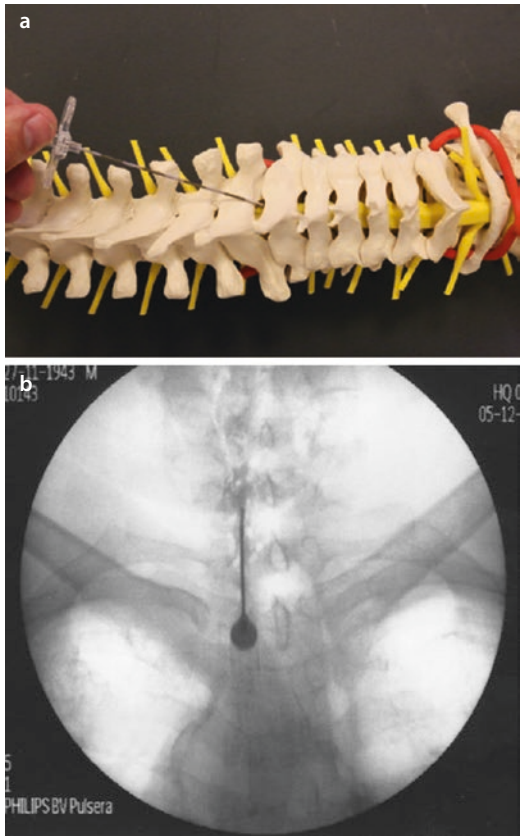


Fig. 9.6 **a, b** Position of the Tuohy needle tip in the epidural space C7/Th1 at the level of Th1 on the left. **a** In the a.p. view on the model; **b** in the a.p. view under BV, contrast enhancement level C6-Th1 in the area of the lateral recessus on the left. (Courtesy of © M. Legat 2018. All Rights Reserved)

ing, pulse oximetry and ECG). Depending on the onset of action of the local anesthetic, functional tests are recommended at the appropriate time, which previously triggered the pain. This allows an adequate assessment to be initiated. If the patient is clinically unremarkable, he can be prepared for discharge. At discharge, the patient is instructed as follows:

For 24 h postintervention he should not drive a vehicle or a machine. The patient should fill out a so-called diagnostic sheet with documentation of the pain relief 30 min to 24 h postintervention, once the pain has already been documented preinterventionally. The patient is also asked to document the preinterventionally existing functional deficits postinterventionally with the respective gain.

If unusual symptoms occur, such as headache, fever, cramps, increasing pain or signs of paralysis, the patient should contact the performing physician immediately.

9.4.5 Summary

A positive effect is a pain relief of at least 50%. If the pain symptoms recur, a second injection can be given within 7 days. The international literature describes that on average 2–4 injections are necessary within 6 months to achieve good pain relief (Manchikanti et al. 2008).

The above techniques apply to both therapeutic and diagnostic injections. For diagnostic injections, the transforaminal technique is mainly favoured, as a more precise result can be achieved.

In a diagnostic intervention, much less contrast medium is needed, approx. 0.2 mL, to obtain only a slight enhancement on the nerve. The same amount of local anesthetic is then applied. This prevents the local anaesthetic from spreading and thus anaesthetising further nerve roots. The course is documented postinterventionally identical to the therapeutic injection.

9.5 Possible Complications

The common complications of transforaminal injection, although rare, relate to nerve injury, vascular injury, intravascular injection, and infection. There are single case reports at the cervical spine regarding the transforaminal technique with artificial intravascular injections of steroids, which are most likely responsible for a spinal cord lesion with paraplegia (Manchikanti et al. 2008). The author therefore strongly recommends not to cross the border of the massa lateralis with the needle tip in the p.a. view.

9.6 Results in the Literature

In 2013, Manchikanti et al. published a review of 15 RCT studies on transforaminal injection as part of the guidelines on interventional techniques in the spine. The overall conclusion of this review was that the evidence is good for the treatment of radicular pain in disc herniation with local anesthetics and steroids, and moderate for treatment with local anesthetics alone. Regarding spinal stenosis, there was moderate evidence for local anesthetics and steroids. These results apply to the lumbar region. Moderate results were generally found in the cervical region.

The Spine Intervention Society (SIS, formerly ISIS) continues to promote transforaminal injections (Bogduk 2004).

The American Society for Interventinal Pain Physicians (ASIPP; Olmarker 1966), on the other hand, advocates the interlaminar technique more in its guidelines for interventional techniques because it has a lower rate of complications in contrast to transforminal application.

References

Bogduk N (Hrsg) (2004) Practice guidelines for spinal diagnostic and treatment procedures, 1. Aufl. International Spine Intervention Society, San Francisco

Manchikanti L, Singh V, Derby R, Helm S, Trescot AM, Staats PS, Prager JP, Hirsch JA (2008) Review of occupational medicine practice guidelines for interventional pain management and potential implications. Pain Physician 11:271–289

Manchikanti L et al (2013) An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part I: Introduction and general considerations. Pain Physician 16:S1–S48

Olmarker K (1966) Mechanical and biochemical injury of spinal nerv roots: an experimental perspective. In: Weinstein JN, Gordon SL (Hrsg) Low back pain: a scientific and clinical overview. American Academy of Orthopaedic Surgeons, Rosemont, S 215–233

Lumbar Epidural Injection

M. Legat

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_10

10.1 Introduction and Indication

Lumbar transforaminal injection is an intervention to deliver a certain amount of steroids combined with local anesthetic to the so-called dorsal root ganglion in the neuroforamen.

There is rigorous evidence for laboratory evaluation of inflammatory processes at the nerve root. Since steroids can suppress inflammation here, intervention is logical.

The transforaminal approach offers the possibility of delivering the necessary medication in the maximum concentration directly to the site of pathology (Olmarker 1996; Yoshizawa et al. 1996). Moreover, with a small amount of local anesthetic alone, a diagnostic statement can be made. For example, this is one way to preoperatively identify the affected nerve root when imaging is inconclusive.

The dorsal epidural space in particular can be reached via the interlaminar access. In a so-called intervention in the lateral recessus, it is possible to infiltrate several nerve roots.

Indications for lumbar transforaminal and interlaminar injection are:

1. Radicular pain is detected anamnestically, clinically and possibly also with electrophysiological findings. It must be acknowledged that electrophysiology may not be able to provide evidence in some cases.
2. A failure to respond to conservative treatment with appropriate medications, physical measures, and physical therapy.

The following **contraindications** arise:

- Absolute contraindications:
  - The patient is unable or unwilling to consent to the intervention.
  - The patient cannot cooperate under the measure.
  - History of anaphylactic reaction to contrast media.
  - An untreated local infection in the area of the intervention.
  - Coagulopathy.
  - Pregnancy.
- Relative contraindications:
  - Drug allergy,
  - Treatment with anticoagulants,
  - Systemic infection,
  - massive cardiovascular or respiratory impairment,
  - Immunosuppression.

10.2 Necessary Instruments

Fluoroscopy with C-arm is required, optimal is the equipment with an additional digital subtraction angiography.

The necessary emergency equipment for resuscitation as well as the necessary monitoring with blood pressure monitoring, pulse oximetry and ECG are a matter of course.

The **materials** needed are:

- Needles:
  - Transforaminal: Needles with a small gauge (23 G to 26 G) are recommended, which should ideally be equipped with a mandrain, length 80–120 mm.
  - Interlaminary: Tuohy cannula 18 G, length 90 mm or 120 mm.
- Skin disinfectant, without iodine.
- Sterile gloves.
- At least 2 syringes with 2 mL or 5 mL, interlaminar additionally LOR (Loss of Resistance) syringe.
- Connecting tube to ensure immobile position of the needle.
- Venous indwelling cannula.

Medications used for injection are:

- Local anesthetics:
  - z. E.g. bupivacaine, 0.25–0.5%,
  - z. E.g. ropivacaine, 0.2–0.75%,
  - z. E.g. lidocaine, 1–2%.
- Water-soluble steroids:
  - z. E.g. betamethasone, 6–18 mg,
  - z. E.g. Triamcinolone, 20–80 mg,
  - z. For example, dexamethasone, 8 mg.
- NaCl 0.9% interlaminar for LOR testing.

Preinterventional documentation should include collection of the following baseline data:

- Pain documentation using the NRS (Numeric Rating Scale).
- Documentation of Activities of Daily Living (ADL) that are impaired by pain.

10.3 Pre-Intervention Education

The patient needs to understand why the intervention is being performed and what both the potential risks and benefits are.

The patient must be informed about infection, allergic reaction, hematoma, unchanged pain symptoms or increase in pain, puncture of the dural sac with spinal headache and arachnoiditis, as well as potential injury to the spinal cord. In addition, the patient should be informed of any short-term weakness or numbness in the lower extremities. Treatment alternatives must be discussed with the patient.

10.4 Implementation of the Intervention

■ Premedication

This is necessary if i.v. sedation is to be performed. Likewise, if the patient is known to be allergic to contrast media, he should be pretreated with H1 or H2 blockers.

■ Storage

The patient is positioned in the prone position.

■ Intervention Techniques

Two different variants of transforaminal intervention are described in the international literature. The historically older technique describes a so-called subpedicular approach. As a second technique, a retroneural position of the needle tip is possible. This variant was developed because of the frequent cranial displacement of the target nerves in fresh disc hernias. With the subpedicular approach, the nerve can be injured here. In addition, with the retroneural approach, injection into the radicular artery can be safely avoided.

The advantage of the **subpedicular approach** is that the target point can be identified with the posterior edge of the vertebral body in question. Most randomized controlled trials have used this technique (Riew et al. 2000; Karppinen et al. 2001; Kim et al. 2012; Vad et al. 2002). The disadvantage of this technique is the possibility of intra-arterial injection.

With the **retroneural approach,** the anterior radicular artery in particular is avoided. The disadvantage of this technique is that it requires more experience to place the needle tip correctly. At the same time, to avoid nerve injury, the needle tip must not penetrate too far ventrally into the neuroforamen. On the other hand, the neuroforamen, in particular the fascia cribriformis, must be reached in order to achieve an effect. Another disadvantage is that there is no evidence for the retroneural approach.

10.4.1 Transforaminal Injection

■ Subpedicular Approach

Target identification: First, an a.p. fluoroscopy of the lumbar spine should be performed. The respective cover and base plates are adjusted orthogradely in the relevant segment. In this setting, the optimal target point is located at the lower pole of the circular pedicle image in the 6 o'clock position. The aiming point is thus located in the upper so-called safe triangle, which is formed at the apex by the pedicle, laterally by a sagittal tangential line of the outer vertebral body edge and as a base by the nerve itself. Normally, the aiming point is covered by the superior facet joint process of the inferior segment, so that a slight oblique adjustment of 10–15 ° is obligatory. This shifts the target point to approximately 7 o'clock for left-sided nerve roots and 5 o'clock for right-sided nerve roots.

The puncture point for the needle is slightly below and lateral to the target point. After skin insertion, the needle is advanced approx. 1 cm, after which the first check is carried out using fluoroscopy. In the so-called target view, the needle is then advanced step by step under regular fluoroscopy (0.5 cm steps). While advancing the needle, the safe triangle should never be left. Should the patient describe an shooting pain, especially in the area of the spinal nerve in question, the needle must be withdrawn approx. 0.5 cm. The needle position should then be changed

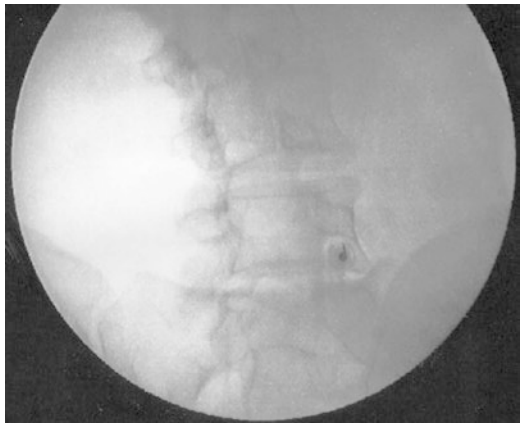


Fig. 10.1 Subpedicular needle position of the L5 nerve root on the right in the light oblique view when reaching the target point (posterior edge of the vertebral body). (Courtesy of © M. Legat 2018. All Rights Reserved)

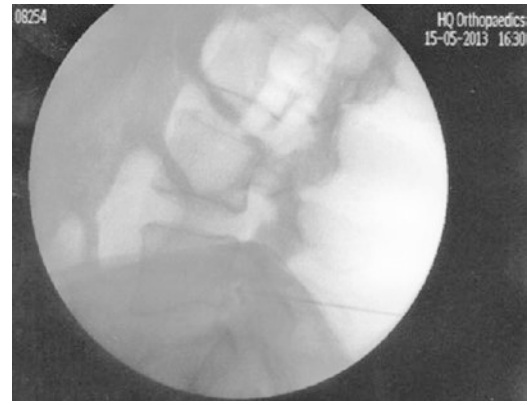


Fig. 10.3 Subpedicular needle position of the right L5 nerve root in lateral view when reaching the target point (posterior edge of the vertebral body), after administration of contrast medium with enhancement at the dorsal nerve root ganglion. (Courtesy of © M. Legat 2018. All Rights Reserved)

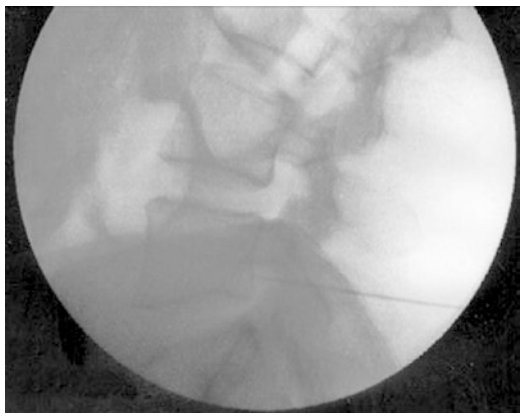


Fig. 10.2 Subpedicular needle position of L5 nerve root on the right in lateral view when reaching the target point (posterior edge of vertebral body). (Courtesy of © M. Legat 2018. All Rights Reserved)

slightly cranially or laterally. When advancing the needle further directly under the pedicle without the patient indicating pain, the target point is easily reached (Fig. 10.1). If this is not possible, the needle tip must come to rest retroneurally.

When the needle tip has reached the target point, the lateral view is set. If the needle is correctly positioned, it touches the posterior edge of the vertebral body (Fig. 10.2).

If the target point is safely reached, approx. 0.2–0.5 mL of contrast medium is injected. If there is already a suspicion in normal fluoroscopy, better under digital subtraction angiography (DSA), that a radicular artery has been punctured, the intervention must be aborted. The intervention is then repeated at a later time. The same procedure applies if the dural sac is punctured. If an intravenous injection is evident, the needle should be withdrawn slightly. A new administration of contrast medium takes place, and if the findings are normal, the intervention can be continued.

Optimal imaging with the contrast medium shows the so-called safe triangle and an enhancement on the nerve root (Figs. 10.3 and 10.4).

If there is too much contrast in the periphery or laterally, the needle should be corrected to a more medial position. If the safe triangle and the target nerve are filled with contrast up to the level of the pathology previously diagnosed by clinic and imaging, the volume used is noted. The therapeutic agent, steroid and local anesthetic or local anesthetic alone, is then injected at the same volume fraction. The needle is then completely removed.

Retroneural Access

The setting of the image converter is identical to the subpedicular approach. The aiming point is also the same. The author then prefers an oblique view to the target point of 15 °.

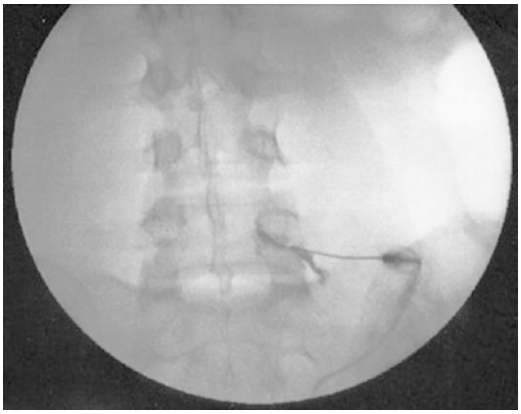


Fig. 10.4 Subpedicular needle position of the right L5 nerve root in a.p. view when reaching the target point (posterior edge of the vertebral body), after administration of contrast medium with enhancement on the nerve root. (Courtesy of © M. Legat 2018. All Rights Reserved)

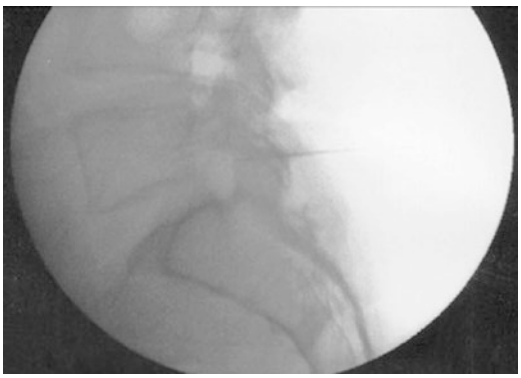


Fig. 10.5 Retroneural needle position of right L5 nerve root in lateral view when reaching the target point (dorsal neuroforamen). (Courtesy of © M. Legat 2018. All Rights Reserved)

The skin insertion of the needle is done over the selected target. The insertion direction is initially directed to the lateral lamina. As soon as this is touched with bony contact, the needle is discreetly retracted and slightly corrected laterally. The lamina is passed (Fig. 10.5), at this moment the needle is swivelled to the lateral view. This avoids too deep an insertion and nerve injury. The needle is then advanced further in the lateral view until the lamina is slightly exceeded (Fig. 10.6).

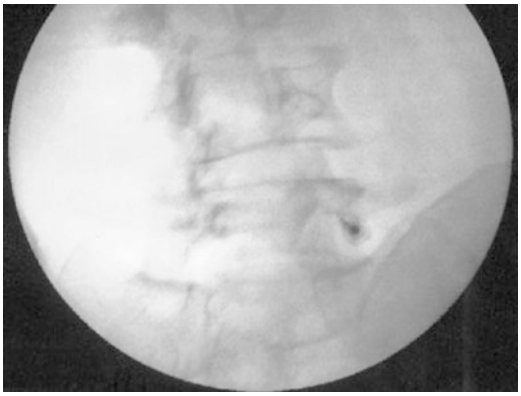


Fig. 10.6 Retroneural needle position of right L5 nerve root in a.p. view when reaching the target point (dorsal neuroforamen). (Courtesy of © M. Legat 2018. All Rights Reserved)

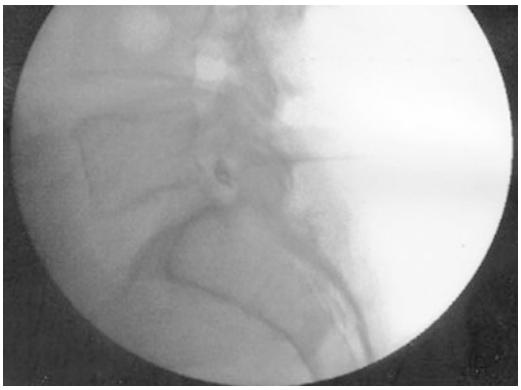


Fig. 10.7 Retroneural needle position of the right L5 nerve root in lateral view when reaching the target point (dorsal neuroforamen), after administration of contrast medium with enhancement on the nerve root. (Courtesy of © M. Legat 2018. All Rights Reserved)

In this position, the injection of contrast medium is performed under real-time fluoroscopy. In case of accidental puncture of an artery, the dural sac or a vein, the procedure is the same as for the subpedicular technique. Once these artificial punctures have been ruled out, contrast medium continues to be injected until the spinal nerve and the dorsal nerve root ganglion are well marked (Figs. 10.7 and 10.8).

The total volume of contrast medium is noted and now the therapeutic medium (usually local anesthetic and steroid) is injected with the same volume fraction.

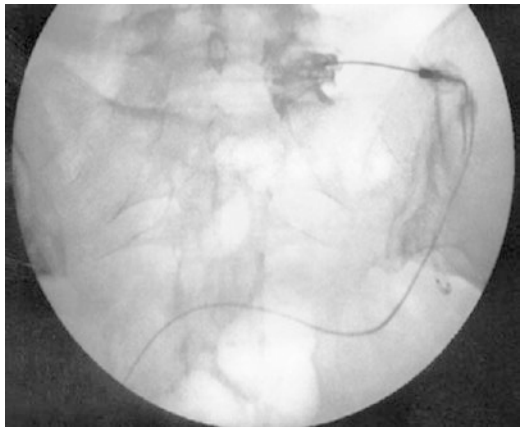


Fig. 10.8 Retroneural needle position of the right L5 nerve root in a.p. view when reaching the target point (dorsal neuroforamen), after administration of contrast medium with enhancement on the nerve root. (Courtesy of © M. Legat 2018. All Rights Reserved)

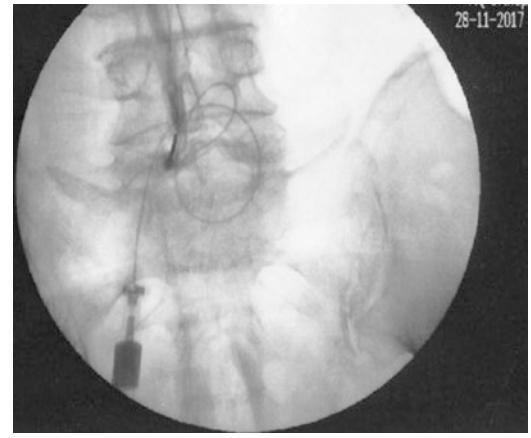


Fig. 10.10 Needle position in the lateral recessus on the right in the a.p.-view height L5/S1 on the left after administration of the contrast medium with enhancement in the dorsal and ventral epidural space. (Courtesy of © M. Legat 2018. All Rights Reserved)

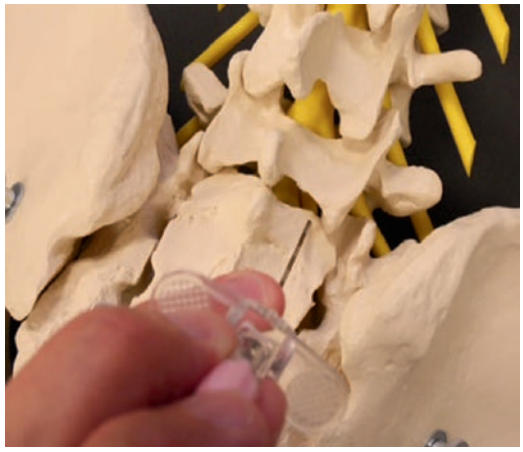


Fig. 10.9 Needle position on the S1 lamina on the right in the a.p. view (model) for the puncture of the L5/S1 level on the right. (Courtesy of © M. Legat 2018. All Rights Reserved)

10.4.2 Interlaminar Injection

Target identification: First, an a.p. fluoroscopy of the lumbar spine should be performed. In the segment in question, the respective cover and base plates are set orthograde. In this setting, the optimal target point on the side in question is on the upper edge of the lamina at the lateral angle (Fig. 10.9). After local anesthesia, the skin insertion of the needle takes place over the selected target. The insertion direction is initially directed towards the lateral lamina. As soon as this is touched with bony contact, the needle is discreetly withdrawn and slightly corrected laterally. The lamina is passed (Fig. 10.10), at this moment the needle is swivelled to the lateral view. This avoids too deep an insertion and nerve injury. The needle is then advanced further in the lateral view until the lamina is slightly exceeded.

In this position, the injection of contrast medium is performed under real-time fluoroscopy. In the event of accidental puncture of an artery, the dural sac or a vein, the procedure is the same as for the subpedicular technique. Once these artificial punctures have been ruled out, contrast medium continues to be injected until the affected nerve roots or lateral recessus are well identified. (Figs. 10.10 and 10.11).

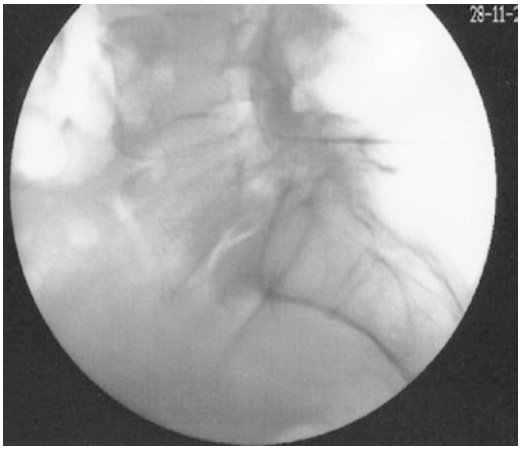


Fig. 10.11 Needle location in the lateral recessus in lateral view height L5/S1 left after administration of contrast medium with enhancement on the L4 and L5 nerve root and in the lateral recessus left. (Courtesy of © M. Legat 2018. All Rights Reserved)

10.4.3 Performance Parameters

The intervention should require only one skin puncture. Correction of the needle direction should be no more than eight times, fluoroscopy time should not exceed 30 s.

10.4.4 Post-Intervention Observation and Instruction

After application of a sterile plaster dressing, the patient is observed for a further 30 min under monitoring (blood pressure monitoring, pulse oximetry and ECG). Depending on the onset of action of the local anesthetic, functional tests are recommended at the appropriate time, which triggered the pain before the intervention. This allows an adequate assessment to be initiated. If the patient is clinically unremarkable, he can be prepared for discharge. At discharge, the patient is instructed as follows:

For 24 h postintervention he should not drive a vehicle or a machine. The patient should fill out a so-called diagnostic sheet with documentation of the pain relief 30 min to 24 h postintervention, once the pain has already been documented preinterventionally. The patient is also asked to document the pre-interventionally existing functional deficits postinterventionally with the respective gain.

If unusual symptoms occur, such as headache, fever, cramps, increasing pain or signs of paralysis, the patient should contact the performing physician immediately.

10.4.5 Summary

A positive effect is a pain relief of at least 50%. If the pain symptoms recur, a second injection can be given within 7 days. The international literature describes that on average 2–4 injections are necessary within 6 months to achieve good pain relief (Manchikanti et al. 2008).

The above techniques apply to both therapeutic and diagnostic injections. For diagnostic injections, the subpedicular technique is mainly favoured, as a more precise result can be achieved.

For a diagnostic intervention, much less contrast medium is needed, approx. 0.2 mL, in order to obtain only a slight enhancement on the nerve. The same amount of local anaesthetic is then applied; spreading of the local anaesthetic and thus anaesthesia of other nerve roots should be avoided. The course is documented postinterventionally identical to the therapeutic injection.

10.5 Possible Complications

The common complications of **transforaminal injection**, although rare, relate to nerve injury, vascular injury, intravascular injection and infection. Single case reports exist at the lumbar spine with intravascular injections of steroids, which are most likely responsible for a spinal cord lesion with paraplegia (Botwin et al. 2000; Houten and Errico 2002).

During **interlaminar injection,** dura injuries can rarely occur; the patient must be informed about post-interventional headaches. Accidental intrathecal applications of local anaesthetics or steroids must be excluded

on the basis of the imaging. Contrast administration would result in a myelogram, which must be clearly identified.

10.6 Results in the Literature

Various studies have been published on this topic over the past 15 years. Most notable is the study by Riew et al. (2000) on the effect of epidural injections on the need for surgical treatment for lumbar radicular pain. Riew et al. were able to demonstrate with a probability of $P > 0.004$ that with transforaminal injection with steroids, 70% of patients did not require surgery, compared with only 35% without this treatment or with epidural injection with local anaesthetic alone.

Vad et al. (2002) reported on the outcome of a group of patients with transforaminal injections of corticosteroids, compared with a group with paraspinal injections of saline. In a 12-month follow-up, they demonstrated that 84% of the patients treated with steroids showed a pain reduction of more than 50%, compared with only 48% in the paraspinal injection patient group. Ghahreman et al. (2010) showed in their study that in the long-term effect of 12 months, transforaminal injection of steroids and local anesthetics was superior to a placebo group with i.m. injections by 50%. In 2013, a review of 15 RCT studies concerning transforaminal injections was published by Manchikanti et al. as part of guidelines on interventional techniques in the spine (Manchikanti et al. 2013). The overall conclusion of this review was that the evidence is good for treatment of lumbar radicular pain for disc herniation with local anaesthetics and steroids, and moderate for treatment with local anaesthetics only. Concerning lumbar spinal stenosis, results were mediocre for local anesthetics and steroids. For post-surgery syndrome, moderate evidence was shown with both the combination of local anesthetics and steroids and local anesthetics alone. All effects were achievable in the short and long term.

References

Botwin KP, Gruber RD, Bouchlas CG, Torres-Ramos FM, Freeman TL, Slaten WK (2000) Complications of fluoroscopically guided transforaminal lumbar epidural injections. Arch Phys Med Rehabil 81:1045–1050

Ghahreman A, Ferch R, Bogduk N (2010) The efficacy of transforaminal injectionof steroids for the treatment of lumbar radicular pain. Pain Med 11:1149–1168

Houten JK, Errico TJ (2002) Paraplegia after lumbosacral nerve root block: report of three cases. Spine J 2:70–75

Karppinen J, Malmivaara A, Kurunlahti M, Kyllnen E, Pienimki T, Nieminen P, Ohinmaa A, Tervonen O, Vanharanta H (2001) Periradicular infiltration for sciatica: a randomized controlled trial. Spine (Phila Pa 1976) 26:1059–1067

Kim HJ, Park JH, Shin KM, Kang SS, Kim IS, Hong SJ, Song CK, Park JC, Yeom JS (2012) The efficacy of transforaminal epidural steroid injection by the conventional technique in far-lateral herniation of lumbar disc. Pain Physician 15:415–420

Manchikanti L, Singh V, Derby R, Helm S, Trescot AM, Staats PS, Prager JP, Hirsch JA (2008) Review of occupational medicine practice guidelines for interventional pain management and potential implications. Pain Physician 11:271–289

Manchikanti L et al (2013) An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part I: introduction and general considerations. Pain Physician 16: S1–S48

Olmarker K (1996) Mechanical and biochemical injury of spinal nerve roots: an experimental perspective. In: Weinstein JN, Gordon SL (Hrsg) Low back pain: a scientific and clinical overview. American Academy of Orthopaedic Surgeons, Rosemont, S215–233

Riew KD, Yin Y, Gilula L, Bridwell KH, Lenke LG, Lauryssen C, Goette K (2000) The effect of nerve-root injections on the need for operative treatment of lumbar radicular pain. A prospective, randomized, controlled, double-blind study. J Bone Joint Surg Am 82-A:1589–1593

Vad VB, Bhat AL, Lutz GE, Cammisa F (2002) Transforaminal epidural steroid injections in lumbosacral radiculopathy: a prospective randomized study. Spine (Phila Pa 1976) 27:11–16

Yoshizawa H, Nakai S, Koboyashi S, Morita T, Shizu N (1996) Intraradicularedema formation as a basic factor in lumbar radiculopathy. In: Weinstein JN, Gordon SL (Hrsg) Low back pain: a scientific and clinical overview. American Academy of Orthopaedic Surgeons, Rosemont, S 235–246

Sensory Innervation of the Sacroiliac Joint

T. Filler

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_11

11.1 Introduction

The innervation of a joint depends on the purpose (self-perception, importance for other structures/tasks of the body, trophism) and phylogenetic aspects. In the case of the sacroiliac joint (SIG), there are also ontogenetic peculiarities. The following presentation builds on the biology, anatomy and biomechanics of the joint to classify the propriosensory (self-perception), which has long been underestimated in a joint considered amphiarthrosis.

The importance of even small movements at the lower end of the spine emerges when it is thought of upwards as a long lever, at the other end of which sits the head. With its position, the vestibular system is positioned. The influence of the vestibular system for the entire locomotor system in an erect biped is obvious. A movement of 1 ° degree in the SIG significantly changes the position of the inner ear and thus its impulse pattern. Only by "offsetting" the position of the head with this impulse pattern can balance be maintained. So as the distance from the head increases, the spinal propriosensors must become more and more sensitive. Even if every smallest movement at the lower end of the spine can be compensated for in the sections above it, it must also be precisely known for this.

Little is known about trophic (autonomic) innervation in SIG, but the peripheral interaction of the sympathetic nervous system with the pain system plays an important role. At present, only general correlations can be referred to here, which, however, are also relevant for the SIG, particularly in the case of the chronification of pain.

In addition to ontogenesis (adaptation of the joint to the stress in the developmental phase), the original function of the joint in horizontal position in phylogenetically older phases is interesting, since the innervation optimized for this over a long period of time was not replaced with the erection of humans, but existing elements were modified and adapted, e.g. in their thresholds, at which they respond to changes with signaling. However, the lowering of thresholds required here also leads collaterally to an easier response of the proprioceptors as pain generators.

The SIG occupies a special position due to its location, its structure, its importance for the upright gait and its innervation. The anatomy is laterally asymmetrical, which also applies to the sensory supply. The sacral and ilial portions are different in terms of cartilage covering, bony support, and susceptibility to pathology, but more important and extensive is the ligamentous apparatus or its nervous endowment. The dorsal supply via the dorsal sacral plexus is more significant than the ventral and occurs via L5-S4 with possible contributions from L2 down and Coc1 up. In this context, the distribution of corpuscular propriosensors is not homogeneous. Little is known about autonomic innervation; zones of referenced pain are nonspecific. The current state of knowledge is explained on the basis of biology, joint anatomy and biomechanics. The very extensive sensory innervation argues for a joint much more oriented to motion than to load transmission. The perpetuated view of amphiarthrosis as a preferentially static joint needs to be broadened to include a reduced focus on the pain system in this context. This will allow a better diagnostic use of the newer knowledge on correlations between pain and propriosensation. At the same time, however, the limitations of previous anatomical knowledge become evident. Nevertheless, some things can be said about the course of the fibers for therapeutic accessibility. Thus, the supplying branches converge on the level of the anlage segment S2 at their exit from the foramina sacralia dorsalia and preferably enter the ligamenta at the same level via the crista sacralis lateralis close to the bone. The additional contributions from other spinal nerves thereby take connection to the lateral nerve arches arising there, whereby a more supraregional supply than with the facet joints becomes recognizable.

11.2 Biology

The paired SIG belongs to the joints near the axis of the body, but unlike the intervertebral joints, it is a secondary formation. The latter have survived on the dorsal side of the os sacrum only in the form of the crista sacralis intermedia as a rudimentary bumpy groin. Neither in its form (facies auricularis), nor in its joint type (nutation joint), its (incomplete) capsule or special strain is a comparable joint to be found in the rest of the body. It also occupies a special position among the pathologies.

Important representatives of the bipeds besides humans and kangaroos are a part of the dinosaurs or their descendants, the birds. For birds or kangaroos, the erection apparently depended less on gaining height than on freeing the front limb. For this purpose, the pelvis was suspended in the legs. Humans, on the other hand, have primarily sought to gain height and have therefore erected the spine. Comparable developments are rare and are often solved in a different way – the hands, however, did not have to be freed by the ancestors of today's man, as they were already "freed" in his origin as a four-handed man. Unlike the comparatively named, a hanging device was not developed laterally in the hip, but medially between the spine and the pelvis. This led to a change in the original suspension of the os sacrum from dorsal to ventral to a suspension from cranial to caudal. But the dorsally applied ligamentous masses have continued to be used. On the one hand, this has massively changed the leverage forces, and on the other hand, the spinal column has been forced to counter-curve lumbarly. These two changes, as well as the change in the cervical spine associated with the straightening (rotation instead of lateralization), are profound and therefore the source of many disorders.

To date, evolution has not allowed the combined joint axis through both joints to migrate below the gravitational lot of the erect body, which would be desirable as an unstable equilibrium, since the muscular forces to be expended for stabilization could then be minimized. Instead, the ligament masses have adapted. In addition, the joint is said to be dependent on the stresses applied to it during the first years of life. This means that the orientation of its shape is shaped by the preferred type of loading during this period. The two conflicting types of loading are dynamic coming from the pelvis (hip joint) or static due to load transfer from the spine. A dynamically used SIG is more likely to result in a horizontal orientation of the joint surfaces, while a statically used SIG is more likely to result in a vertical orientation of the joint surfaces. This option of adapting the anatomy to individual needs rather than a genetic default is considered an evolutionary advantage.

The human biology of the suspension of the os sacrum in the os ilium is not made for sitting, but serves the movement in the hip. Modern society, however, increasingly needs seated people, whereby load transfer in the sense of thrust forces becomes effective. Few studies are available on the postulated but controversial future evolution of the os sacrum, which could have an influence on the joint. It has been suggested that there is an evolutionary tendency for the lumbar spine to shorten in favour of an os sacrum consisting of 6 vertebrae (so-called sacralisation, e.g. in 6% of the North American population) (Vleeming et al. 2012). This is thought to increase load transmission capacity. However, this is not supported in all statistics and also finds some contradiction in a variation of the originating spinal nerves of the lumbar plexus tending more towards caudalization (Horwitz 1939). The requirements of an obstetric pathway also conflict with this (Vleeming et al. 2012). Fusion with the os coccygeum is more common (24% in women and 30% in men, increasing with age) (Vleeming et al. 2012).

11.3 Joint Anatomy

The osseous segment parts S1 and S2 as well as parts of S3 usually form the basis of the joint on the side of the os sacrum. Its variable structure alone makes the joint rich in variation. Anatomically, the adult joint surface, which averages 17.5 cm^2, is C-shaped. The

joint is classified as a synovial joint, although significant portions (75% of the cranial surface) are not synovial (Walker 1986). An incomplete fibrous capsule exists. Ventrally, it is relatively thin, despite the overlying ligamentous apparatus, and is therefore subject to little mechanical load or allows movement. The ventral area of the joint is furthest away from the dorsal axis, which already morphologically relativizes the "low mobility". Movements of the SIG are preferably measured dorsally, i.e. close to the axis, from which the impression of amphiarthrosis has been consolidated. However, this view is not undisputed and depends very much on the type of measurement. The dorsal ligaments merge into the iliolumbar ligamentous apparatus. A capsule is often rudimentary here. The dorsal border of the joint is formed by the transition into a stable ligamentous apparatus. Basically, when considering the size of the joint, the area of the ligamentous apparatus should also be included, which is approximately 22.3 cm^2. The significant intraindividual lateral asymmetry is striking.

The sacral articular surface is preferably concave, but often has a central elevation. The iliac side is of complementary construction. Topographically, the lower limb of the joint is in contact with the upper margin of the incisura ischiadica major, consequently with the suprapiriform division of the hole. Only the posterior border of the joint is palpable just below the spina iliaca posterior superior under the ligaments. From there the joint space spreads horizontally ventrally. The weight-bearing ligaments run from the dorsal edge of the pelvis to the lateral surface of the sacrum and may show increased pressure sensitivity here.

The cartilaginous surfaces show structural differences between the sacral and ilial sides even in neonates (Bowen and Cassidy 1981; Kampen and Tillman 1998; Vleeming et al. 2012; Walker 1986). Sacrally, 4 mm of hyaline cartilage is found, whereas ilially the 1–2 mm thick cartilage is fibrous at many sites. The amount of intra-cartilaginous glycosaminoglycans differs between the two sides. Furthermore, there is a conspicuously low amount of type II collagen in the ilial (especially cranial) cartilage, which is otherwise typical of articular cartilage that is degenerating (as in osteoarthritis). The ilial cartilage also degenerates on average 10–20 years earlier than the sacral cartilage. One reason seems to be the connection of the cartilage with the ligamentous apparatus in the upper third of the joint. The age changes are also differentiated. Sacrally they occur much less frequently. There does not appear to be a "normal" joint in old age (Walker 1986). Overall, however, there are too few data on age-related tissue changes. This also applies to sex differences, but the cartilage area seems to tend to be larger in men.

Only the lower anterior third largely corresponds to what is generally understood by a joint. This strange structure and the strikingly irregular surface indicate that there are still some unknown factors in the biomechanics of the joint. If one wants to explain the differences biologically, different types of loading on the two sides suggest themselves. If the functions known for this are derived from the morphology, the sacral side is therefore constructed more for pressure absorption, while the ilial opposite side is more under shear stress. This cannot be explained by a cartilage-cartilage interaction in the classical sense of a sliding-rolling movement in a joint. One possible interpretation would be that the os ilium moves preferentially against the os sacrum and that the latter is the resting pole for all the various movements.

If one compares the relationship of the cartilaginous surface to the attachment surface of the ligamentous apparatus with the situation of other joints, it quickly becomes clear that the ligamentous apparatus dominates. This is responsible for proprioception and nociception anyway. Diagnostically and therapeutically, the joint space is therefore of secondary importance. It is also more difficult and less reliable to address than the (dorsal) ligamentous portion. Due to the large ligamentous masses, the receptors there can only be reached to a limited extent from within the joint space, whereas the distribution of substances within the ligamentous structures is guaranteed due to gaps (Fortin et al. 1999b).

Embryologically, a three-layered structure emerges in the eighth week of intrauterine development, which, in addition to sacral and iliac cartilage, has a mesenchymal zone that anticipates the later joint space. The final formation of a joint space can be demonstrated from the 34th week of gestation (Vleeming et al. 2012; Walker 1986). Along the way, in the tenth week, unlike other joints, the joint emerges from the center **and** periphery of this anlage, whereas typically a joint emerges only from the center of such a preform. It is not until the 7th–eighth month in utero that the joint can be considered fully differentiated. Few other joints are finalized so late and receive so little movement until then. Sex differentiation occurs from about the fourth intrauterine month. Coalescence of the 5 sacral vertebrae does not occur until after birth and ends between about 25 and 30 years of age. This late differentiation of the bony foundation may be one of the reasons for the different cartilaginous surfaces between the os sacrum and os ilium. The SIG retains a smooth surface until puberty. However, the roughness that occurs thereafter is considered physiological (Vleeming et al. 2012).

11.4 Biomechanics

For the os sacrum, the keystone model is cited as an analogy, since the bone tapers caudally. However, it would then have to additionally taper ventrally according to the load bearing from the spine in order to contract the ossa ilii through the ligaments. However, the facies pelvina is wider than the facies dorsalis. The ligamentous apparatus may also be overestimated because of its powerful extension. For example, the axial interosseous dorsal ligamentous portions (14% of the total area) are heavily interspersed with fatty tissue and are only marginally more stable than the elastic ligaments of the spine, despite the absence of elastic elements. Despite the postulated load transfer, the articular surfaces are essentially parallel and not at right angles to the load coming from the spine. This makes little sense especially if the joint is an amphiarthrosis, as is often colocated. In fact, it can support six times the medially directed load, but can withstand only one-twentieth the axial load and one-half the torsional force (each compared to the lumbar spine) (Dreyfuss et al. 2004). With increasing hypomobility, the ratio becomes worse. Against this background, the joint can hardly be seen in the function often attributed to it as a shock absorber. In the movement during walking, the joint is rather to be considered differentiated in its parts and in total cranially more exposed to pressure or caudally more tensile load. The distance of the centre of gravity of the body is associated with changes in the stability of the joint. The further ventrally a vertical line through the centre of gravity lies in front of the joint, the stronger the rotational forces are due to the increasing virtual lever arm through the dorsally located centre of rotation of the combined joints. This is further amplified in the context of pregnancy (Vleeming et al. 2012).

Subchondrally, the bone layer of the os sacrum is thin and the cancellous bone runs at right angles to the cartilage. Iliacally, such regularities are not to be found, which speaks for strongly changing directions of loading and supports the previously expressed explanation of the differences. On both sides, vascularizations extending to just below the cartilage are conspicuous, which could be related to the conspicuousness of the joint in various rheumatic processes. In addition, in humans, vessels are sympathetically accompanied into the periphery, which creates a special innervation situation here that gains significance in the context of the peripheral coupling of the sympathetic to the nociceptive system. The irregular surface also suggests special features. Since the synovial fluid in particular determines the biomechanics and since this fluid is recruited on the one hand from cartilage (which, as described, has two different types with regard to the glycoprotein components) and synovia, and on the other hand its functionality depends essentially on the cartilage surface, this joint is a unique specimen to which the usual joint considerations cannot be transferred without further ado.

Internal rotation and abduction restrictions are associated with coxarthrosis. These relative malpositions of the os ilium can only be compensated to a very limited extent in the SIG and block the equilateral or both SIGs in their terminal positions. If the condition persists for a long time, it could be helpful in terms of pain therapy to pay attention to normalization of the position after insertion of a total hip arthroplasty. In general, a lowering of one side due to leg malpositions (real length differences of the legs are rarer) leads to an increased pressure load on this joint. This increases the tensile stress on the associated ligamentous apparatus, causing the proprioceptive system to react painfully at this point due to the continuous stimulus.

The mobility of the joint is controversial (McGrath 2004). The main focus is on sliding movements of the joint surfaces against each other. These take place around a central axis located in the dorsal ligamentous mass and thus outside the joint surfaces in the sense of a rotation. Rolling movements are only found to a lesser extent. The joint axis of one side runs obliquely through the pelvis. The movements of both joints, which are coupled via the pelvic ring, can be in the same or opposite directions. During flexion in the hip, the os ilium of the same side slides dorsocaudally and during extension cranioventrally. A nutation in the same direction in both joints rotates the os ilium dorsally (and anteriorly downward), a counter-nutation in the same direction in both joints rotates it ventrally. With left and right opposite nutations, as in walking, the pelvis torques and the symphysis comes under tension and pressure. Unlike damage to the iliosacral ligaments, rupture of the symphyseal groove or transection of the sacrotuberal or sacrospinous ligaments should have no effect on movement. In this regard, range of motion decreases with age and increases with pregnancy. While a rotation (radiologically) about the axis of 4 ° is reported for the normal situation, the figures are not well quantified in pregnancy. There is one study on physiological mobility, but it shows no difference between symptomatic and asymptomatic joints (Sturesson et al. 1994).

In general, all signs of degenerative joint disease are present in the SIG: Joint space narrowing, subchondral sclerosis, ankylosis, intra-articular gas formation and osteophyte formation.

Muscles with direct action on the joint are:

- M. gluteus maximus,
- M. piriformis,
- M. coccygeus,
- M. gluteus medius (via its fascia),
- M. biceps femoris, Caput longum (via the Lig. sacrotuberale),
- M. erector trunci,
- M. latissimus dorsi (via the fascia thoracolumbalis, which also makes reference to the connective tissue of the M. gluteus maximus).

Only the first two pull across the joint. Muscles with indirect effect on the joint via traction on the pelvis are mainly:

- M. iliopsoas,
- M. tensor fasciae latae,
- M. rectus femoris,
- M. obliquus abdominis externus,
- M. obliquus abdominis internus,
- Transversus abdominis.

The lumbar multifidi and obliquus abdominis internus muscles are tensed to stabilize the spine before movements are transmitted. In SIG pain, this response pattern is slowed. Conversely, tension of the transversi abdominis muscles reduces the mobility of the SIG. The activity patterns of the lumbopelvic muscles change in SIG pain, without a clear explanation being given to date. The muscles that influence the SIG and have a caudal effect, such as the gluteus maximus muscle or the caput longum of the biceps femoris muscle, also show delayed (gluteus) or increased (biceps) activity during SIG pain (Foley and Buschbacher 2006). Here, proprioceptive controls of the musculature via the SIG that are not yet understood are conceivable.

11.5 Innervation

The innervation of the SIG has long been controversial and continues to be so (Foley and Buschbacher 2006). The joint was considered the main source of deep-seated back pain until 1934 when disc herniations in the lumbar region began to come into focus. Since then, anatomical studies of SIG innervation have been secondary and textbooks have perpetuated old statements, some without examination of the original primary sources, some unreferenced. This also includes only slightly tested statements on the innervation of the joint from ventral branches of the spinal nerves. It can probably be considered certain that dorsal (mainly L5-S3) and ventral (L4 and L5) innervation are distinct (Forst et al. 2006; Murata et al. 2001). Innervation from dorsal branches of the spinal nerves is the most substantial (Forst et al. 2006; Fortin et al. 1999a; Murata et al. 2001). Somewhat more substantial were clinical studies that addressed, for example, Referred Pain and preferably made S1-S3 references. Overall, the prevailing view for a long time was that this joint did not require a distinct innervation because of alleged low mobility. Consistently, no meaningful work on central nervous processing of sensory input can be found in the literature. Part of the picture is also that an extensive search for peripheral receptive structures is only possible on very few sacroiliac joints because of the size of the tissue area to be assigned, or allows structures to be found rather randomly because of the small sample materials of patients with only few references (see, e.g., Sakamoto et al. 2001; Vilensky et al. 2002). It is known, however, that the distribution of corpuscular structures is not homogeneous.

What can be considered certain is a pronounced exchange of fibers of the dorsal nerves along the Ligg. iliosacralia, which are localized in the form of loops below the spina iliaca posterior superior. Hence, it is also referred to as a dorsal (posterior) sacral nerve plexus. Here, too, as in the rest of the spine, innervation takes place across segments, so that the exact localization seems to be less relevant than the relative information, i.e., the registration of change of state. From there, it is not surprising that Ikeda (1991) demonstrated ventral innervation from L5. The paper was published in Japanese and therefore limited in its distribution. The outputs of this plexus cross the crista sacralis lateralis (counterpart of the processus transversi of the fused vertebrae) laterally usually at the level of the corresponding tubercles of S2 and S3 (Roberts et al. 2014). If the associated spinal nerve branches are to be therapeutically visited at their exit, in addition to the clustering and distribution for the sacral branches, the exit point in the foramina sacralia dorsalia can also be considered. Here, the fibers always lie laterally in the foramina and converge already in this medial plane into the aforementioned transfer region via the crista sacralis lateralis to the joint, thus lying in the cranial foramina laterocaudally and in the caudal foramina laterocranially (Roberts et al. 2014). The resulting dorsal plexus is fed primarily from the lateral thicker branches of the dorsal spinal nerve branches of S1–S4. S5 and Coc1 participate from the hiatus sacralis. L5 is also regularly involved. The plexus lies under the dorsal ligamentous apparatus and usually forms a relatively thick nerve from the branches of the aforementioned loops, which supplies its surroundings and the sacrotuberous ligament. Lateral asymmetries are common (up to 30% are described) (Horwitz 1939; Nakagawa 1966).

The peripheral nerves found in the dorsal ligaments and the mechanoreceptors that probably depend on them have been little studied. Although both myelinated and unmyelinated fibers have been demonstrated, the ratio has not been determined, leaving it unclear whether the relationship is similar to other joints (50:50). Unmyelinated fibers may be nociceptive or vegetative. Association with vessel walls argues for sympathetic fibers. Efferent myelinated fibers are unlikely because no muscle can be addressed. Therefore, intraligamentous myelinated fibers are most likely proprioceptive. However, a precise classification of propriosensors is pending (Vilensky et al. 2002).

Since joints control the acting musculature via their propriosensory system, disruptions in the SIG are to be expected in these muscles. A differentiated analysis of such dependencies is often empirical knowledge. The entirety of the innervation of these muscles originates from Th12-S4. The innervation of the joint can be from L3-S4 and is thus much more extensive than in zygapophyseal joints. The existence of mechanoreceptors has been established.

Efferents and afferents (propriosensory) of a muscle can usually be assigned to the same spinal nerves. Conversely, muscles supplied by spinal nerves located further cranially (Th12-L2) also have only a slight influence on the SIG, such as the psoas muscle, or—expressed the other way round—cannot be controlled well by the SIG. It acts more on the covered facet joints. This situation, which will be described in more detail below, as well as the embryological origin of the joint, is evidence that the SIG must not be seen as analogous to the articulationes intervertebrales, but must be considered independently.

One particular observation should be mentioned, the confirmation and extension of which is pending on juvenile articular surfaces. In 2010, the working group around Szadek found intra-cartilaginous structures in SIG cartilage of cadavers with a mean age of 70 years, which showed a positive immune response for substance P and CGRP (calcitonin gene-related peptide) (Sadek et al. 2010). To date, there are no demonstrated nerve fibers in cartilage. Neuropeptides have not been searched for. This would support the theory that pain signals could originate from within the joint.

All studies focus on the pain system, so that the recently discovered changes in the proprioceptive system for pain perception after chronic stimulation have often been ignored, although e.g. Vilensky had already reported on this connection of the proprioceptive system with the pain system in 1998 (Vilensky 1998). In 1999, the SIG again came to attention as a source of low back pain. The number of nociceptive units here is at least a factor of 25 greater. However, they respond only to 70 g of load difference. For comparison: nociceptors of the lumbar intervertebral joints already react at 6 g difference, those of the disci at well over 200 g (241 g). To date, however, SIG pain as an entity is controversial. Our own investigations have shown that innervation occurs in approx. 30% via a long-distance nerve on the Ligg. sacroiliaca dorsalia from L3-L5. This means that a patient can have SIG pain if these rr. dorsales are disturbed, and a not insignificant percentage of patients do not have a problem at the SIG at all with SIG pain, but one finds spinal nerve damage further cranially.

Numerically, SIG-induced isolated low back pain is reported in 15–30% of the North American population (Borowsky and Fagen 2008; Dreyfuss et al. 2004; Yin et al. 2003). Because of the difficulty in delineation, a diagnosis ex juvantibus may well be a rapidly targetable measure. Conversely, however, there are no prospective studies comparing the resulting therapeutic modalities.

Zones of referenced pain lie dorsally essentially in the gluteal region or further cranially, especially in areas of L3-S2, suggesting an extrasympathetic connection to the associated spinal nerves, since there are no sympathetic nerve cells in the spinal cord below L2. Because the reference zones are also lateral to the thigh and may extend to the foot, sensations are rather nonspecific. Radiologically, the joint is also not very accessible and thus no study is available to indicate CT, MRI or bone scan with definite signs of pain from the SIG. Because of the very extensive and innervated ligamentous apparatus, intra-articular injection has limited sensitivity, as the main source of signals leading to pain perception cannot be fully reached from here. The volume that can be applied is also very limited with an approximate physiological amount of synovial fluid of about 1 mL. The accuracy of targeting the joint space is also limited anatomically because of the uneven articular surface and the cartilage coatings that sometimes split into lamellae (Fortin and Tolchin 1993). Furthermore, the joint is not cleanly addressable dorsally because of its incomplete capsule there.

References

Borowsky CD, Fagen G (2008) Sources of sacroiliac region pain: insights gained from a study comparing standard intra-articular injection with a technique combining intra- and peri-articular injection. Arch Phys Med Rehabil 89:2048–2056

Bowen V, Cassidy JD (1981) Macroscopic and microscopic anatomy of the sacroiliac joint from embryonic life until the eighth decade. Spine 6(6):620–628

Dreyfuss P et al (2004) Sacroiliac joint pain. J Am Acad Orthop Surg 12:255–265

Foley BS, Buschbacher RM (2006) Sacroiliac joint pain: anatomy, biomechanics, diagnosis, and treatment. Am J Phys Med Rehabil 85:997–1006

Forst SL, Wheeler MT, Fortin JD, Vilensky JA (2006) The sacroiliac joint: anatomy, physiology and clinical significance. Pain Physician 9:61–68

Fortin JD, Tolchin RB (1993) Sacroiliac joint provocation and arthrography. Arch Phys Med Rehabil 74:1259

Fortin JD, Kissling RO, O'Connor BL, Vilensky JA (1999a) Sacroiliac joint innervation and pain. Am J Orthop 28(12):687–690

Fortin JD, Washington WJ, Falco FJE (1999b) Three pathways between the sacroiliac joint and neural structures. AJNR Am J Neuroradiol 20:1429–1434

Horwitz MT (1939) The anatomy of (a) the lumbosacral nerve plexus – its relation to variations of vertebral segmentation, and (B), the posterior sacral nerve plexus. Anat Rec 74(1):91–107

Ikeda R (1991) Innervation of the sacroiliac joint – macroscopical and histological studies. J Nippon Med Sch 58:587–593

Kampen WU, Tillman B (1998) Age-related changes in the articular cartilage of human sacroiliac joint. Anat Embryol 198:505–513

McGrath MC (2004) Clinical considerations of sacroiliac joint anatomy: a review of function, motion and pain. J Osteopath Med 7(1):16–24

Murata Y, Takahashi K, Yamagata M, Takahashi Y, Shimada Y, Moriya H (2001) Origin and pathway of sensory nerve fibers to the ventral and dorsal sides of the sacroiliac joint in rats. J Orthop Res 19(3):379–383

Nakagawa T (1966) A study on the distribution of nerve filaments over the iliosacral joint and its adjacent region in the Japanese. J Jap Orthop Assoc 40: 419–430

Roberts SL, Burnham RS, Ravichandiran K, Agur AM, Loh EY (2014) Cadaveric study of sacroiliac joint innervation: implications for diagnostic blocks and radiofrequency ablation. Reg Anesth Pain Med 39:456–464

Sadek K, Hoogland PVJM, Zuurmond WWA, de Lange J, Perez RSG (2010) Possible nociceptive structures in the sacroiliac joint cartilage: an immunohistochemical study. Clin Anat 23:192–198

Sakamoto N, Yamashita T, Takebayashi T, Sekine M, Ishii S (2001) An electrophysiologic study of mechanoreceptors in the sacroiliac joint and adjacent tissues. Spine 26(20):E468–E471

Sturesson B, Selvik G, Uden A (1994) Movements of the sacroiliac joints: a roentgen stereophotogrammetric analysis. Spine 19:1475–1482

Vilensky JA (1998) Innervation of the joint and its role in osteoarthritis. In: Brandt KD, Doherty M, Lohmander LS (eds) Osteoarthritis. Oxford University Press, Oxford, pp 176–188

Vilensky JA, O'Connor BL, Fortin JD, Merkel GJ, Jimenez AM, Scofield BA, Kleiner JB (2002) Histologic analysis of neural elements in the human sacroiliac joint. Spine 27(11):1202–1207

Vleeming A, Schuenke MD, Masi AT, Carreiro JE, Danneels L, Willard FH (2012) The sacroiliac joint: an overview of its anatomy, function and potential clinical implications. J Anat 221:537–567

Walker JM (1986) Age-related differences in the human sacroiliac joint: a histological study; implications for therapy. JOSPT 7(6):325–334

Yin W, Wilard F, Carreiro J, Dreyfuss P (2003) Sensory stimulation-guided sacroiliac joint radiofirequency neurotomy: technique based on neuroanatomy of the dorsal sacral plexus. Spine 28(20):2419–2425

Radiofrequency Denervation of the Sacroiliac Joint

M. Schneider

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_12

12.1 Indication and Prevalence

The sacroiliac joint (SIG) as a possible generator of pain in the lower spine was first described by Goldwaith in 1911 (Goldthwait 1911) and was repeatedly mentioned in the literature in the following decades as a possible cause of unclear pain conditions. In 1994, Fortin's work, in which he was able to obtain pain responses in asymptomatic volunteers by distension of the joint capsule, presented radiating pain and was able to resolve it by intra-articular injection of local anesthetic (Fortin et al. 1994).

There are different sources on the prevalence of pain originating from the SIG. In essence, however, it is now thought that between 15% and 30% of all pain manifesting below L5 laterally is from the SIG (Cohen et al. 2013; Schwarzer et al. 1994).

However, an even higher rate is found when considering the prevalence of SIG-induced pain after lumbar fusion surgery. Publications from the 2000s show a prevalence of between 32% and 60% (Katz et al. 2003; Longo et al. 2014). Since lumbar fusion operations have increased massively in the last 20 years, the pain generator SIG should not be disregarded, especially in this patient group.

12

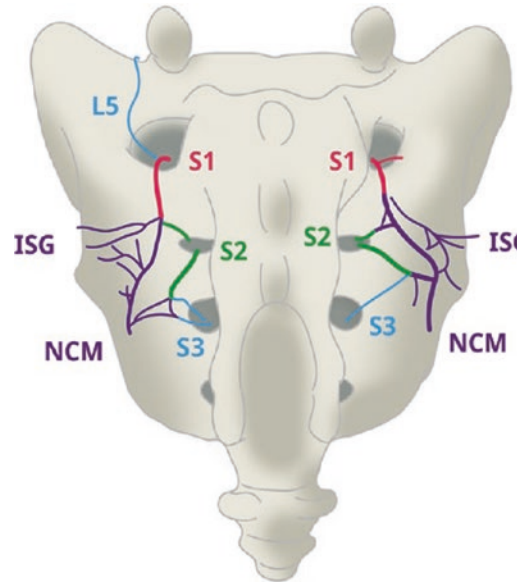
12.2 Preinterventional Diagnostics

In comparison to clinical examinations, for example in the case of radicular pain, the problem arises in the case of SIG that no single clinical examination is sufficient for the diagnosis of SIG-induced pain. It has therefore proved useful to perform a series of clinical provocation tests for SIG, with the greatest specificity and selectivity being achieved in the presence of 3 tests (Laslett et al. 2005; Young et al. 2003).

The tests can be performed quickly on an examination couch in the supine and lateral positions. In the supine position, the P4 test (Posterior Pelvic Pain Provocation Test), the Faber test and the distraction test can be performed, and in the lateral position, the Gaenslen test and the compression test (Szadek et al. 2009).

Even the presence of 3 positive provocation tests does not allow a confirmed diagnosis. Here, the golden standard is currently still the two-stage intra-articular injection (double SIG block) to verify the diagnosis (Dussault et al. 2000).

Critically, however, it has been noted in recent years that only the intraarticular receptors are addressed in the case of an intraarticular block. Anatomically speaking, however (Chap. ► 11), the SIG complex consists of almost 2/3 of the posterior ligamentous apparatus, a fact to which several studies have drawn attention (Ikeda 1991). Consideration has been given as to why one might not anesthetize the dorsal branch of the sacrum corresponding to the S1–S3 foramina in a manner analogous to lumbar blocks on the medial branch. Extensive anatomical studies (Grob et al. 1995; Ikeda 1991; Roberts et al. 2014; Willard 1998) have shown that the main branches arise from S1 to S3, which then travel to the dorsal ligamentous apparatus and also to the joint. One study (Roberts et al. 2014) found that in 8%, the dorsal branch at L5 is also still involved. This is illustrated in ◘ Fig. 12.1.



◘ **Fig. 12.1** Distribution of dorsal branches at SIG: L5 8% (% of branches found in cadaver study), S1 and S2 100%, S3 88%. (According to Roberts et al. 2014). *NCM* Nervi clunium medii, *Lila* posterior sacral network ("posterior sacral network")

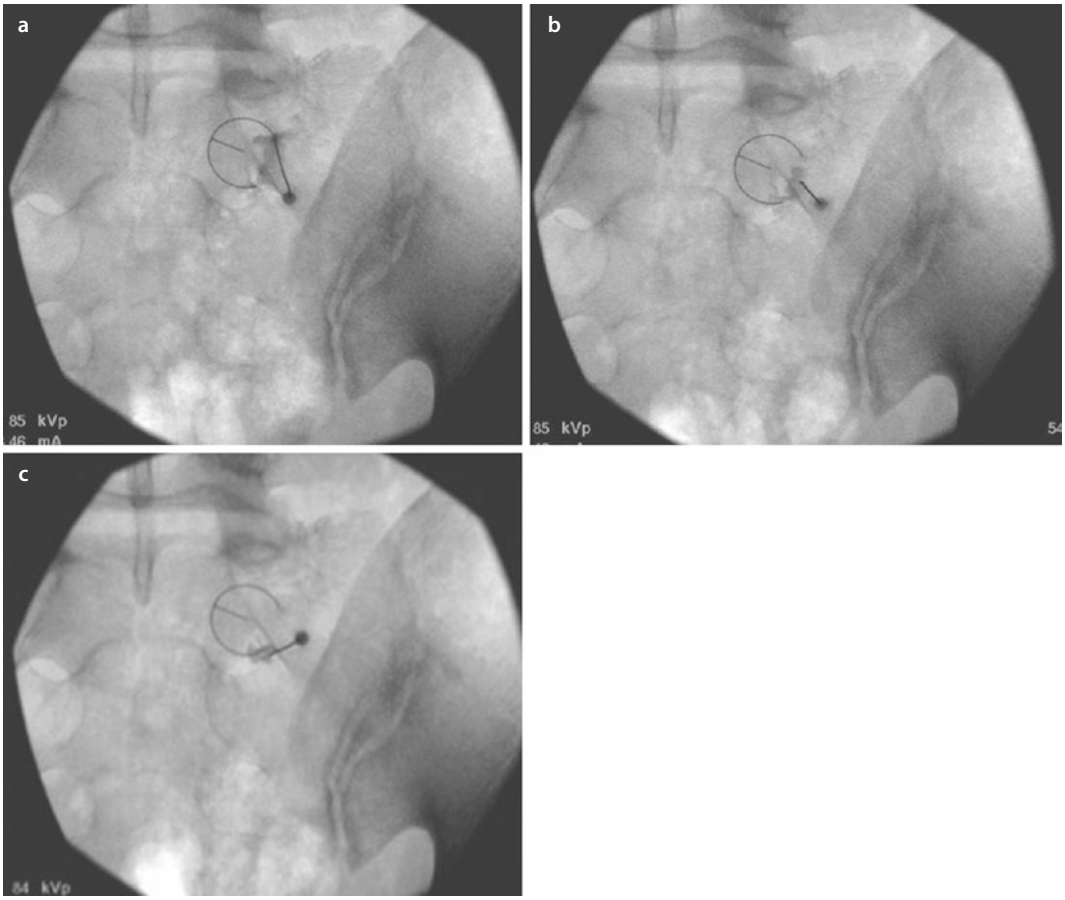


Fig. 12.2 **a–c** Multiside multilevel injection. **a** Upper target point at S1; **b** middle target point at S1; **c** lower target point at S1. (Courtesy of Halyard)

In contrast to the lumbar spine, however, the anatomy of the dorsal branches on the sacrum is highly variable. This affects not only the exit of the site from the foramen but also the distance from the sacrum. Dreyfuss et al. (2008) found that a single injection at a foramen does not lead to the desired success. Only multiple injections according to a precise protocol (multisided multilevel injections) reach the potential dorsal branches at S1–S3 to the desired extent (Dreyfuss et al. 2009) (Fig. 12.2a–c Halyard injections).

12.3 Necessary Instruments

The anatomical considerations (▶ Sect. 12.1) also explain why, in current work and also in reviews, conventional radiofrequency therapy, in which only a relatively small lesion zone is reached, does not provide sufficient pain relief. For this reason, it was necessary to develop radiofrequency techniques with a larger lesion zone.

Several techniques are currently on the market, including the Cosman palisade technique (▶ www.cosmanmedical.com) and the Simplicity™ electrode from Abott, formerly St. Jude Medical (▶ www.sjm.de; ▶ www.abbott.com), but both have shown poor results in controlled studies. Both techniques use a bi- or multipolar method, i.e., the lesion zone is created between 2 or more electrodes, not around an electrode tip.

Since there are several systems on the market, some of which are completely different, this chapter will focus on the radiofrequency system that currently has the best evidence in the available literature.

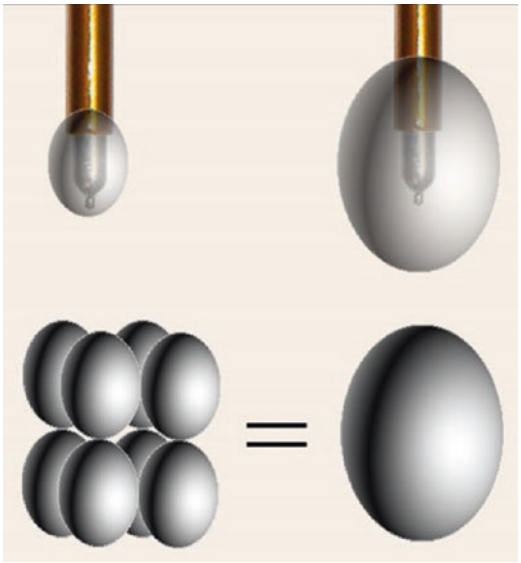


Fig. 12.3 Comparison of lesion size for conventional (*left*) and water-cooled radiofrequency electrode (*right*) (factor 8). (Courtesy of the company Halyard)

In order to do justice to the special features of both the individual anatomy of the sacrum (which varies from patient to patient) and the individual nerve course, a water-cooled electrode was developed by the Baylis company from Canada. This was used with the same protocol as described by Dreyfuss et al. (2009), namely with 3 lesions each at S1 and S2 and 2 lesions at S3 as well as a lesion on the dorsal branch at L5. The best evidence to date has been shown for this in various papers (▶ Sect. 12.6). The cooled radiofrequency system is currently marketed by Halyard Health (▶ www.halyardhealth.de).

The good results are explained by the fact that, due to the water cooling of the electrode, the tissue lying directly at the tip of the cannula is cooled and thus a larger isotherm can be achieved with this method and thus a larger lesion zone (Fig. 12.3). RCT studies are also available for this method (▶ Sect. 12.6).

12.4 Pre-Intervention Education

The risks are essentially the same as for lumbar facet joint denervation and facet block (▶ Chap. 7). The patient must be informed about the risk of bleeding and infection. Accidental injury to spinal nerves is unlikely in the sacral region because, in contrast to the lumbar block, the dorsal branch is addressed outside the foramen, thus ensuring a much greater distance to the spinal nerves S1–S3. Only in the case of L5 on the dorsal branch is it necessary to pay attention to the exact position of the radiofrequency cannula, since the L5 spinal nerve lies directly ventrocaudal here.

As with lumbar facet denervation, coagulation of sensitive skin branches may cause a sunburn-like phenomenon or a temporary furiness in the sacral area. This usually disappears over the course of a few weeks, but should be communicated to the patient.

12.5 Implementation of the Intervention

The intervention is performed with the patient in the prone position. Sterility should be as in surgery with draping of the surgical area. In fluoroscopy, the floor plate of LWK5 and the cover plate of the sacrum are adjusted and, as in lumbar denervation, the dorsal branch at L5 is visualized first (Fig. 12.4). Local anesthesia of the entry point and the branch canal. This is followed by adjustment of the sacral foramina S1–S3 and, if necessary, placement of the epsilon for better orientation. This is achieved by tilting the C-arm slightly caudocranially depending on the curvature of the sacrum and then pivoting a few degrees ipsilaterally until the anterior and posterior foramina largely project over each other. Target positions on the left side 8–10 mm lateral to the center each are 9:30, 8:00, and 6:30 for S1 and S2, and positions 2:30 and 4:00 for S3 (Fig. 12.5). At a distance from the center less than 8–10 mm, there is a greater risk of lesioning cutaneous branches.

A lateral image prevents malposition in the sacral canal or cortical intrusion (Fig. 12.6).

After the position of the radiofrequency cannula has been documented, the stylet is removed, the electrode is inserted and, if nec-

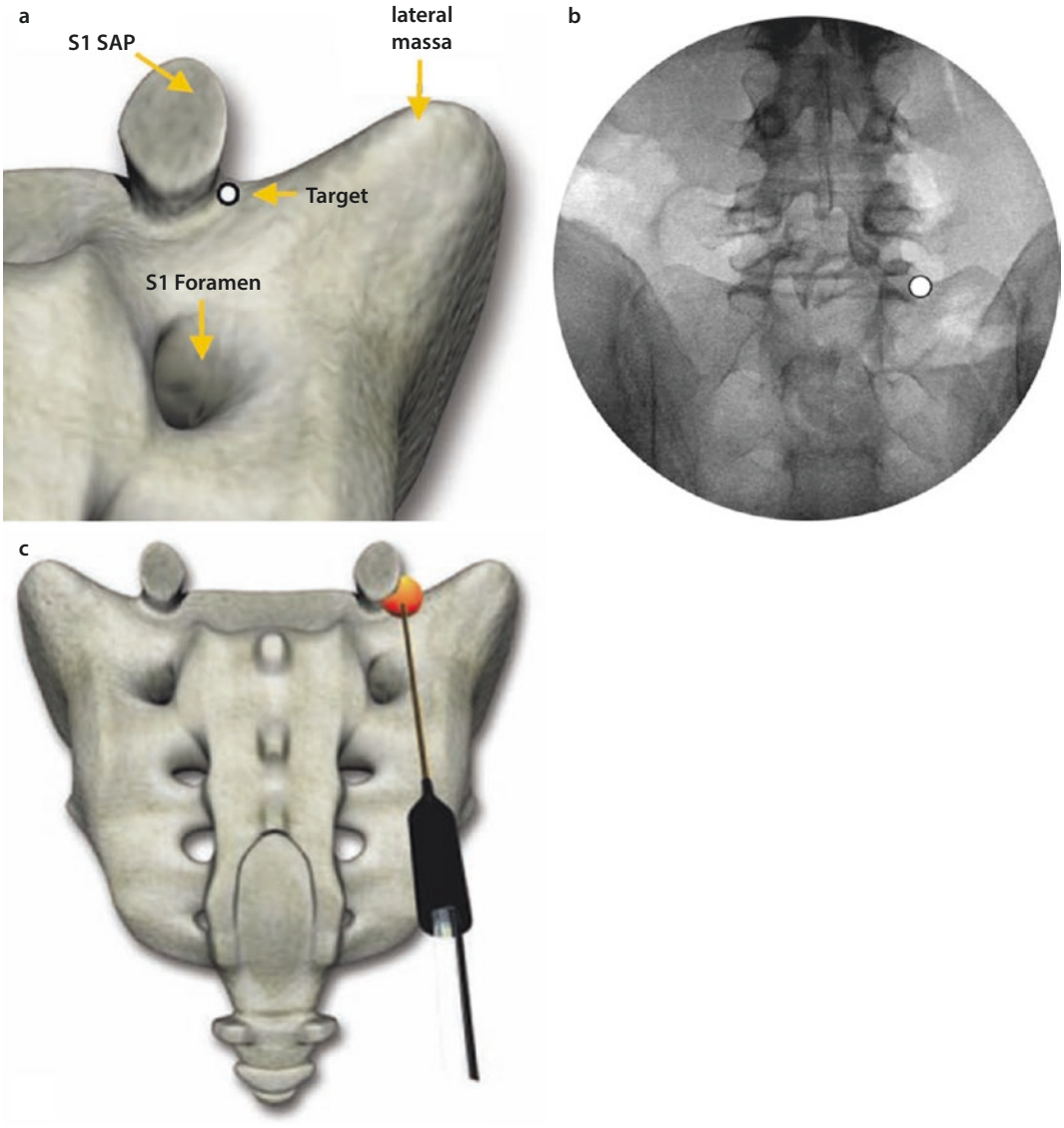


Fig. 12.4 **a–c** Target for dorsal branch L5. **a** Anatomical location; *SAP* superior articular process of S1; **b** Radiological image; **c** Location of radiofrequency cannula on dorsal branch L5. (With kind permission of the Halyard company)

essary, sensitive and motor testing at 50 Hz and 2 Hz is performed, taking into account the impedance (100–500 ohms).

Then, a maximum of 1 mL of local anesthetic is injected and the lesion is placed at 60 °C for 2.30 min (Fig. 12.7). Normally, one cutaneous puncture is sufficient for each foramen.

Since the electrodes expect a plausible temperature before the lesion (if the temperature is too high or too low, no lesion is possible, the device switches off), 2 lesions further apart should always be carried out one after the other, so that the tissue can be cooled down in between.

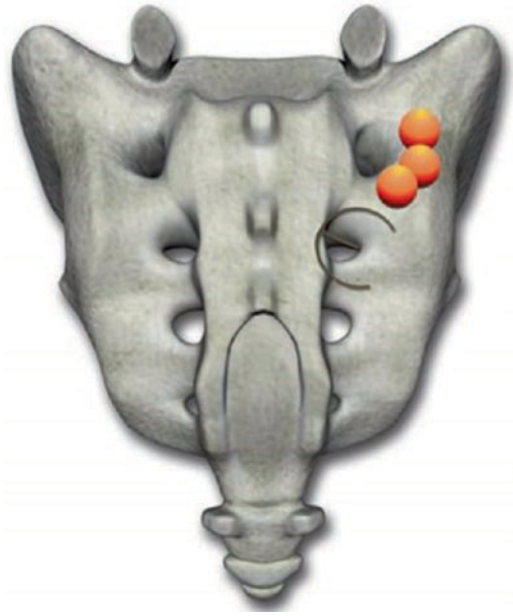


Fig. 12.5 Target points at S1, location of epsilon at S2. (With kind permission of the company Halyard)

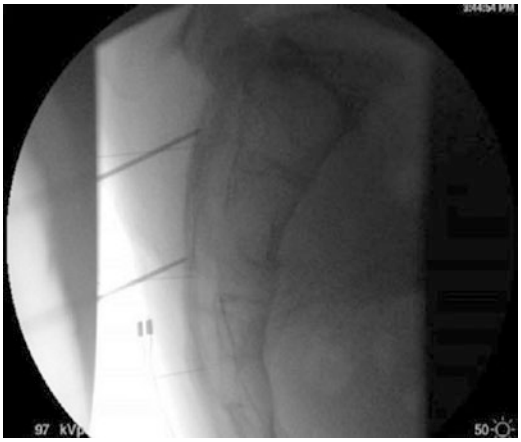


Fig. 12.6 Determining the adequate depth in the lateral beam path. (Courtesy of the company Halyard)

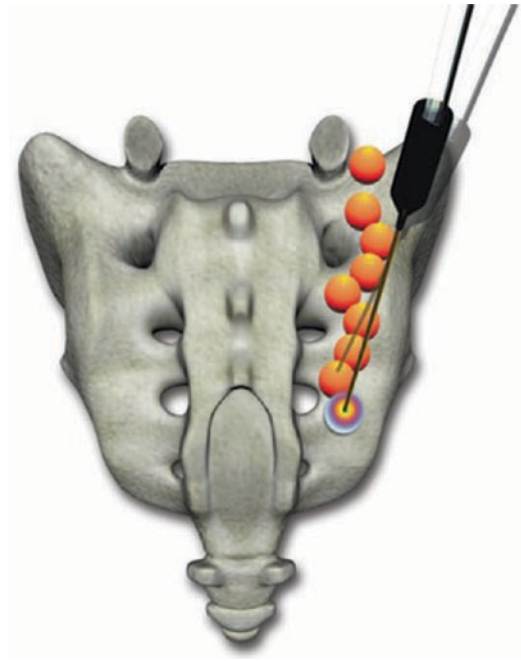


Fig. 12.7 Lesion sites of a complete SIG denervation (water-cooled procedure). (Courtesy of the Halyard Company)

12.6 Possible Complications

In addition to the usual risks associated with interventions with needles, such as the risk of bleeding and the risk of infection due to the spread of germs, a lesion of the spinal nerves must be minimized with radiofrequency denervation at the SIG. The spinal nerve L5 is particularly at risk here, as it is easy to slip over the edge of the massa lateralis into the depths during radiofrequency of the dorsal branch at L5. Sensitive testing at 50 Hz can avoid such a misalignment without damaging the nerve. If radiation into the L5 dermatome

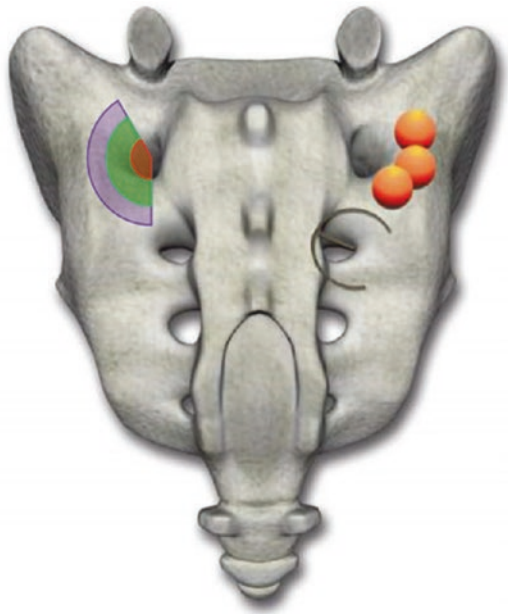


Fig. 12.8 *Left* optimal distance (*green*) to the foramen. (Courtesy of the Halyard Company)

occurs during sensitive testing, the test must be stopped immediately and the needle repositioned.

Of course, there is a similar risk with the S1–S3 foramina. However, if you see a clear distance between the radiofrequency cannula and the foramen in the image converter, the risk is certainly lower. Sclerosing the nerve too close to the foramen can also cause dysesthesia of the skin. However, this should be avoided by using the Epsilon (Fig. 12.8).

Nevertheless, even if the distance from the foramen is correct, the patient should be informed that such sunburn-like dysesthesias may occur, which usually disappear after a few weeks.

12.7 Results in the Literature

In a pilot study on the treatment of SIG pain with a small number of cases (9 patients), Cohen and Abdi reported that after block of the medial branches of L4 and L5 and the lateral branches of S1–S3 with an initial pain relief of more than 50%, 8 patients showed a persistent pain improvement of more than 50% over a period of 9 months (Cohen and Abdi 2003).

For cooled radiofrequency therapy, Kapural et al. (2008) published an initial case series, and in the same year a randomized controlled trial of water-cooled radiofrequency denervation was published in PainMed by Cohen et al. (Cohen et al. 2008). This was followed 4 years later by a randomized, placebo-controlled study by Patel et al. (2012).

Stelzer also published an extensive case study in PainMed with 126 patients who were selected by examination and showed a 50% improvement in pain after intra-articular SIG block (Stelzer et al. 2013). Here, according to an appropriate protocol, the L5-S3 branches were denervated with water-cooled radiofrequency electrodes. The follow-up period was for a maximum of 20 months; after 6–12 months, more than 50% pain improvement was found in 71% of patients, and after 12 months, still in 48% of patients. Stelzer et al. also investigated the course of taking opioids and non-steroidal anti-inflammatory drugs (NSAIDs). The results are shown in Fig. 12.9.

Last but not least, the cost savings due to a reduced use of medication led to the introduction of this work when radiofrequency therapy of the sacroiliac joint was included in the insurance catalogue of benefits in Belgium.

In their work on cooled radiofrequency denervation in the treatment of painful sacroiliac joint, Ho et al. (2013) still showed significant improvements in pain scores from 7.4 to 3.1 in the 2-year results (Fig. 12.10).

The good study situation has led to Van Zundert et al. (2011) describing both conventional radiofrequency therapy and water-cooled radiofrequency treatment in their book (see also ▶ Chap. 7) with regard to SIG pain, but only cooled radiofrequency treatment received a recommendation $2B^{+}$. Similar findings were made in the comprehensive presentation of the American Society of Interventional Pain Physicians (ASIPP) guidelines. Only radiofrequency treatment with water-cooled electrodes received a good level of evidence (grading "good", "fair" and "limited") (Manchikanti et al. 2013).

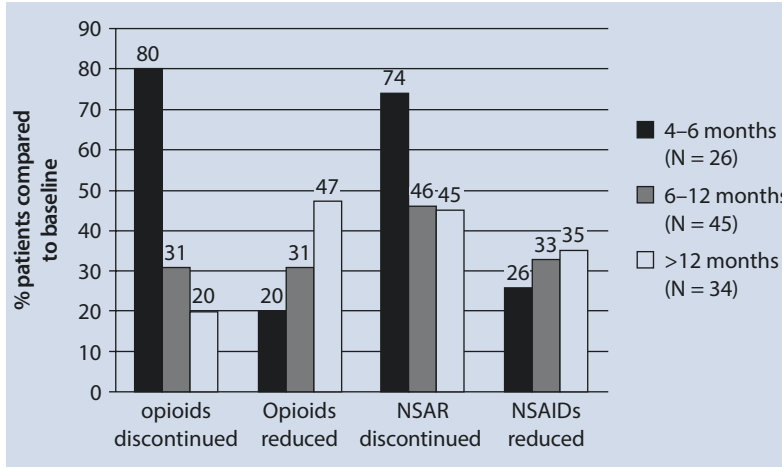


Fig. 12.9 Reduction in medication use after water-cooled SIG denervation. (After Stelzer 2013)

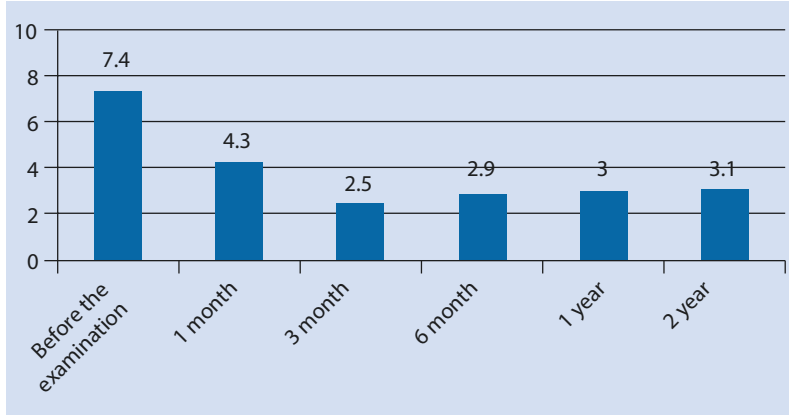


Fig. 12.10 Average pain scores (using the Numeric Rating Scale) over time after cooled radiofrequency denervation of the sacroiliac joint. (According to Ho et al. 2013)

A multi-center study of the Simplicity electrode is currently being conducted in Berlin and Cologne, but the results have not yet been published.

12.8 Conclusion and Clinical Relevance

Complaints that extend below L5 laterally to the gluteal fold, sometimes beyond, can often be attributed to the sacroiliac joint by the appropriate clinical tests and targeted blocks.

Presumably because of the difficulty of clinical examination and the lack of correlation with imaging, these complaints were frequently assigned to nonspecific back pain. The use of provocation tests (▶ Sect. 12.1) and the blocks of the dorsal branches L5-S3 according to the procedure propagated by Dreyfuss et al. (2009), which have been recommended for almost 10 years, have led to the specific diagnosis of SIG dysfunction being made more often. In the present chapter, it is pointed out that the sacroiliac joint alone is not the addressee of the procedures, but much

more the entire SIG complex must be considered, which also includes the dorsal ligamentous structures, which are also massively provided with nociceptors.

In addition to conventional radiofrequency therapy, there are several procedures on the market that all aim to denervate the dorsal branches of the sacral foramina. However, based on the current state of studies, water-cooled radiofrequency denervation is favored by various parties.

In appropriate courses, not only the technical execution of the corresponding injections should be taught, but in parallel more manual examination techniques should be taught, whose positive proof (at least 3 provocation tests positive) makes the presence of a SIG dysfunction probable.

References

Cohen SP, Abdi S (2003) Lateral branch blocks as a treatment for sacroiliac joint pain: a pilot study. Reg Anesth Pain Med 28:113–119

Cohen SP, Hurley RW, Buckenmaier CC, Kurihara C, Morlando B, Dragovich A (2008) Randomized placebo-controlled study evaluating lateral branch radiofrequency denervation for sacroiliac joint pain. Anesthesiology 109:279–288

Cohen SP, Chen Y, Neufeld NJ (2013) Sacroiliac joint pain: a comprehensive review of epidemiology, diagnosis and treatment. Expert Rev Neurother 13:99–116

Dreyfuss P, Snyder BD, Park K, Willard F, Carreiro J, Bogduk N (2008) The ability of single site, single depth sacral lateral branch blocks to anesthetize the sacroiliac joint complex. Pain Med 9:844–850. https://doi.org/10.1111/j.1526-4637.2008.00517.x

Dreyfuss P, Henning T, Malladi N, Goldstein B, Bogduk N (2009) The ability of multi-site, multi-depth sacral lateral branch blocks to anesthetize the sacroiliac joint complex. Pain Med 10:679–688. https://doi.org/10.1111/j.1526-4637.2009.00631.x

Dussault RG, Kaplan PA, Anderson MW (2000) Fluoroscopy-guided sacroiliac joint injections. Radiology 214:273–277. https://doi.org/10.1148/radiology.214.1.r00ja28273

Fortin JD, Aprill CN, Ponthieux B, Pier J (1994) Sacroiliac joint: pain referral maps upon applying a new injection/arthrography technique. Part II: clinical evaluation. Spine (Phila Pa 1976) 19:1483–1489

Goldthwait JE (1911) The lumbo-sacral articulation; an explanation of many cases of lumbago, sciatica and paraplegia. Boston Med Surg J 164:365–372

Grob KR, Neuhuber WL, Kissling RO (1995) Innervation of the sacroiliac joint of the human. Z Rheumatol 54:117–122

Ho K-Y, Hadi MA, Pasutharnchat K, Tan K-H (2013) Cooled radiofrequency denervation for treatment of sacroiliac joint pain: two-year results from 20 cases. J Pain Res 6:505

Ikeda R (1991) Innervation of the sacroiliac joint. Macroscopical and histological studies. Nihon Ika Daigaku Zasshi 58:587–596. https://doi.org/10.1272/jnms1923.58.587

Kapural L, Nageeb F, Kapural M, Cata JP, Narouze S, Mekhail N (2008) Cooled radiofrequency system for the treatment of chronic pain from sacroiliitis: the first case-series. Pain Pract 8:348–354

Katz V, Schofferman J, Reynolds J (2003) The sacroiliac joint: a potential cause of pain after lumbar fusion to the sacrum. J Spinal Disord Tech 16:96–99

Laslett M, Aprill CN, McDonald B, Young SB (2005) Diagnosis of sacroiliac joint pain: validity of individual provocation tests and composites of tests. Man Ther 10:207–218. https://doi.org/10.1016/j.math.2005.01.003

Longo UG, Loppini M, Berton A, Laverde L, Maffulli N, Denaro V (2014) Degenerative changes of the sacroiliac joint after spinal fusion: an evidence-based systematic. Br Med Bull 112:47–56

Manchikanti L et al (2013) An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part II: guidance and recommendations. Pain Physician 16: S49–S283

Patel N, Gross A, Brown L, Gekht G (2012) A randomized, placebo-controlled study to assess the efficacy of lateral branch neurotomy for chronic sacroiliac joint pain. Pain Med 13:383–398. https://doi.org/10.1111/j.1526-4637.2012.01328.x

Roberts SL, Burnham RS, Ravichandiran K, Agur AM, Loh EY (2014) Cadaveric study of sacroiliac joint innervation: implications for diagnostic blocks and radiofrequency ablation. Reg Anesth Pain Med 39:456–464. https://doi.org/10.1097/AAP.0000000000000156

Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N (1994) Clinical features of patients with pain stemming from the lumbar zygapophysial joints. Is the lumbar facet syndrome a clinical entity? Spine (Phila Pa 1976) 19:1132–1137

Stelzer W, Aiglesberger M, Stelzer D, Stelzer V (2013) Use of cooled radiofrequency lateral branch neu-

rotomy for the treatment of sacroiliac joint-mediated low back pain: a large case series. Pain Med 14(1):29–35

Szadek KM, van der Wurff P, van Tulder MW, Zuurmond WW, Perez RS (2009) Diagnostic validity of criteria for sacroiliac joint pain: a systematic review. J Pain 10:354–368

Van Zundert JV, Hartrick C, Patijn J, Huygen F, Mekhail N, van Kleef M (2011) Evidence-based interventional pain medicine according to clinical diagnoses. Pain Pract 11:423–429. https://doi.org/10.1111/j.1533-2500.2011.00490.x

Willard F (1998) The long posterior interosseous ligament and the sacrococcygeal plexus. In: Third interdisciplinary world congress on low back and pelvic pain, Chicago

Young S, Aprill C, Laslett M (2003) Correlation of clinical examination characteristics with three sources of chronic low back pain. Spine J 3:460–465. https://doi.org/10.1016/S1529-9430(03)00151-7

Endoscopic Facet Denervation

G. Ostermann and A. Igressa

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_13

13.1 Indication

With increasing age and a reduction in the height of the intervertebral discs, the load on the facet joints increases, which can lead to painful changes. Like every joint in the human body, the facet joint also has a joint capsule which, in addition to guiding the joint, also ensures that the joint is supplied by vessels and nerves. A nearby nerve, the ramus dorsalis medialis, is responsible for the transmission of pain impulses from the joint and joint capsule.

If irritation of the joint capsule occurs, the pain is transmitted via this branch as back pain to the pain centres in the spinal cord and brain and is then referred to as a "facet syndrome".

In addition to degenerative changes with age, the following factors can also be causes of painful facet joints:

- Whiplash accident,
- Overloading and incorrect loading due to e.g. sport or heavy physical work,
- Overweight in combination with bad posture,
- general lack of movement.

Facet syndrome mainly affects people over the age of 50. Mostly this clinical picture occurs in the area of the lower lumbar spine, but can also affect the facet joints of the cervical spine, rarely those of the thoracic spine.

Minimally invasive facet denervation in the form of cryodenervation and thermocoagulation has been an effective and safe method of treating so-called facet syndrome for many years (Leggett et al. 2014). As a unique feature in the treatment of facet joint syndrome, endoscopic facet denervation is a visually controlled procedure (Fig. 13.1).

Although the anatomical course of this nerve pathway is generally well known and uniform, data are published time and again that demonstrate not inconsiderable deviations for individual cases. The authors of these reports emphasize that good endoscopic visual control is important in order to really eliminate the nerve accurately and effectively.

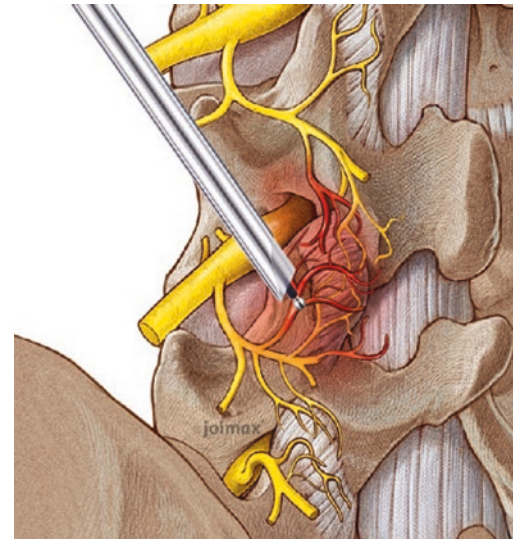


Fig. 13.1 Endoscopic facet denervation in the region of the facet joint L4/5. (Courtesy of joimax® GmbH, Karlsruhe)

This makes it possible for the first time to achieve a complete destruction of all target structures in the form of the rr. dorsales of the spinal nerve on one side and the facet joint capsule itself including the nerve structures running in it on the other side under direct endoscopic view (Jeong et al. 2014).

Since endoscopic facet denervation is usually performed under intubation anesthesia, the patient's compliance with the procedure is not important. It is important to note that endoscopic facet denervation uses a monopolar current. This covers a large area at the target point where the nerve structures to be denervated run. The probability of the recurrence of symptoms can thus be reduced to a minimum.

The neuronal supply of the facet joints takes place through the spinal nerve emerging from the neuroforamen. A supply of the adjacent segments via the ramus posterior can also be regarded as certain. The nervous supply of the opposite side via the ramus communicans is also known (Bogduk et al. 1982). This situation underlines the importance of surgical treatment of both the adjacent segments and the opposite side as an overall therapeutic concept.

The presence of a confirmed facet syndrome can be considered an indication for endoscopic facet joint denervation. Furthermore, a positive response to infiltrations of the facet joints can be considered an indication for endoscopic facet denervation, as well as the condition after frustrated facet thermocoagulation or facet cryodenervation. Endoscopic facet denervation is also indicated in cases of resistance to conservative treatment.

Overall, endoscopic facet denervation can be used to prevent chronicity of symptoms.

An ongoing pension procedure as well as a reliably diagnosed neuropsychological disease can be regarded as a relative contraindication.

Absolute contraindications are anticoagulation that cannot be interrupted (exception: ASS), tumor disease in the target area, and the patient's inability to be anesthetized.

13.2 Preinterventional Diagnostics

A detailed anamnesis and the obligatory physical examination of the patient by the attending physician are unavoidable and take first place in the diagnosis. A neurological exploration should be performed to exclude neurological deficits and typical pain points should be clarified by palpation.

The complaints most frequently expressed by affected patients are of a dull, piercing, stabbing diffuse nature and are difficult to localize, especially if they persist over a longer period of time. Often it is a matter of so-called start-up pain after prolonged lying or sitting, which recedes with movement. Pain usually intensifies with reclination of the lumbar spine. If the pain radiates, it often extends dorsolaterally to or just below the back of the knee.

Laboratory tests should be performed to rule out other possible causes of the back pain, such as inflammatory diseases.

It is also important to exclude pathomorphological findings in neuroradiological diagnostics in the sense of herniated discs, spinal canal stenosis, olistheses or similar diseases in which endoscopic facet denervation is very unlikely to lead to the desired success. In some patients, MRI diagnostics may reveal facet joint effusions or facet joint hypertrophies. However, these should only be regarded as additional criteria and not as a mandatory prerequisite for endoscopic facet denervation.

Since, in general, clinical tests do not have sufficient sensitivity and specificity with regard to clarifying the facet joint as the cause of the patient's complaints (Hancock et al. 2007), diagnostic infiltrations with short-acting local anesthetic of the corresponding facet joints must be performed in the course of the diagnostic clarification. Only if the patient's response to the diagnostic infiltrations is positive should the performance of endoscopic facet denervation be considered. Here it is important that there are always at least two positive responses; according to current findings, a block with placebo should also be performed. Only in this way can the greatest possible certainty of the presence of facet joint syndrome be achieved (Bogduk 2010).

13.3 Necessary Instruments

To perform endoscopic facet joint denervation, the Joimax company has developed a set of instruments specifically for this therapy procedure, which contains all the instruments required for the procedure (◘ Fig. 13.2). The patient is positioned on a radiolucent, electrically adjustable operating table. A C-arm is also obligatory for exact localization of the anatomical structures as well as for clear placement of the optics.

Furthermore, a standard orthopaedic endoscopy tower with a camera, which must have a bayonet connection, as well as a cold light source and roller pump are required.

The actual endoscopy screen for facet denervation contains special optics, the access instruments, the working channel and various rangeurs for removing soft tissue. This allows an optimal view of the target structures to be achieved. Furthermore, a special monopolar probe is required. This can be connected to a commercially available high-frequency gener-

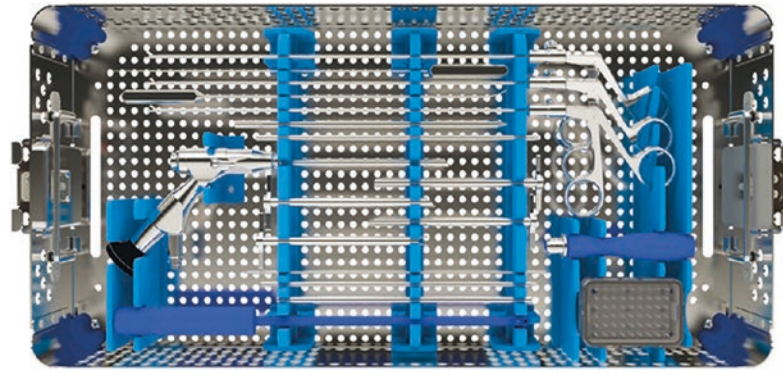


Fig. 13.2 Complete instrument set. (Courtesy of joimax® GmbH, Karlsruhe)

ator via a handpiece, which is also included on the sterile tray.

If the procedure is to be performed on a patient with a pacemaker or implanted defibrillator, the monopolar electrode must be omitted in favor of bipolar coagulation. This does not have a negative impact on the outcome, only the incision-suture time is prolonged.

The procedure is usually performed under intubation anesthesia in a standard operating room. The length of stay is 3 nights postoperatively. The probability of the occurrence of postoperative complications can thus be reduced to a minimum.

13.3.1 Costs

The multicyte instrumentation from the Joimax company required to perform the procedure costs approx. 16,000 € per screen including VAT. This includes all necessary instruments as well as the optics. Furthermore, disposable items are required for each operation, which together cost approx. 285 € incl. VAT. This includes the cover, the monopolar probe as well as the access kit.

The order address is: joimax® GmbH, Amalienbadstraße 41, Raumfabrik 61, 76,227 Karlsruhe, Germany.

13.4 Pre-Intervention Education

The patient must be informed about the forthcoming procedure both verbally and in writing.

Important points here are bleeding and secondary bleeding, inflammation up to and including spinal abscess, nerve injury with accompanying paresis and insensitivity of the corresponding supply area, as well as dura injury with cerebrospinal fluid loss syndrome. It is also important to inform the patient that success of the procedure cannot be guaranteed and that surgical follow-up is possible if complications occur. The patient should be informed that there is no precise information in the literature regarding the extent of the expected pain reduction. The patient should also be informed about the radiation exposure.

Due to the general anaesthesia, a separate anaesthesiological information of the corresponding department is also obligatory at least 24 h before the planned intervention. If the patient has any known internal or other pre-existing conditions, he/she should be presented to the anaesthetist a few days before the planned procedure so that any necessary preliminary examinations can be carried out or existing findings on the condition of the pre-existing condition can be provided.

13.5 Implementation of the Intervention

Endoscopic facet joint denervation is performed under general anesthesia of the patient as standard. This may seem time-consuming, but there are perfectly understandable reasons for it.

The procedure routinely treats the lower 3 segments LW3/4-LW5/SW1 on both sides. From the outside, this can be done through only two skin incisions of approx. 0.7 cm, but it means that a total of 12 target regions are coagulated in depth. Together, this makes up a large area, which can certainly be considered painful.

The patient, who is under intubation anaesthesia, is positioned in the abdominal position (Fig. 13.3). After sterile washing and draping, two 0.7 cm skin incisions are made under X-ray control at the lateral edge of the transverse process of the LWK5 on both sides. The beam path should be parallel to the cover plate of the LWK5 (Fig. 13.4).

Next, insert the spinal needle to the medial edge of the transverse process at the transition to the articular facet. After removing the stylet, the guide wire is inserted. The dilator is inserted over the guide wire (Fig. 13.5) and the working channel is inserted above it (Fig. 13.6).

Until the working channel is correctly placed, each step should be documented by a short X-ray check. The endoscope can now be inserted via the working channel (Fig. 13.7).

The first soft connective tissue to appear can be removed with the aid of the rangeur (Fig. 13.8), and any bleeding that occurs

Fig. 13.3 De-lordosed positioning of the patient. (Courtesy of joimax® GmbH, Karlsruhe)

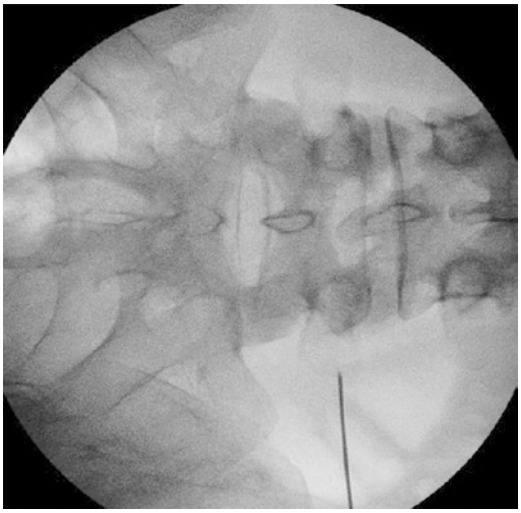


Fig. 13.4 Position of the skin incision in the a.p. radiographic corridor, parallel to the cover plate LWK5

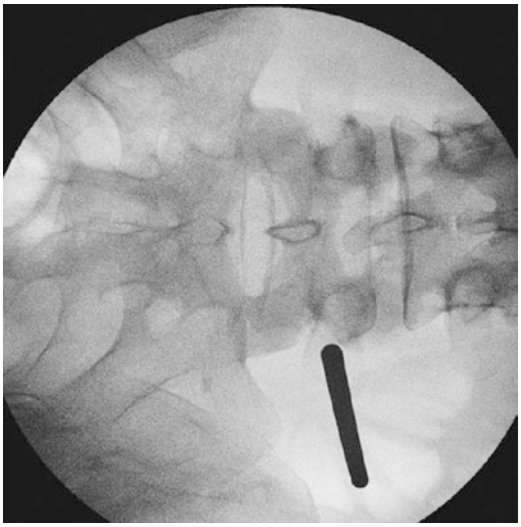


Fig. 13.5 Position of the dilator at the medial border of the proc. transversus LWK5 (here after already removed guide wire)

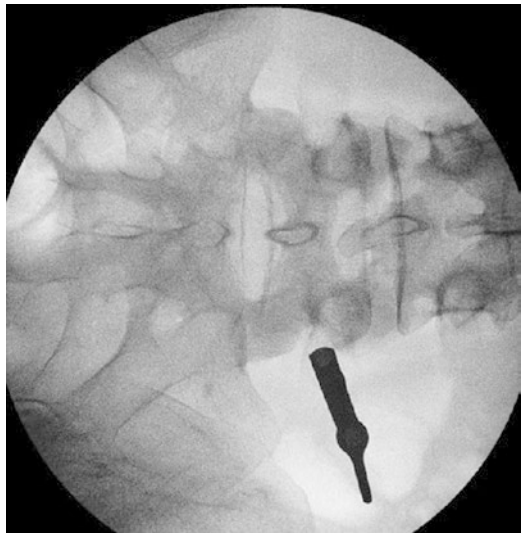


Fig. 13.6 Position of the working channel in the region of the proc. transversus LWK5

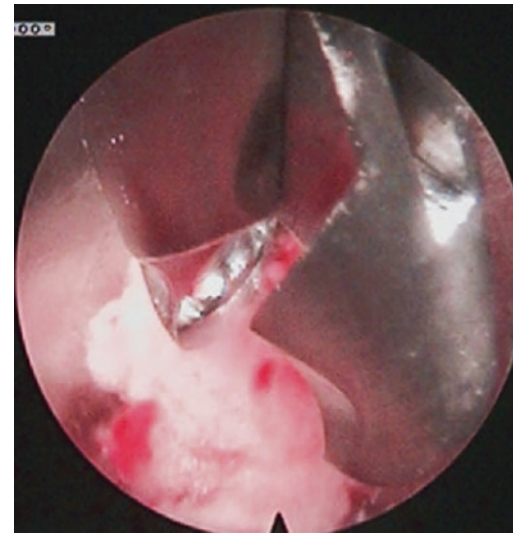


Fig. 13.8 Removal of soft tissue using Rangeur

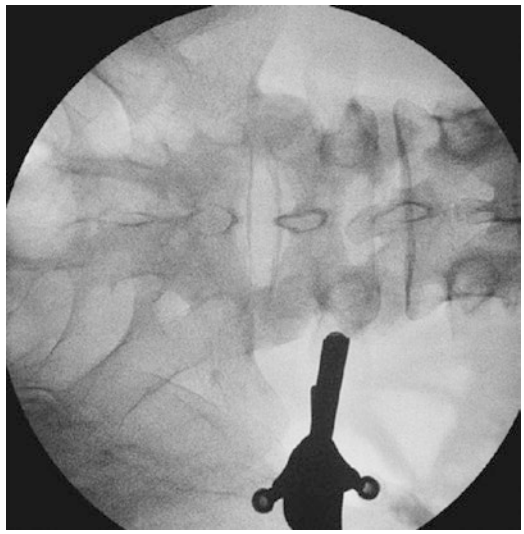


Fig. 13.7 Inserted endoscope at the target point of the proc. transversus LWK5 right side

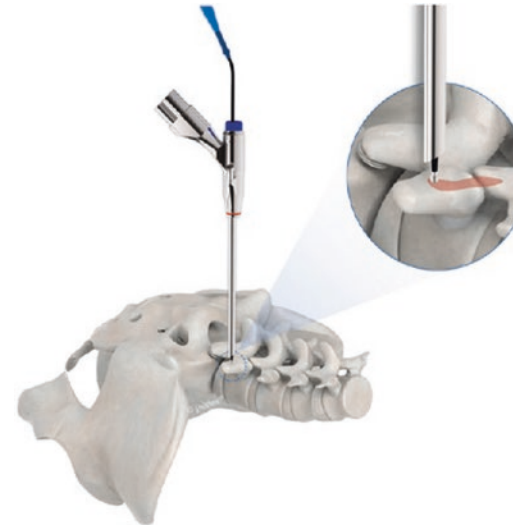


Fig. 13.9 Monopolar coagulation probe. (Courtesy of joimax® GmbH, Karlsruhe)

can be coagulated with the aid of the monopolar electrodes (Fig. 13.9).

The neuronal structures to be denervated run in the soft tissue surrounding the joint facets. Thus, the further procedure should be determined by the use of the monopolar electrode. Larger pieces of tissue and fatty tissue are best removed using a rangeur and the remaining tissue remnants are denervated using bipolar coagulation.

This procedure should be continued until the anatomical structure of the medial edge of the proc. transversus is clearly visible at the transition to the articular facet (Fig. 13.10). The same procedure should be performed bilaterally in the region of LW3/4, LW4/5 and LW5/SW1.

After denervation of the nerve structures leading to the joint facets, the small nerve branches running in the joint capsules themselves and in the soft tissue structures sur-

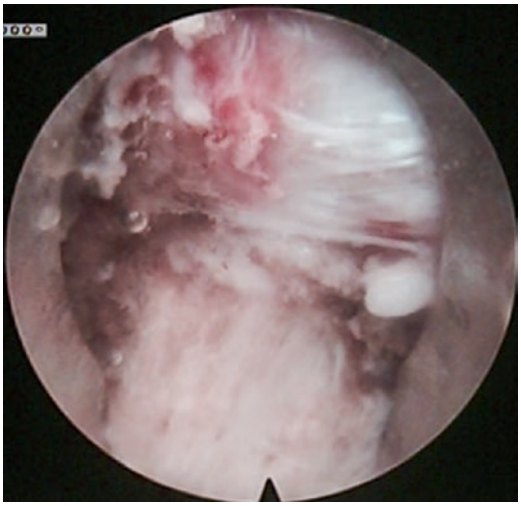


Fig. 13.10 Illustration of the anatomical structures, here the medial edge of the proc. transversus at the transition to the facet joint capsule

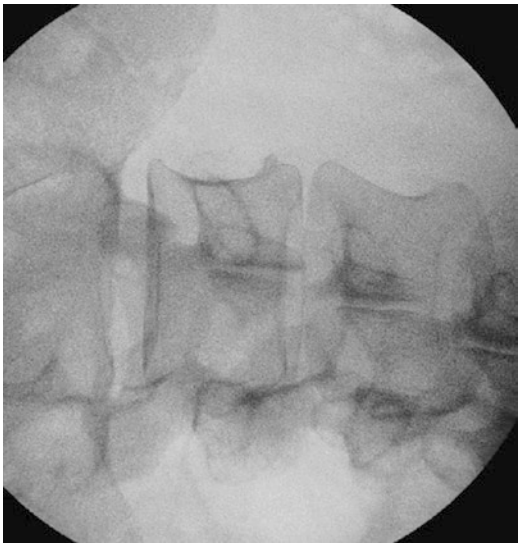


Fig. 13.11 Semi-oblique representation of the articular facet with figure of Scotty dog

rounding the joint capsules are also approached. This is also done under X-ray fluoroscopy. The so-called oblique view is used for this. This means that the X-ray tube is rotated by approx. 20° to the side to be treated, parallel to the facet joint gap of the joint facet to be denervated. The image of the so-called Scotty dog is obtained (Fig. 13.11).

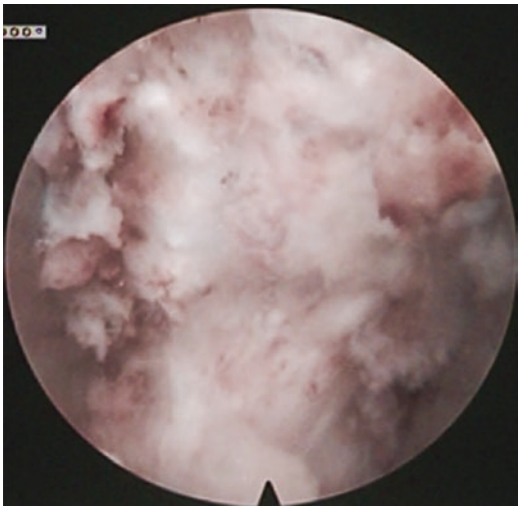


Fig. 13.12 Coagulated facet joint capsule, here at the transition to the proc. transversus

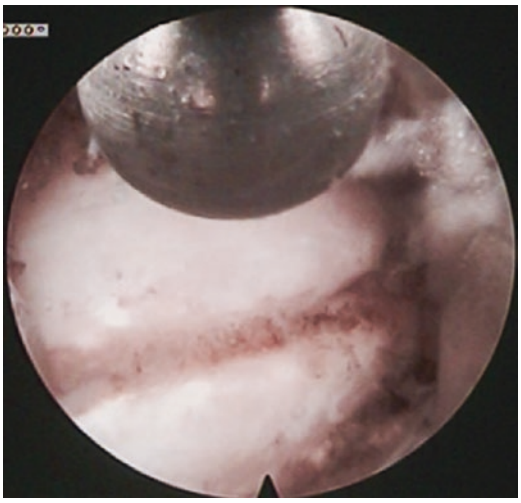


Fig. 13.13 Illustration of a facet joint space after coagulation in joints with pronounced degenerative changes

The facet joint capsule is denervated as far as possible with the monopolar electrode via this approach (Fig. 13.12). In the case of very pronounced spondyloarthrotic changes with a severely hypotrophic capsule, which occurs particularly after multiple pretreatments, the joint space can be exposed (Fig. 13.13). This procedure should also be performed on both sides of LW3/4 to LW5/SW1 in all joint facets to be approached.

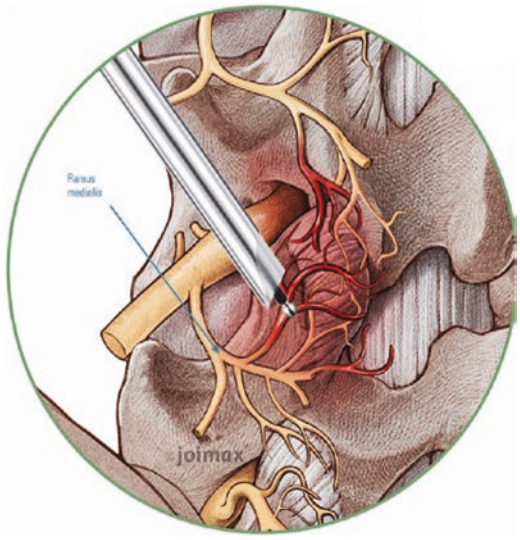


Fig. 13.14 Due to the 30-degree optics, treatment of all 3 levels to be treated is possible via two skin incisions. (Courtesy of joimax® GmbH, Karlsruhe)

Since the field of view of the optic is inclined by 30°, all three levels to be treated can be approached via only two skin incisions above the middle segment to be treated by rotating the optic accordingly (Fig. 13.14).

13.6 Possible Complications

Due to the minimal invasiveness of the endoscopic surgical technique, surgery-related complications are very rare. In particular, serious complications such as persistent nerve disorders or intraspinal hemorrhage are virtually non-existent. Postoperative inflammations such as abscesses, meningitis and spondylodiscitis are also virtually non-existent. However, these cannot be completely avoided statistically.

In principle, any complications known from conventional operations are possible. Especially during the learning phase, as with all other techniques, there is an increased risk of complications occurring.

The authors themselves have not experienced any serious complications in their many years of experience with endoscopic facet denervation.

13.7 Results in the Literature

The procedure of endoscopic facet denervation is absolutely state-of-the-art. The first operations of this type were performed in Europe in 2012. Since the introduction of the procedure, only a few studies have been published on this technique.

Jeong et al. (2014) concluded in their study that endoscopic facet denervation of the medial branch is an effective alternative treatment procedure suitable for chronic low back pain originating in the facet joints and is associated with pain relief for a long time.

Also, Li et al. reported that endoscopic dorsal rhizotomy is a safe and effective procedure for the treatment of facetogenic chronic low back pain, which offers a better clinical outcome than conservative treatment methods (Li et al. 2014).

Haufe and Mork (2010) show that facet joint pain plays a significant role in the cause of chronic back pain. The effectiveness of various denervation techniques such as radiofrequency ablation has already been demonstrated over a period of up to 3 years. The results of the study by Haufe u. Mork prove a corresponding effectiveness of endoscopic facet debridement and facet denervation. Further studies with larger numbers of cases and a control group are necessary to confirm the results of this study and thus substantiate the effectiveness of this method (Haufe and Mork 2010).

Siddiqi et al. (2013) also confirmed the effectiveness of endoscopic rhizotomy in the lumbar spine with the results of their study. Pain relief can last up to 5 years. In endoscopic assistance, visualization is assigned a relevant advantage over conventional percutaneous denervation techniques. This consists of a higher certainty to capture the ramus dorsalis as well as an associated improvement in long-term results. A significant majority of patients without deformity benefit from durable improvement in lumbar back pain and disability at 5-year follow-up. In addition, 3 separate newly identified anatomic variants of the medial branch anatomy may provide

insight into improved technique through endoscopic and high-frequency rhizotomy in the treatment of the painful lumbar joint (Siddiqi et al. 2013).

Yeung et al. (2011) are the first to describe not only the effectiveness of endoscopically assisted rhizotomy, but also to confirm better and longer lasting results when compared with pulsed radiofrequency ablation. The anatomical variations in facet interval, as demonstrated in dissections of cadavers, suggests the need for visualization of the neural structures, as enabled by the endoscopically guided technique (Yeung et al. 2011).

In a study published in 2016, Jentzsch et al., a research group from Switzerland, present their innovative data. By extending the technique with the addition of 3D navigation, the precision and exact localization could be improved once again. Beyond the already proven improved effectiveness of endoscopically assisted rhizotomy, this extension could provide a further improvement in accuracy (Jentzsch et al. 2016).

13.8 Conclusion and Clinical Relevance

Patients usually feel a significant relief of discomfort immediately after the procedure or are completely pain-free. Since the nerve fibers can grow back, it is sometimes necessary to treat again after months or years.

Results from clinical studies show that endoscopic facet denervation can achieve significant pain relief in more than 70% of all cases. They also show that many of the patients become completely pain-free and that their resilience in everyday life increases again.

Recently, first long-term results were published (Siddiqi et al. 2013). The observation period after endoscopic facet joint denervation was up to 5.3 years and still the patients felt significantly better than before the procedure.

References

Bogduk N (2010) On diagnostic blocks for lumbar zygapophysial joint pain. F1000 Med Report 2:57. https://doi.org/10.3410/M2-57

Bogduk N, Wilson AS, Tynan W (1982) The human lumbar dorsal rami. J Anat 134(Pt 2):383–397

Hancock MJ, Maher CG, Latimer J, Spindler MF, McAuley JH, Laslett M, Bogduk N (2007) Systematic review of tests to identify the disc, SIJ or facet joint as the source of low back pain. Eur Spine J 16:1539–1550. https://doi.org/10.1007/s00586-007-0391-1

Haufe SMW, Mork AR (2010) Endoscopic facet debridement for the treatment of facet arthritic pain – a novel new technique. Int J Med Sci 7(3):120–123

Jentzsch T, Sprengel K, Peterer L, Mica L, Werner CM (2016) 3D navigation of endoscopic rhizotomy at the lumbar spine. Clin Neurosci 23:101–105. https://doi.org/10.1016/j.jocn.2015.04.026

Jeong SY, Kim JS, Choi WS, Hur JW, Ryu KS (2014) The effectiveness of endoscopic radiofrequency denervation of medial branch for treatment of chronic low back pain. J Korean Neurosurg Soc 56(4):338–343. https://doi.org/10.3340/jkns.2014.56.4.338

Leggett LE, Soril LJ, Lorenzetti DL, Noseworthy T, Steadman R, Tiwana S, Clement F (2014) Radiofrequency ablation for chronic low back pain: a systematic review of randomized controlled trials. Pain Res Manag 19(5):e146–e153

Li ZZ, Hou SX, Shang WL, Song KR, Wu WW (2014) Evaluation of endoscopic dorsal ramus rhizotomy in managing facetogenic chronic low back pain. Clin Neurol Neurosurg 126:11–17

Siddiqi F et al (2013) Five year long-term results of endoscopic dorsal ramus rhizotomy and anatomic variations of the painful lumbar facet joint. (präsentiert an der Konferenz der Society for Minimally Invasive Spine Surgery)

Yeung AT, Zheng Y, Yeung C, Field J, Meredith C (2011) Endoscopic dorsal rhizotomy, a new anatomically guided MIS procedure, is more effective than traditional pulsed radiofrequency lesioning for non-discogenic axial back pain. (Poster 247 an der Konferenz der International Society for the Advancement of Spine Surgery)

Epidural Neurolysis, Minimally Invasive Catheter Technique According to Racz

A. Veihelmann

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_14

Ischialgiform leg pain represents a large proportion of chronic low back pain. This is also referred to as radicular pain and typically projects to the dermatome of the underlying pathologically altered nerve root, which may be compromised for a variety of reasons. For example, inflammatory processes may be associated with radiculitis or, much more commonly, there may be compression of a nerve root due to various degenerative conditions such as disc herniation, flavum hypertrophy, neuroforaminal narrowing due to calcification, spondylolisthesis, or even scarring. The diagnosis can become problematic if the pain cannot be clearly assigned to a dermatome or if the interpretation of the imaging does not match the pain distribution. Other degenerative changes such as facet syndrome or the sacroiliac joint can also cause so-called pseudoradicular leg pain (Vroomen et al. 2000).

If higher-grade sensorimotor deficits do not occur, the complaints can be alleviated in approx. 80% of patients by conservative therapy over a period of approx. 6–10 weeks to such an extent that they can resume their normal lives without specific therapy. In the remaining 20%, invasive procedures have to be carried out, whereby ECT—prior to a surgical sequestrectomy in the case of a herniated disc or decompression in the case of other causes—can be performed as a minimally invasive option here. However, after open interventions in the disc space, epidural fibrosis occurs in about 10–30%, which in turn can lead to a pain problem in the sense of postnucleotomy syndrome (Weinstein et al. 2006; Babar and Saifuddin 2002).

More than 20 years ago, Racz and Holubec presented a minimally invasive technique for the lysis of epidural adhesions and thus for the treatment of lumbosacral radicular pain syndromes (Racz et al. 1982). The so-called epidural adhesiolysis or epidural catheter therapy (ECT) can reduce pain and low-grade neurological symptoms in herniated discs or postnucleotomy syndrome without a long convalescence period or even avoid open surgical intervention.

This procedure enjoys worldwide application, partly because of its relatively simple technique after adequate training in minimally invasive techniques on the spine.

The basic theoretical and scientific background are pain conditions caused by epidural adhesions and fibrosis, in which the site of action cannot be safely reached by individual injections due to the adhesions and the adhesion of nerve roots lead to the radicular pain. The exact mechanism of chronic pain with radiculopathy after adequate sequestrectomy or decompression has not been fully elucidated. Kuslich et al. investigated this in 193 patients who received a local anesthetic applied to the epidural space after lumbar spinal surgery. The results led the authors to the assumption that sciatica only results when the nerve root is compressed, swollen, stretched, or caked by scar tissue (Kuslich et al. 1991).

The cause of pain-relevant scar tissue in the spinal canal has been investigated several times. Accordingly, there are several possible causes including surgical trauma, annulus tears, infection, hematoma or intrathecal contrast medium, as is well documented in the literature (Bosscher and Heavner 2010; Cooper et al. 1995).

Scar tissue can be found in various areas of the epidural space. Dorsal epidural scar tissue may thus result from absorption of a hematoma (Songer et al. 1990). In the ventral epidural space, fibrosis may result from posterior defects of the annulus fibrosus or even after disc surgery, causing chronic pain. The lateral epidural space consists of epiradicular structures outside the nerve root canal, also called lateral recessus. Scarring due to lateral disc herniation, facet hypertrophy, and foraminal stenosis is possible here (Iwabuchi et al. 2001; Olmarker and Rydevik 1991).

In lumbar radicular pain, in addition to a mechanical component due to compression, inflammatory involvement due to proinflammatory mediators (e.g. cytokines) has also been demonstrated (Igarashi et al. 2004). In this context, epidurally applied cortisone can have an anti-inflammatory effect. The positive effect of epidurally applied cortisone in chronic back pain was described as early as 1964 by Lindholm and Salenius, which confirmed inflammation as an accompanying phenomenon (Lindholm and Salenius 1964).

In the descriptions of drug application for epidural adhesiolysis/EKT according to Racz, local anaesthetic (ropivacaine), hyaluronidase and 10% NaCl were applied in addition to steroids. Different compositions and applications of these drugs have been investigated in numerous studies (Anderson et al. 2000). Hyaluronidase is said to lead to initial lysis and thus to better flooding of the drugs to the nerve root. The 10% NaCl is used for local pain reduction, partly due to its relative selectivity of the C-fibers (Devulder et al. 1995; Heavner et al. 1999).

For various reasons, such as concerns about allergies and questionable necessity, the use of hyaluronidase is predominantly avoided today (Heavner et al. 1999; Anderson et al. 2000).

The following drugs are used nowadays: after correct positioning of the catheter

- one-time corticosteroid 20–40 mg (1–2 mL triamcinolone, Volon®) or better dexamethasone palmitate (Lipotalon® 4–8 mg),
- Ropivacaine 10 mg/mL (10 mL),
- followed by 10 mL of a 10% hypertonic saline solution via a perfusor and on the following days.

For safety reasons, the author recommends the use of dexamethasone palmitate, as this consists of smaller crystals in a fat sheath and is therefore less dangerous in the event of accidental intravascular administration.

In principle, in the case of intervertebral disc protrusions, intervertebral disc herniations and epidural fibrosis as well as nerve root compression detected in slice imaging with pure pain symptoms, the focus is initially on **conservative measures** with analgesics according to the WHO staging scheme and physiotherapy or manual therapy. This combination with specific stabilizing and manual techniques can often bring about an improvement combined with participation. If necessary, these should be supplemented with non-steroidal anti-inflammatory drugs (NSAIDs), metamizole or centrally acting analgesics such as synthetic opioids and muscle relaxants. Adjuvant therapy may include multiple epi–/periradicular infiltration.

Only if this purely conservative therapy does not lead to the hoped-for success can epidural adhesiolysis using catheter technology be considered.

The advantage of the catheter technique is that, in addition to the above-mentioned chemical adhesiolysis, certain mechanical manipulations of adhesions can also be performed with the coil spring catheter (Heavner et al. 1999). In a recent study, however, it was shown that the possibilities for mechanical adhesiolysis seem limited with the material used (Birkenmaier et al. 2012).

14.1 Indication

The following main indications for ECT are given by the first author:

- Failed Back Surgery,
- Postnucleotomy syndrome,
- Ruptures of the annulus fibrosus,
- Multilevel osteochondrosis,
- Facet syndrome,
- Spinal stenosis,
- Chronic lower back pain after unsuccessful spinal cord stimulation/spinal opioids.

In this context, it should be mentioned that the first author is co-owner of Epimed, the company that manufactures the epidural catheter, and thus economic interests in a generous indication cannot be safely ruled out.

Based on the study results (▶ Sect. 14.7) and his own experience, the author recommends the following indications:

- unsuccessful conservative therapy for 6 weeks,
- Radicular pain syndrome associated with mediolateral disc protrusion/herniation,
- Postculeotomy syndrome,
- Neuroforaminal stenosis with unilateral sciatica/claudication,
- Soft part spinal stenosis with unilateral ischialgia/claudication,
- Pain intensity on the visual analogue scale (VAS) >4.

The main indication for ECT is therefore the radicular pain patient with corresponding

findings on imaging (herniated or bulging disc or epidural fibrosis) who is refractory to conservative treatment. In exceptional cases, soft tissue-related spinal stenosis or foraminal narrowing may also be an indication (Manchikanti et al. 2017). If necessary, a nerve root block must be performed to confirm the diagnosis (Gerdesmeyer et al. 2005). Higher grade motor paresis resistant to therapy due to nerve root compression is a criterion for exclusion. These should be rapidly decompressed openly or endoscopically.

Contraindications to epidural adhesiolysis/epidural catheter therapy include:

- higher-grade motor deficits (need for surgical decompression),
- Malignancies in the service area,
- Infections,
- Immune suppression,
- no correlation in the imaging,
- Pregnancy,
- anticoagulant therapy/coagulation disorder,
- Allergies to the medications used.

14.2 Preinterventional Dignostics

In addition to conventional X-ray diagnostics, MRI is the diagnostic method of choice. This allows the visualization of intervertebral disc structures as well as possible nerve root compression due to prolapsed intervertebral disc tissue or epidural fibrosis. In the case of severe complaints, it may also be useful to exclude an infectious genesis of the pain by means of a contrast medium MRI. Only in case of contraindications (pacemaker, defibrillator) a computer tomography is performed.

14.3 Necessary Instruments

The instrument set is shown in Fig. 14.1 and includes the following items:

- sterile wash-up and drape set;
- Introducer needle: curved or straight needles for conduction anaesthesia (for access transforaminal or via hiatus sacralis) RX™ Coudé & RX™ Straight Epidural Needles (Epimed Company®) (Fig. 14.2);
- Epidural catheter: Length 33.25″ (845 mm) or 24″ (610 mm), size 043″ (19 ga) (Fig. 14.3);
- Medications:
- 10 mL ropivacaine (10 mg/10 mL),
- with 2 mL of 40 mg triamcinolone (Volon®) or 4/8 mg dexamethasone palmitate (Lipotalon®),
- 10 mL 10% NaCl solution via perfuser (10 mL in 30 min);
- Image converter/fluoroscopy.

Fig. 14.1 Instrument set for epidural catheter therapy according to Racz

Fig. 14.2 Epimed insertion needle®. (With the kind permission of the company Epimed)

Fig. 14.3 Catheter tip of the spiral spring catheter from Epimed®. (Courtesy of Epimed)

The one-time costs of the special instruments from Epimed® amount to approx. 100–130 €.

Order address: Olga E. Hillier, distributor of orthopedic and medical products, general representative of Epimed® Int. for Germany and Austria, Schreivogelstrasse 34, D-81737 Munich. E-mail: kontakt@epimed.de; Internet: ► www.epimed.de.

14.4 Pre-Intervention Education

In addition to the usual possibilities of complications such as bleeding, infection with the corresponding need for surgery, meningitis, permanent nerve lesion, bladder/rectum paralysis up to paraplegia and disturbance of sexual function, the off-label use of drugs such as the cortisone preparation and the 10% NaCl must be explained.

Even if it is extremely improbable and seems almost impossible when used correctly, it is necessary to provide information about a catheter rupture with retention or surgical removal of the remaining part. It can happen that with repeated correction of the position and frequent pushing back and forth of the coil spring catheter, the outer sheath ruptures and thus shears off. However, attentive use of catheter placement should be able to avoid this.

Furthermore, the possibility of aborting the procedure in the event of an accidental intradural position must also be explained. According to the literature and the experience of the author, in the case of an intradural misplacement, no immediate retry should be carried out, but the procedure should be aborted and retried in 3 weeks at the earliest.

Recently, it has also become urgent to provide information about the possibility of obtaining a second opinion.

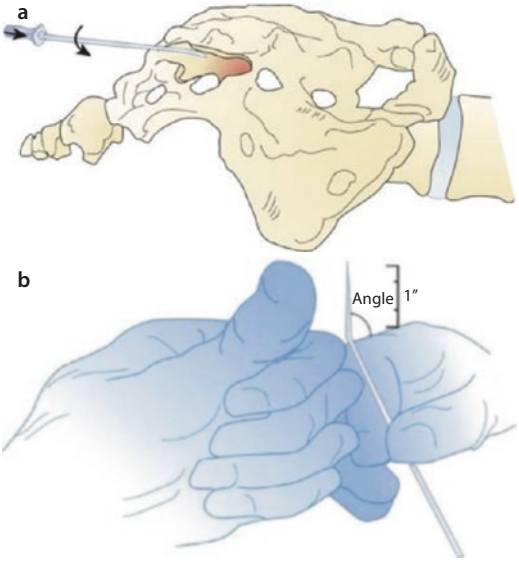
14.5 Implementation of the Intervention

The procedure should be performed under operating conditions in the operating room under sterile conditions. The patient should be given the option of analgesia and absolutely a single-shot antibiotic. General anesthesia is not necessary and should be avoided for safety reasons. Otherwise, the procedure should be performed under operating room conditions. The patient is positioned in an unlorded prone position. After skin disinfection and sterile draping, the image converter is set, initially in lateral view.

The approach can be lumbar via the sacral hiatus (up to the level of LWK3/4) or higher transforaminal.

Access via sacral hiatus: First, visualization of the sacral hiatus (not always 100% visualizable, then proceed according to palpation) (■ Fig. 14.4a, b).

Infiltration of the skin approx. 1 cm lateral to the rima ani (for hygienic reasons not directly in the rima) with local anaesthetic and shifting the skin medially (■ Fig. 14.5). After a short wait, approach the sacral hiatus with the insertion needle, which is bent slightly cranially. Then turn the introducer needle in the direction of the desired side. Insertion of the catheter with navigation to the desired side in the a.p. view, control of the ventrolateral position in the lateral ray path. Advance the catheter to the desired level, where mechanical neurolysis can also be attempted—as described above (■ Fig. 14.6a, b).



■ **Fig. 14.4** Epidural catheter therapy. **a** Access via hiatus sacralis, **b** Bending of the coil spring catheter. (From Racz and Noe 2016)

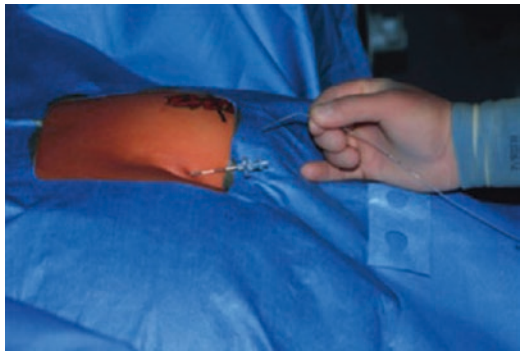


Fig. 14.5 Insertion needle and coiled spring catheter pre-bent at the end

After the catheter has been placed over the sacral hiatus under image converter control, the epidural position is checked using contrast medium ("fir tree") (Fig. 14.7a, b).

After catheter implantation and verification of the epidural location by contrast medium (e.g. Solutrast), various drugs are injected via the catheter to the disc protrusion or herniation. First, the mixture of 12 mL ropivacaine with one-time triamcinolone 20/40 mg or dexamethasone pamitat 4/8 mg is injected, and then the 10% NaCl solution is injected after excluding new neurological defi-

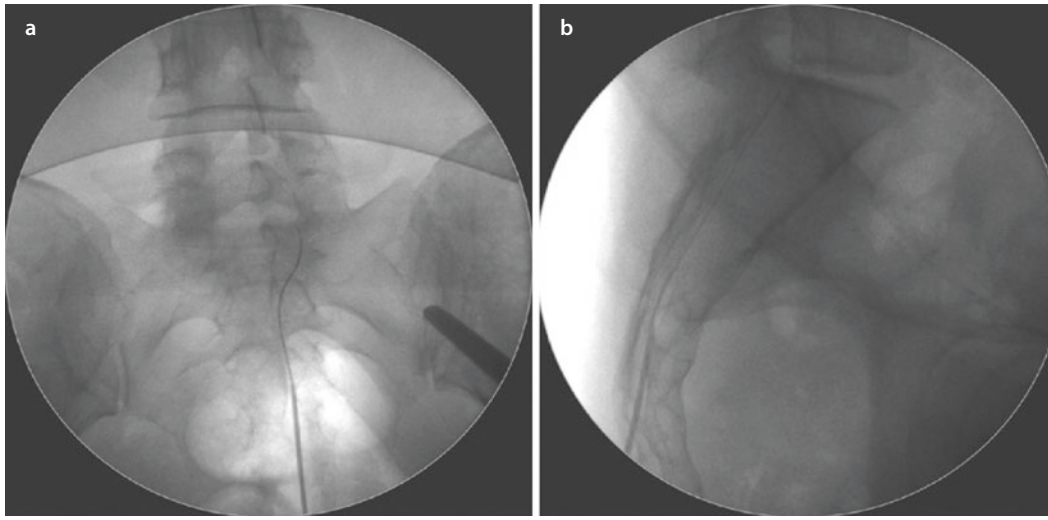


Fig. 14.6 Correct position of the catheter at LWK5/SWK1 right in the a.p. view **a** and in the lateral view **b**

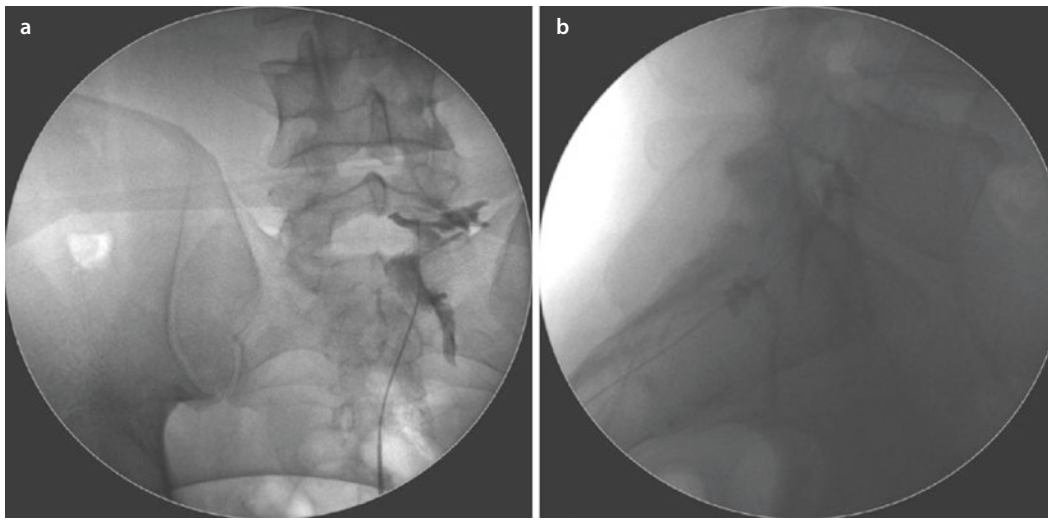


Fig. 14.7 The contrast medium shows the epidural position of the catheter with irrigation around the L5 and S1 nerve roots on the right, **a** in anteriorposterior and **b** in lateral projection

cits in the extremities, after a bacterial filter flushed with 0.9% Nacl solution is attached. The 10% NaCl solution should be injected via a perfusor in the recovery room, for example. After the implantation, the catheter is sutured and a dressing is applied, which must be carefully closed towards the anus. It is recommended to use a foil plaster under the dressing.

Under the idea of an anti-inflammatory and anti-edematous effect, the injections of these drugs (except the corticosteroid) are repeated daily during the total 3-day inpatient stay. The catheter is removed on the second postoperative day after the last injection and the patient is discharged.

In the author's opinion, it is important to continue antbiotic prophylaxis by oral administration of e.g. clindamycin 300 mg 1-0-1 until the sixth postoperative day.

In the **transforaminal approach,** the C-arm is brought into oblique position (oblique view) and the superior articular process is approached with the needle in tunnel view. Rotating the needle 180 ° allows blunt passage of the intertransverse ligament without nerve damage in case of accidental contact. The C-arm is adjusted for a lateral view and the intraforaminal position is secured. The catheter is placed at the desired ventrolateral site.

To **access the cervical spine,** the introducer needle is inserted paramedian at the level of Th1-Th2 or Th2-Th3 contralateral to the affected side and pushed epidurally. From this level, the lower and middle segments of the cervical spine can usually be reached:

1.5 segments below, the skin penetration takes place in the a.p. setting of the image converter. After a depth of approx. 2–3 cm, the position is checked in the lateral image (Fig. 14.8a, b). After the epidural position has been reached using the loss-of-resistance technique described above, 0.5–1 mL of contrast medium is injected. After verification of the correct position, injection of a 2-mL test dose of a total of 6 mL ropvacaine and 10 mg triamcinolone is performed. If distribution intrathecally or intravascularly can be ruled out after 5 min, the remainder (4 mL) is

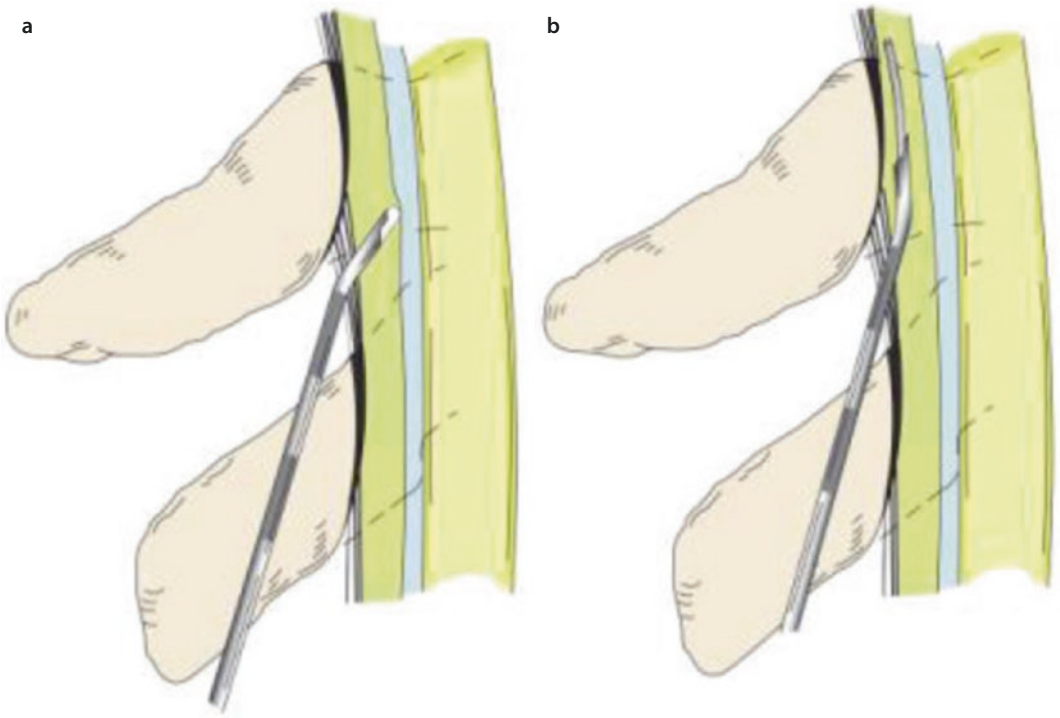


Fig. 14.8 **a**, **b** Correct procedure for puncturing the cervical spine with the insertion needle. (From Racz and Noe 2016)

injected. After a waiting time of about 20 min, 5 mL of hypertonic NaCl solution is infused via perfusor over a period of 30 min under permanent circulation monitoring.

14.6 Possible Complications

The method, which is often described as being free of complications, does indeed harbour the possibility of serious complications, as we have seen in our own patients. In addition to the usual risks of infection and bleeding, which we have not seen in any of our approx. 800–1000 patients, 3 patients had a cerebrospinal fluid leakage due to accidental dural puncture, one patient had a temporary bladder emptying disorder and 2 patients had meningitis (which healed without consequences).

Similar to our own experience, in a follow-up of 250 patients, twisted needle tips were found in 4.8% of patients, sheared catheter parts in 0.4%, intrathecal placements in 4.4%, and epidural abscesses in 1.2% (Talu and Erdine 2003).

In comparison, in a large follow-up study of 10,000 epidural infiltrations, accidental intravascular injections were found in 11.6% of 839 patients, transient nerve irritations in 1.9% and dural punctures in 1.8%, i.e. there is also a similarly high complication rate with these single injections (Manchikanti et al. 2012). More dramatic complications (such as respiratory depression to respiratory arrest with the need for intubation) have been described, for example, in the case of accidental intrathecal application, especially cervical (Jamison et al. 2014).

Thus, these complications are not negligible, but dramatic consequences with irreversible damage are extremely rare.

14.7 Results in the Literature

The first description of epidural adhesiolysis by Racz and Holubec took place in 1989 in the form of a retrospective analysis after 6–12 months. Here, the short-term results were very good in 72.2% of the 72 patients, but only in about one third even after 12 months (Racz and Holubec 1989). Later studies by Manchikanti et al. tested the effect of a modified 1-day application in patients with chronic back and/or leg pain (Manchikanti et al. 2004). Seventy-five patients with small disc herniation or low-grade nerve root compression were randomized into 3 groups, all of whom received lidocaine, steroids, and 0.9% NaCl injections: the control group received no targeted contrast-enhanced adhesiolysis, group II received adhesiolysis and 0.9% NaCl, and group III received adhesiolysis and 10% NaCl. It was shown that 72% of the patients with adhesiolysis and 10% NaCl solution had the best results after 12 months with more than 50% improvement of the initial symptoms. Thus, 10% NaCl was always used in most subsequent studies.

In our own prospective randomized and controlled study we could demonstrate that both leg and back pain in patients with radicular pain (due to disc herniation or epidural fibrosis in the context of postnucleotomy syndrome) had a significant improvement compared to a purely conservative therapy group even after 12 months. However, a limiting factor in our study was that 12 patients in the conservative group crossed over to the epidural catheter group after 3 months and there was a rather high drop-out of patients after 1 year (Veihelmann et al. 2006).

In another placebo-controlled study of our research group, 90 patients with radicular pain syndrome were randomized and divided into 2 groups: Group 1 received placebo therapy with 0.9% NaCl solution infused into the subcutaneous tissue above the sacrum, and Group 2 received verum therapy (with ECT) with standard 3-day infusions. After 3, 6 and 12 months, the reduction in pain and discomfort (measured by the Oswestry Disability Index) was significantly greater in the epidural catheter group compared to the placebo group (Gerdesmeyer et al. 2013).

Epidural catheter therapy has also been studied for lumbar spinal stenosis. In a study by Manchikanti et al. 25 patients with chronic

lumbar back pain due to spinal stenosis were randomized into a treatment group with adhesiolysis and a group with only caudal infiltration. As a result, the patients treated with adhesiolysis still had significantly less pain at 12 months than the patients who received epidural infiltration only (Manchikanti et al. 2009). However, a major criticism of this study is that the two groups repeated the therapy with different frequency during the observation period, which could contribute to a distortion of the results.

Overall, there is still a certain discrepancy regarding the classification of the evidence in the systematic meta-analyses for ECT both in the treatment of spinal stenosis and, albeit weakened, in the treatment of epidural fibrosis in postnucleotomy syndrome. Overall, the evidence in the most recent review by Helm et al. is described as strong, although further good-quality, prospectively randomized studies are desirable for further clarification (Helm et al. 2016).

The effectiveness of ECT for cervical use has been investigated in some studies, but data from randomized trials are lacking. Compared with lumbar application, the risk of complications is higher, as is known from case reports of cervical infiltrations (Browers et al. 2001; Rozin et al. 2003). In prospective studies, a 6-month follow-up after ECT showed significant improvement in over 70% of patients with chronic pain from central cervical stenosis (Park et al. 2013a). In another retrospective analysis of 128 patients with cervical disc herniation and epidural adhesiolysis, a significant reduction in pain score for arm and neck pain was obtained at 12 months. No serious complications were found in this study (Park et al. 2013b).

Although the evidence for cervical epidural neurolysis/ECT is still limited, the data suggest promising results in selected patients with cervical brachialgia due to disc herniation/nerve root compression and exhausted conservative therapy.

14.8 Conclusion and Clinical Relevance

In summary, epidural catheter therapy is a useful, effective and safe treatment for radicular pain syndrome/ischemia with a correlating finding (disc herniation, protrusion, epidural fibrosis or soft tissue spinal stenosis) with nerve root contact on MRI or CT. The evidence for ECT for such an indication is strong ("strong"), as shown in a recent meta-analysis from 2016 (Helm et al. 2016). Careful patient selection and sterile application are essential prerequisites for successful ECT. Thus, epidural neurolysis/ECT can precede microscopic-assisted/endoscopic sequestrectomy or decompression. Higher-grade motor deficits are a contraindication to ECT. In the author's opinion, osteochondrosis, facet syndrome alone and pure lumbalgia do not constitute a confirmed indication.

References

Anderson SR, Racz GB, Heavner J (2000) Evolution of epidural lysis of adhesions. Pain Physician 3(3): 262–270

Babar S, Saifuddin A (2002) MRI of the post-discectomy lumbar spine. Clin Radiol 57(11):969–981

Birkenmaier C, Baumert S, Schroeder C, Jansson V, Wegener B (2012) A biomechanical evaluation of the epidural neurolysis procedure. Pain Physician 15(1):E89–E97

Bosscher HA, Heavner JE (2010) Incidence and severity of epidural fibrosis after back surgery: an endoscopic study. Pain Pract 10(1):18–24

Browers PJ, Kotting EJ, Simon MA, Prevo RL (2001) A cervical anterior spinal artery syndrome after diagnostic blockade of the right C6-nerve root. Pain 91:397–399

Cooper RG, Freemont AJ, Hoyland JA, Jenkins JP, West CG, Illingworth KJ, Jayson MI (1995) Herniated intervertebral disc-associated periradicular fibrosis and vascular abnormalities occur without inflammatory cell infiltration. Spine 20(5):591–598

Devulder J, Bogaert L, Castille F, Moerman A, Rolly G (1995) Relevance of epidurography and epidural adhesiolysis in chronic failed back surgery patients. Clin J Pain 11(2):147–150

Gerdesmeyer L, Lampe R, Veihelmann A, Burgkart R, Göbel M, Gollwitzer H, Wagner K (2005) Chronic radiculopathy. Use of minimally invasive percutaneous epidural neurolysis according to Racz. Schmerz 19(4):285–295

Gerdesmeyer L, Wagenpfeil S, Birkenmaier C, Veihelmann A, Hauschild M, Wagner K et al (2013) Percutaneous epidural lysis of adhesions in chronic lumbar radicular pain; a randomized double-blind, placebo-controlled trial. Pain Physician 16:185–196

Heavner JE, Racz GB, Raj P (1999) Percutaneous epidural neuroplasty: prospective evaluation of 0.9% NaCl versus 10% NaCl with or without hyaluronidase. Reg Anesth Pain Med 24(3):202–207

Helm S, Racz GB, Gerdesmeyer L, Justiz R, Hayek SM, Kaplan ED, El Terany MA, Knezevic NN (2016) Percutaneous and endoscopic adhesiolysis in managing of chronic low back and lower extremity pain: a symptomatic review. Pain Physician 19:E245–E281

Igarashi A, Kikuchi S, Konno S, Olmarker K (2004) Inflammatory cytokines released from the facet joint tissue in degenerative lumbar spinal disorders. Spine 29(19):2091–2095

Iwabuchi M, Rydevik B, Kikuchi S, Olmarker K (2001) Effects of anulus fibrosus and experimentally degenerated nucleus pulposus on nerve root conduction velocity: relevance of previous experimental investigations using normal nucleus pulposus. Spine 26(15):1651–1655

Jamison DE, Hsu E, Cohen SP (2014) Epidural adhesiolysis: an evidence-based review. J Neurosurg Sci 58(2):65–67

Kuslich SD, Ulstrom CL, Michael CJ (1991) The tissue origin of low back pain and sciatica: a report of pain response to tissue stimulation during operations on the lumbar spine using local anesthesia. Orthop Clin North Am 22(2):181–187

Lindholm R, Salenius P (1964) Caudal, epidural administration of anesthetics and corticoids in the treatment of low back pain. Acta Orthop Scand 34:114–116

Manchikanti L, Rivera JJ, Pampati V, Damron KS, McManus CD, Brandon DE et al (2004) One day lumbar epidural adhesiolysis and hypertonic saline neurolysis in treatment of chronic low back pain: a randomized, double blind trial. Pain Physician 7:177–186

Manchikanti L, Cash KA, McManus CD, Pampati V, Singh V, Benyamin R (2009) The preliminary results of a comparative effectiveness evaluation of adhesiolysis and caudal epidural injections in managing chronic low back pain secondary to spinal stenosis: a randomized, equivalence controlled trial. Pain Physician 12:E341–E354

Manchikanti L, Malla Y, Wargo BW, Cash KA, Pampati V, Fellows B (2012) A retrospective evaluation of complications of 10.000 fluoroscopically guided epidural injections. Pain Physician 15:131–140

Manchikanti L, Pampati V, Benyamin RM, Hirsch JA (2017) Cost utility analysis of lumbar interlaminar epidural injections in the treatment of lumbar disc herniation, central spinal stenosis, and axial or discogenic low back pain. Pain Physician 20(4): 219–228

Olmarker K, Rydevik B (1991) Pathophysiology of sciatica. Orthop Clin North Am 22(2):223–234

Park CH, Lee SH, Lee SC (2013a) Preliminary results of the clinical effectnivness of percutaneous adhesiolysis using a Racz catheter in the management of chronic pain due to cervical central stenosis. Pain Physician 16:353–358

Park EJ, Park SY, Lee SJ, Kim NS, Koh DY (2013b) Clinical outcomes of epidural neuroplasty for cervical disc herniation. J Korean Med Sci 28:461–465

Racz G, Holubec J (1989) Lysis of adhesions in the epidural space. In: Paj P (Hrsg) Techniques of neurolysis. Kluwer, Boston, S57–72

Racz G, Noe CE (Hrsg) (2016) Technique of neurolysis, 2. Aufl. Springer International Publishing, Switzerland

Racz GB, Sabonghy M, Gintautas J, Kline WM (1982) Intractable pain therapy using a new epidural catheter. JAMA 248(5):579–581

Rozin L, Rozin R, Koehler SA, Shakir A, Ladham S, Barmada M et al (2003) Death during transforaminal epidural steroid nerve root block (C7) due to perforation of the left vertebral artery. Am J Forensic Med Pathol 24:351–355

Songer MN, Ghosh L, Spencer DL (1990) Effects of sodium hyaluronate on peridural fibrosis after lumbar laminotomy and discectomy. Spine 15(6): 550–554

Talu GK, Erdine S (2003) Complications of epidural neuroplasty: a retrospective evalaution. Neuromodulation 6:237–247

Veihelmann A, Devens C, Trouillier H, Birkenmaier C, Gerdesmeyer L, Refior HJ (2006) Epidural neuroplasty versus physiotherapy to releive pain in patients with sciatica: a prospective randomized blinded clinical trial. J Orthop Sci 11:365–369

Vroomen PC, de Krom MC, Slofstra PD, Knottnerus JA (2000) Conservative treatment of sciatica: a systematic review. J Spinal Disord 13(6):463–469

Weinstein JN, Lurie JD, Tosteson TD, Skinner JS, Hanscom B, Tosteson AN, Herkowitz H, Fischgrund J, Cammisa FP, Albert T, Deyo RA (2006) Surgical vs nonoperative treatment for lumbar disk herniation. JAMA 296(20):2451–2459

Minimally Invasive Therapy of Metastases to the Spine Using the Cavity Coblation Method

D. Dabravolski, A. Lahm, and H. Merk

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_15

15.1 Introduction and Indication

Tumors and metastases to the spine are very distressing conditions. Their treatment has made considerable progress in recent decades. Nevertheless, for numerous patients with multiple metastases with osteolyses and fractures to several vertebral bodies or in other organs, until recently there were hardly any other effective treatment options available apart from purely conservative therapy measures such as chemotherapy and possibly radiation, pain therapy, etc.

In the case of oligometastases, the performance of a radical open and extensive operation such as ventrodorsal fusion with tumor resection and vertebral body replacement is associated with considerable intraoperative and postoperative risks (massive bleeding, increased risk of injury to blood vessels and nerves, wound healing disorders and considerable infection risks due to large areas of contamination and long operating times). Various intraoperative and postoperative mechanical complications such as loosening and fractures of the osteosynthesis material, fractures and connection decompensation of adjacent vertebral bodies/segments are also very often observed here (Bartels et al. 2008; Delank et al. 2011; Kreitz 2009; Suva et al. 2011). In addition, for many patients with a reduced general condition, there are contraindications for major surgical interventions in the area of the spine, especially in the case of cardiopulmonary restrictions or other surgical high risks, which preclude longer operating times and blood loss.

In any case, in both curative and palliative situations, the goals of surgical treatment are: to minimize trauma to the soft tissues and bone by using minimally invasive techniques, to reduce blood loss, and to maintain the stability of the vertebra and spinal segment. Also very important are: correction of the deformity or reduction of compression fractures, decompression and widening of the spinal canal with as complete removal of the tumor tissue as possible, prevention of fractures in the case of massive osteolysis of the vertebral body and, in general, especially the reduction of pain and improvement of the quality of life.

In order to optimise and further improve the care of patients with multiple metastases with vertebral body destructions, the modern minimally invasive cavity coblation method, which has only been known for a few years, is successfully used in our clinic as well as in some other clinics. Until now, coblation (= "controlled ablation") has been used with relatively small numbers of cases mainly in the USA, Japan and France, in Germany in the area of the spine only in a few clinics, occasionally also in arthroscopies and in otorhinolaryngology (Bortnick 2001; Hall and Littlefield 2001).

The cavity coblation method has considerable advantages and peculiarities or differences from the other surgical methods that have been known for some time, such as kyphoplasty and vertebroplasty. In vertebroplasty (Mathis and Wong 2003), the cement usually runs around the tumor and the tumor is not significantly reduced in size. In kyphoplasty (Dudeney et al. 2002; Hentschel et al. 2005; Nussbaum et al. 2004), although the balloon creates a cavity, tumor cells are only displaced to the side, which is why there is a very high risk of tumor spread into the vessels here. In radiofrequency kyphoplasty (Drees et al. 2010; Elgeti and Gebauer 2010; Licht and Kramer 2010; Miko et al. 2009), too, the tumor is not removed and is likewise only pushed to the side by the bone cement, and there is also a risk of tumor spread via the vessels. In both methods, there is no removal of the tumor tissue (Elgeti and Gebauer 2010; Hentschel et al. 2005; Nussbaum et al. 2004; Reidy 2003). Coblation, on the other hand, is the controlled ablation with a pre-bent plasma probe, in which the tissue dissolution takes place without any harmful thermal effect at very low temperatures due to the plasma field energy.

Traditional other known treatments for spinal metastases are:

- Cryotherapy is performed at very low temperatures and is technically complex; in the process, complete metastasis removal is not possible and there is a high risk of

injury to healthy tissue (Callstrom et al. 2006a, b; Gangi and Buy 2010).
- Laser therapy is performed at high local temperatures of approximately 500–600 °C, also with a not inconsiderable risk of injury to healthy tissue (Gangi and Basile 2005; Woloszko 2000).
- Radiofrequency therapy (Dabravolski et al. 2017; Dupuy et al. 2000; Gangi and Buy 2010), e.g. with the Rita StarBurst™ MRI device, uses radiofrequency current and generates a very high temperature (>400 °C) to damage tumor cells. Here, too, complete destruction of the tumor or metastasis is not possible, and there is also a great risk of injury to the surrounding healthy tissue or to nerves, organs and vessels.

The cavity coblation method is approved for treatment in Germany as well as in several other countries. All patients are informed in detail about the therapy methodology, the treatment strategy, the course of the study or the therapy control intervals, data protection, possible complications, etc. as standard.

15.2 Preinterventional Diagnostics

Patients from different age groups, especially elderly multimorbid patients, with vertebral body destruction such as osteolysis and compression fractures with risk of instability and therapy-resistant pain syndrome in all sections of the spine caused by osteolytic metastases from different primary tumors can be treated by the cavity coblation method.

Preoperatively, an appropriately comprehensive diagnosis including tumor staging must be routinely performed in every patient:
- clinically (including a detailed history, neurological status, pain intensity according to the visual analogue scale [VAS]),
- radiological (X-ray in 2 planes, CT and MRI with contrast medium [obligatory], whole-body skeletal scintigraphy and, if necessary, whole-body positron emission tomography with F18-FDG),
- histopathological (to be attempted preoperatively if possible and available), especially if the primary tumor is already known, or intraoperatively, a biopsy must also be taken from all affected vertebral bodies in each patient.

In doing so, the correct diagnosis of the primary tumor or metastases to the spine in each patient, and thus the indication for surgical treatment, can be correctly determined and confirmed clinically and radiologically as well as histologically. Preoperatively, the size and configuration of all osteolyses or metastasis-related widening of affected vertebral bodies should be precisely defined radiologically in order to select the correct treatment and surgical strategy.

15.3 Necessary Instruments

The procedure should take place in a specially equipped operating room under standard sterile conditions. The patient is positioned in the prone position for the spine and lumbar spine procedures and in the supine position for the cervical spine procedures on a carbon operating table suitable for fluoroscopy (carbon table). X-ray fluoroscopy is performed using a C-arm with image intensifier.

Special Surgical Instruments

- Arthrocare System Controller with foot switch and patient cable (reusable and sterilizable) is provided by manufacturer on permanent loan.
- Arthrocare probe set (not reusable): consists of the probe (Cavity™ SpineWand) with the probe cable and an infusion unit for the purpose of introducing a saline solution, e.g. 0.9% NaCl solution (approx. 300–400 mL required) into the surgical area to generate the plasma field. Costs approx. 1000 € per probe.

  Order address: Arthrocare AG was purchased or taken over by Smith & Nephew GmbH in 2015/2016. Contact details in Germany: Smith & Nephew

GmbH, Friesenweg 4, Haus 21, D-22763 Hamburg (► info@smith-nephew.com, ► www.smith-nephew.de).

- Kyphoplasty set (Medtronic) incl. Access trocars standard (for lower cervical spine) and if necessary with extra-thin ends (express set, for cervical spine and upper cervical spine). Costs approx. 800–900 € incl. Cement.
- OsteoCool™ radiofrequency (RF) ablation system (Medtronic) (not reusable): Ablation device with the same working principle, ablation temperature approx. 50–72 °C. Probe set consists of the OsteoCool RF ablation probe (different lengths of active tips: 7, 10, 20 mm) with the probe cable and an infusion unit for the purpose of introducing a saline solution, e.g. 0.9% NaCl solution (approx. 300–400 mL are required) into the operating area to generate the RF ablation field. Costs: 1 probe approx. 1500 €, 2 probes for bilateral simultaneous ablation (recommended and preferred) approx. 2400 €.

  Ordering address: Medtronic GmbH, Earl-Bakken-Platz 1, D-40670 Meerbusch (deutschland@medtronic.com).

15.4 Pre-intervention Education

The patient must be informed in detail by the attending physician or the surgeon about his diagnosis, clinical and radiological findings, the indications for the intervention, the procedure, all risks and alternative possible procedures at a sufficient time interval provided for by law (at least 1 day or 1 night before the planned operation).

Possible risks include injury to blood vessels, internal organs, the dura, spinal structures including the spinal cord, the risk of cement leakage with cement embolism and spinal canal stenosis, bleeding/after-bleeding, infections and neurological deficits, etc.

In addition, the anaesthesiologist must also inform the patient about the anaesthesia, including all possible special features and risks, as the operation is performed under general short anaesthesia (ITN). This is particularly important and necessary if the coblation cavity is to be combined with an additional microsurgical spinal canal decompression and/or a percutaneous spondylodesis with internal fixator (in this case, additional information about any necessary intraoperative and postoperative transfusion of blood components, especially erythrocyte concentrates, fresh frozen plasma [FFP]).

In addition, the patient must be informed in detail about the pre-, intra- and especially the postoperative procedure. Immediately postoperatively (a few days after surgery), chemotherapy and local radiation (radiotherapy) of the affected vertebrae should also take place, which significantly minimizes the risk of local recurrence and can significantly improve the therapy results. In parallel, intensive physiotherapy with strengthening of the back muscles and a walking and back school should also be carried out postoperatively. In certain cases, especially with extensive multilevel metastases and existing risk of stability directly after surgery or within the first weeks, the patient should wear a trunk orthosis for several weeks (approx. 6–10 weeks) for additional stabilization and prevention of secondary deformity. Regular clinical and radiological checks are very important after the operation.

15.5 Implementation of the Intervention

Principle of the Cavity Coblation Method

The removal of metastases or tumor tissue from a vertebral body is performed using a special plasma probe, the Cavity™ SpineWand (Fig. 15.1). The probe creates a cavity in the tumor lesion by plasma field generation (coblation = controlled ablation) under low temperature (approx. 42–70 °C, cold energy) based on plasma-mediated radiofrequency energy. The removal of tumor tissue not only creates a free space for cement replenishment, but also achieves complete destruction and vaporization of tumor cells, as the use of the plasma field breaks molecular bridges in the

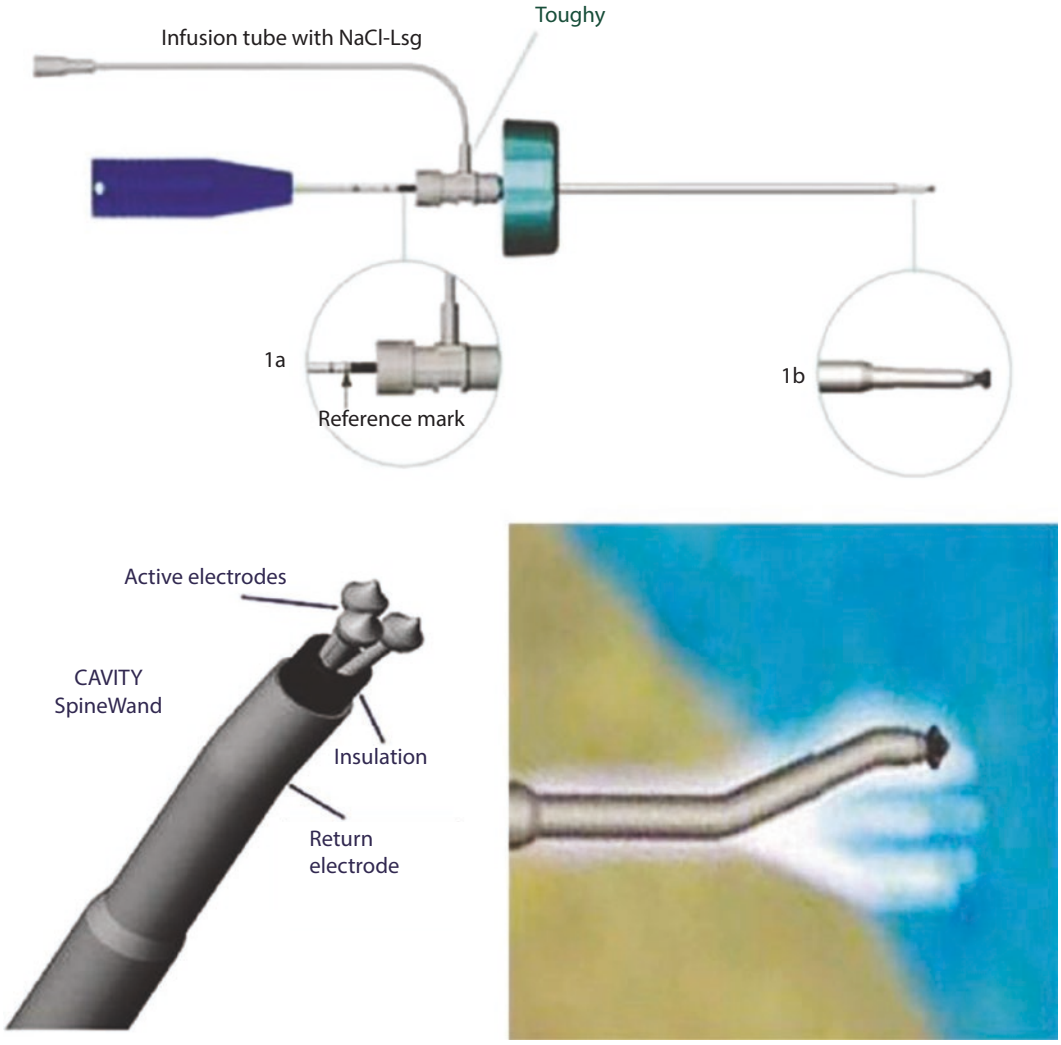


Fig. 15.1 Instrumentation: The Cavity unit, incl. Cavity™ SpineWand, has several active electrodes to generate the plasma field. Ablation is performed only in the forward motion. Electrolyte solutions e.g. NaCl are required to generate the plasma field (Mathis and Wong 2003; Nussbaum et al. 2004). The probe is pre-curved to create more space. Clinical results demonstrate the effectiveness of the Cavity™ SpineWand. 2.5–3.5 cm^2 tumors can be removed, creating a cavity ("cavity"). (Courtesy of Arthrocare)

tumor tissue, leading to denaturation of the molecules and finally to their conversion into the gaseous state (Bartels et al. 2008; Georgy and Wong 2006, 2007; Reidy 2003; Roqué 2011; Stadler et al. 2001). The resulting advantages are considerable; for example, by creating space and simultaneously coagulating and eliminating the tumor, the bone cement can be placed without pressure. The risks of extravasation and tumor spread are significantly minimized. Other surgical risks, especially blood loss, as well as complication risks and surgical times are significantly lower and shorter (Buy et al. 2006; Callstrom et al. 2006b; Do and Rippy 2005; Gangi and Buy 2010; Georgy and Wong 2006, 2007). The plasma probe is pre-bent distally and can be rotated, with ablation in multiple directions forward only under permanent radiographic guidance in 2 planes.

Coblation

Together with the Cavity™ SpineWand, the System Controller generates a plasma field for tissue ablation. **Coblation is a controlled and non-heat controlled procedure**. Bipolar radiofrequency energy is directed to a conductive medium (usually a saline solution, NaCl 0.9%) to create a focused charged plasma field. The plasma field has enough energy to break molecular bonds in the tissue. The tissue is dissolved at relatively low temperatures (42–70 °C). Because radiofrequency current does not flow directly through the tissue during coblation, tissue heating is minimal. The result is targeted volumetric ablation of the diseased target tissue or tumor tissue with minimal damage to surrounding healthy tissue.

Cavity coblation is combined with balloon kyphoplasty (Dudeney et al. 2002; Hentschel et al. 2005; Nussbaum et al. 2004) using specially made extra-thin trocars (Express Kyphoplasty Set, Medtronic) in order to subsequently fill the defect or stabilize the vertebrae with a cement application and thus reduce the fracture or kyphosis.

In addition, the cavity coblation technique can also be successfully and easily combined with percutaneous minimally invasive corrective spondylodesis with internal fixator and microsurgical decompression (in the case of metastasis resection from the spinal canal in the case of posterior edge defect), which above all significantly minimizes blood loss intraoperatively.

15.5.1 Surgical Technique of Cavity Coblation

The operation is performed in the prone position under short intubation anaesthesia. Access to one or more affected vertebral bodies is percutaneously transpedicular or extrapedicular in the thoracic and lumbar spine (Fig. 15.2), and ventrolateral in the cervical spine. X-ray controls in 2 planes are performed continuously throughout the operation.

- **Surgical step 1**: Insertion of the access trocars, if necessary with a thread, in order to obtain a better and stable hold. First, biopsy material for microbiological and histopathological examination should be taken from each affected vertebral body through a special biopsy cannula.
- **Surgical step 2**: Working with the Cavity™-SpineWand probe and coblation in several directions, removal of the tumor with minimal blood loss, as the blood vessels of the tumor are coagulated by the plasma energy, creation of the tumor-free space, a cavity (Fig. 15.3). The remnants of the tumor and the NaCl solution residues are removed or flushed out through the cannula with the aspirator under pressure.
- **Surgical step 3**: Insertion of the bone cement or kyphoplasty. Kyphoplasty not only increases the free space in the verte-

Fig. 15.2 Surgical step 1: Insertion of the special thin access cannula/trocar transpedicularly or extrapedicularly. (Courtesy of the Arthrocare company)

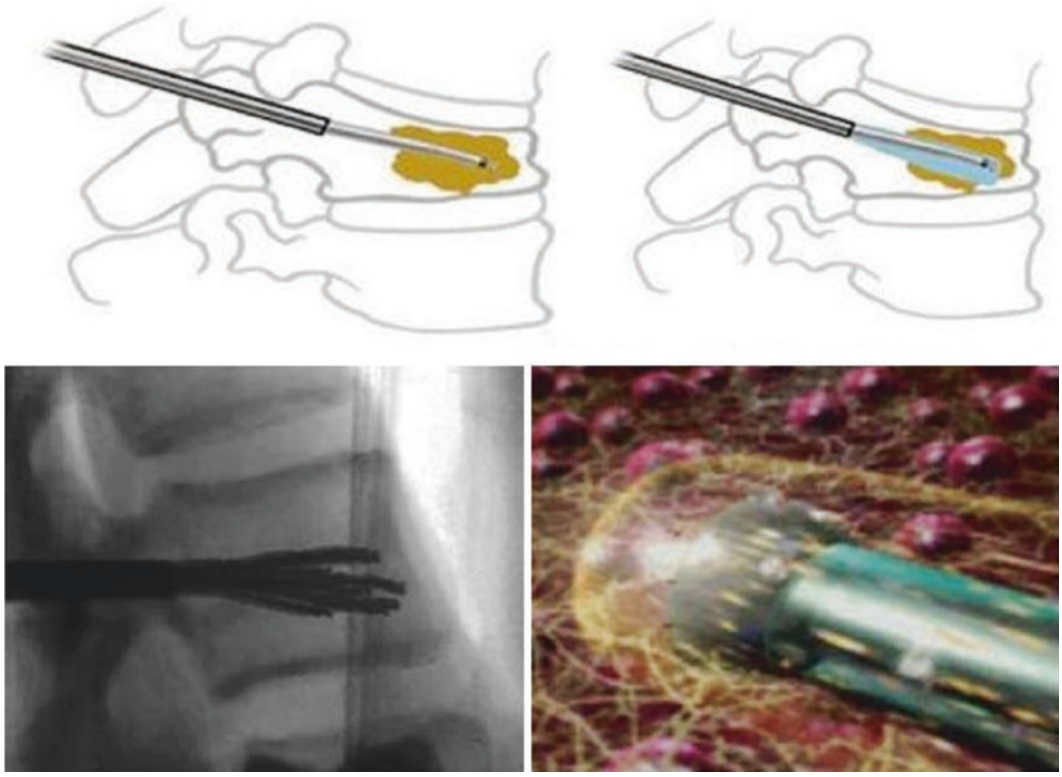


Fig. 15.3 OP step 2: Working with Cavity™ SpineWand, tumor removal by the coblation effect, tumor-free space is created. (Courtesy of the Arthrocare company)

bral body, but also allows reduction in the case of fractures (Fig. 15.4).

In one surgical session, either only one vertebral body or 2, 3 or more vertebral bodies can be effectively treated using cavity coblation.

15.5.2 Postoperative

Postoperative clinical and radiological controls of the treatment outcome should be planned and performed at regular intervals (recommended after 2, 14 days, after 3, 6, 12, 24, 36, 48 and 60 months). They should include a questionnaire interview with information on pain intensity according to VAS, impairment or improvement in quality of life, etc. Special attention should be paid to tumor staging (every 6 months in the first 2 years and annually thereafter: X-ray, CT and MRI, whole-body PET or scintigraphy), especially if local recurrence or further metastasis is suspected.

It is important that chemotherapy and local radiation (radiotherapy) of the affected vertebrae take place immediately after surgery in order to significantly minimize the risk of local recurrence. In addition, the primary tumor must be treated as quickly as possible. Intensive physiotherapy to strengthen the back muscles and walking and back training should also be carried out immediately postoperatively. If necessary, the patient must also wear a trunk orthosis for a certain time after the operation to optimise stability. Regular clinical and radiological checks are very important in the course after the operation.

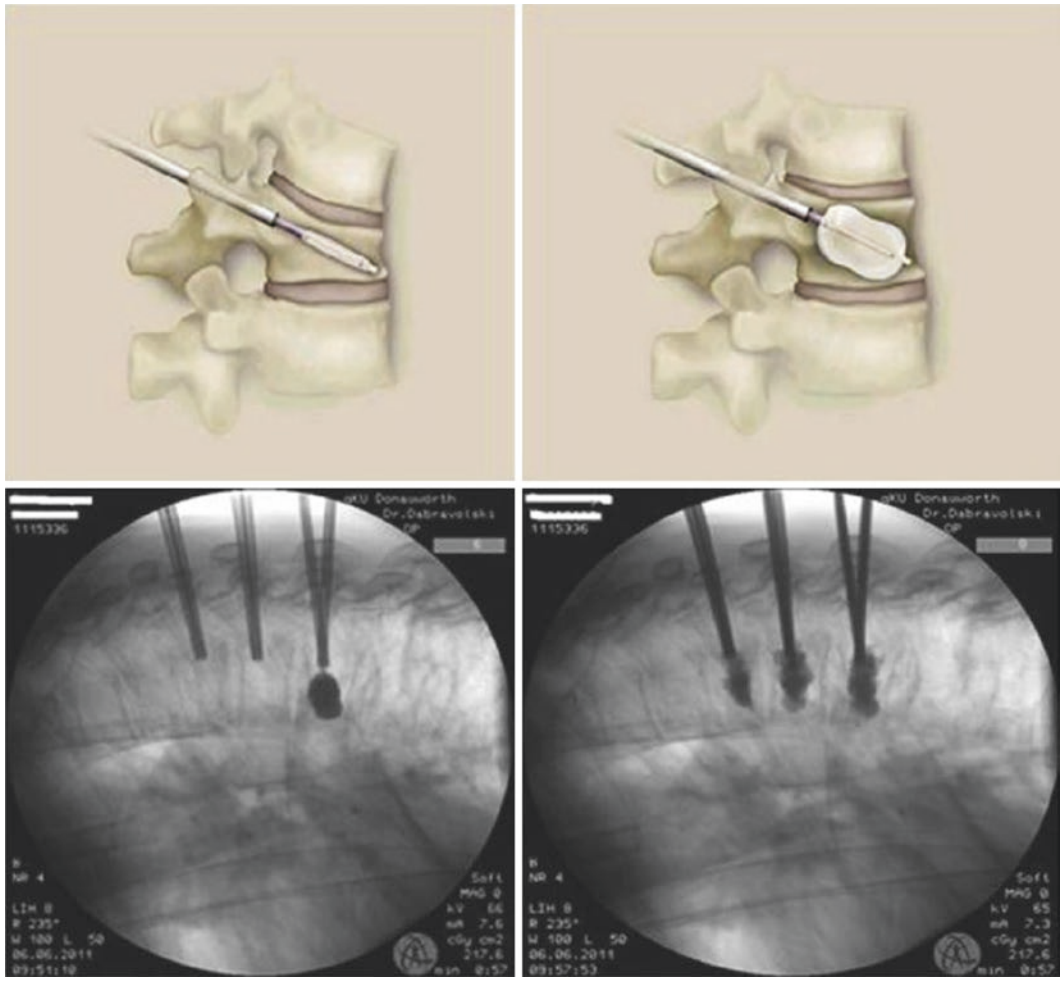


Fig. 15.4 **Surgical** step 3: Insertion of the cement (beforehand, the remnants of the tumor and the NaCl solution residues are sucked away through the cannula under pressure). If necessary, fracture reduction by balloon kyphoplasty is performed beforehand. (With kind permission of the company Arthrocare)

15.6 Possible Complications

The minimally invasive cavity coblation method followed by kyphoplasty has significantly fewer complications compared to other open treatment methods.

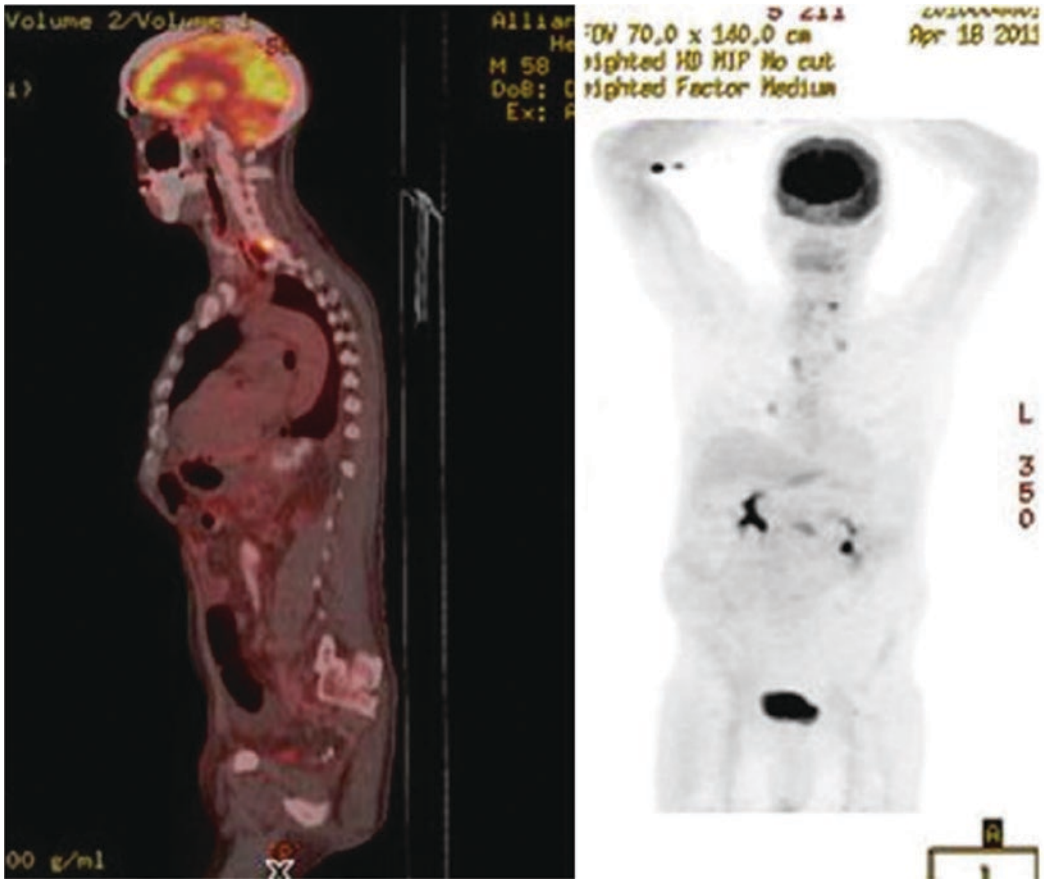
Nevertheless, the following complications are possible: injuries to vessels and nerves, internal organs, spinal cord (in the case of operations on the thoracic and cervical spine), cement leakage from the defect (possibly also dorsally with stenosis), cement embolisms, wound healing disorders and infections, secondary deformities or post-sintering of vertebral bodies, local recurrences of the tumor.

15.7 Results in the Literature

When treating patients with metastases to the spine, it is crucial to find and treat not only the primary tumor but also any metastases present. In the extensive surgical treatment, metal fixators made of titanium are used in many cases, which have a negative effect on the image quality of computed tomography and especially MRI due to their size and the formation of many large artifacts. Implants made of steel are anyway a contraindication for performing the most important diagnostic procedure in the search for local tumor foci in the context of recurrence diagnosis, magnetic

resonance imaging (MRI) (Bartels et al. 2008; Dabravolski et al. 2017; Delank et al. 2011; Kreitz 2009; Ulmar et al. 2007). Here, F18 whole-body positron emission tomography (F18-FDG-GK-PET) offers a successful application, which is also effectively used in our clinic in patients with metastases to the spine in primary tumor staging as well as in recurrence control. In the treatment of metastases to the spine, F18-FDG-PET is a very valuable additional examination method (to X-ray, CT and MRI) for detecting metastases to the spine and skeletal system as well as in lymph nodes, lungs, brain, liver and other organs (◘ Fig. 15.5).

Several known traditional methods of treatment of metastases to the spine have in part considerable disadvantages or side effects. For example, cryotherapy or thermotherapy is carried out at very low or very high temperatures and is very time-consuming, complete removal of the metastases is generally not possible, and there is a considerable risk of injury to healthy tissue, nerves, vessels and internal organs (Callstrom et al. 2006b; Gangi and Buy 2010). Laser therapy is also carried out at higher temperatures locally with approx. 500–600 °C, this involves, among other things, a risk of injury to healthy tissue (Woloszko 2000). Radiofrequency current therapy, e.g. with Rita-Starburst™-MRI-Device, works with radiofrequency current and also generates a very high temperature (>400 °C) in order to damage tumour cells; however, complete destruction of the tumour or metastasis is hardly possible. Again, there is a risk of injury to the surrounding healthy tissue including the spinal cord, nerves and



◘ **Fig. 15.5** Tumor staging preoperatively using F18-FDG whole-body positron emission tomography (PET) in a 56-year-old patient with multiple metastases of pancreatic carcinoma to the liver and C7

vessels (Dabravolski et al. 2017; Delank et al. 2011; Dupuy et al. 2000; Gangi and Basile 2005; Gangi and Buy 2010). The method of kyphoplasty in combination with intraoperative radiotherapy, which has been known for several years, is promising according to the first results and publications (Bludau et al. 2015), but it is very complex and expensive and can only be performed in large centers with special equipment for radiotherapy.

The percutaneous cavity coblation method for the treatment of tumors and metastases of the spine is a comparatively safe, minimally invasive and less traumatic procedure for patients with higher surgical risks, which has been proven by short- and long-term results in several clinical studies. The percutaneous minimally invasive approach significantly reduces surgical risks, especially blood loss, and shortens surgical times. Other important features include rapid postoperative pain reduction and restoration of stability of the tumor-affected vertebral body or spinal segment (Callstrom et al. 2006b; Dabravolski et al. 2017; Do and Rippy 2005; Gangi and Basile 2005; Gangi and Buy 2010; Georgy and Wong 2006, 2007; Suva et al. 2011).

To date, a few clinical studies, mostly with smaller case numbers, have been conducted on cavity coblation, predominantly in the United States, Japan, and France (Bortnick 2001; Buy et al. 2006; Callstrom et al. 2006b; Do and Rippy 2005; Gangi and Buy 2010; Georgy and Wong 2006, 2007; Hall and Littlefield 2001).

15.7.1 Own Clinical Results

In comparison with the "classical" cavity coblation method, this technique was modernized, renewed and completed in our clinic (Dabravolski et al. 2017):

- Through combination with balloon kyphoplasty (Dudeney et al. 2002; Hentschel et al. 2005; Nussbaum et al. 2004) (with specially manufactured extra-thin balloons and trocars), we were additionally able to perform fracture reduction and kyphosis correction in one or more segments of the lumbar spine as well as the thoracic and cervical spine after tumor removal.
- After tumor destruction by cavity coblation, the tumor remnants are suctioned or flushed out of the vertebral body under pressure before kyphoplasty/cement filling is performed, which significantly reduces the risk of recurrence.
- The method was always combined with local radiation or radiotherapy as well as chemotherapy immediately postoperatively in order to eliminate tumor residues and thus avoid local recurrence. The simultaneous treatment of the primary tumor (surgery, radiotherapy, chemotherapy) is obligatory. Since cavity coblation does not create large wound areas (even when multiple segments are treated), local radiotherapy and chemotherapy can be administered practically immediately, or as early as a few days postoperatively, whereas in extensive surgery with extensive wound areas, radiatio and chemotherapy can only be administered after several weeks due to a significantly increased risk of a serious wound healing disorder (Bartels et al. 2008; Dabravolski et al. 2017; Delank et al. 2011; Efremov 2000; Kreitz 2009; Ulmar et al. 2007). Due to the low intraoperative temperatures generated (only 42–70 °C, cold plasma field energy), the healthy tissues and organs are not injured, which significantly improves the repair processes in the lesion area.
- Cavity coblation has also been combined with mini-open or microsurgical decompression for spinal stenosis, which significantly minimized blood loss and surgical times (Dabravolski et al. 2017).

The results of our own clinical study in the treatment of many tumor patients are very positive and promising, showing good efficacy of the method for the treatment of multiple spinal metastases (Dabravolski et al. 2017). Within 6 years (2008–2014), 302 patients (188 female, 114 male, age 31–92 years. Mean age 65.4 years) with a total of 987 vertebrae affected by tumors or spinal metastases with destructions/osteolyses and fractures were treated with this method (Table 15.1,

Table 15.1 Treated tumors and metastases to the spine in our clinical trial. (Dabravolski et al. 2017)

Tumours/metastases	N (number of patients)	% (of all clinical cases)
Tumors		
Hemangioma (large, symptomatic, with refractory pain syndrome)	28	9.27
Metastases from		
Breast cancer	61	20.2
Plasmacytoma	48	15.89
Bronchial carcinoma	40	13.25
Renal carcinoma	31	10.26
Uterine/ovarian carcinoma	27	8.94
Thyroid cancer	22	7.28
Bladder/prostate cancer	19	6.29
Pancreatic cancer	12	3.97
Gastrointestinal carcinoma	10	3.31
Malignant melanoma	4	1.32
Total	**302**	**100**

Figs. 15.6 and 15.7). In 62 cases, dorsal percutaneous instrumentation and straightening was also performed. All patients immediately showed a significant reduction in pain and an improvement in satisfaction and quality of life. In several cases, treatment was combined with chemotherapy or radiotherapy, which significantly reduced the recurrence rate. Patients could be mobilized quickly after surgery, and blood loss was minimal. In a total of 274 treated patients with metastases and 903 operated vertebral bodies, local recurrence occurred in only 37 (13.5%) patients and 65 (7.2%) vertebral bodies, respectively.

Especially in the case of hemangiomas, which show a marked tendency to bleed and a risk of cemented embolism, ablation and coagulation of the tumor vessels significantly minimized both risk factors.

The complication rate was also minimal: in 40 cases (40 vertebral bodies out of a total of 987, in only 4.1%) there was a minor cement leakage laterally or into the disc space, without clinical relevance.

15.7.2 Problems and Specific Features of the Method

The treatment of metastases to the spine is still a challenge for physicians today. Very important is the close interdisciplinary coop-

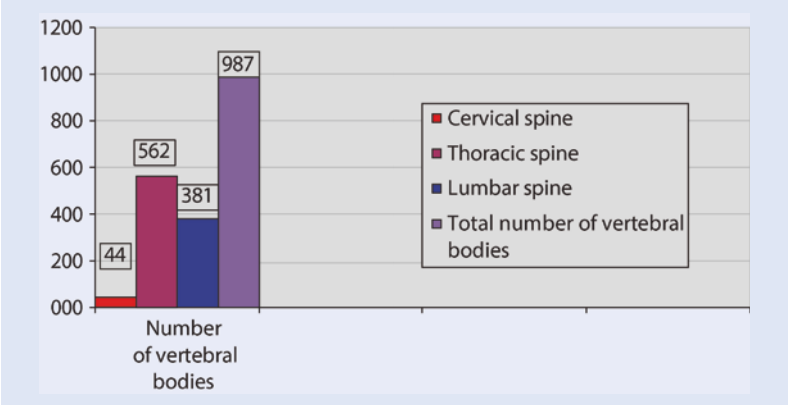


Fig. 15.6 Distribution of treated vertebrae by spinal segment. (From Dabravolski et al. 2017)

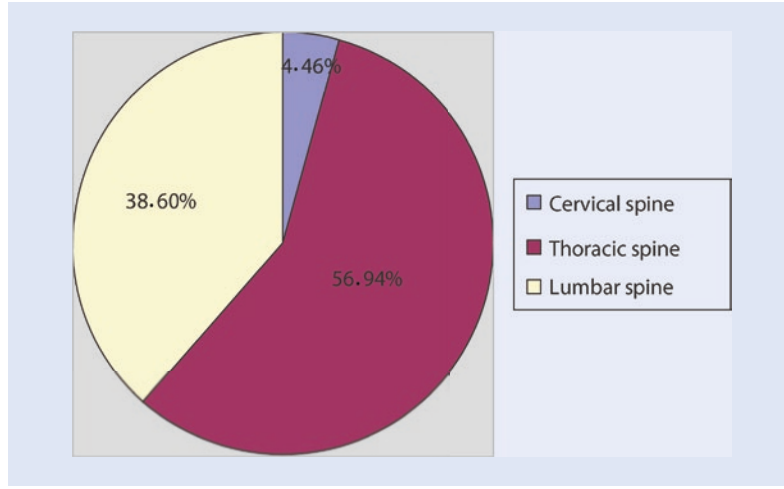


Fig. 15.7 Percentage distribution of treated vertebral bodies in spinal segments. (From Dabravolski et al. 2017)

eration of physicians from different disciplines and specialties. Depending on the bony stability, the compression of neural structures, the radiosensitivity of the tumor tissue, the pain symptomatology and, last but not least, the overall prognosis, an individually adapted therapy for spinal metastases must be planned (Bartels et al. 2008; Dabravolski et al. 2017; Delank et al. 2011; Kreitz 2009; Tokuhashi et al. 1990; Tomita et al. 2001; Ulmar et al. 2007).

The correct indication and selection of the appropriate treatment method are very important in the treatment of spinal metastases. The appropriate therapy must always be determined individually on the basis of various criteria and parameters (clinical, radiological, histopathological, etc.). Here, the well-known scoring systems are helpful (e.g. Tokuhashi score, Karnofsky index, Tomita score, etc.) in deciding which method is most suitable and to what extent (palliative vs. radical surgical tumor resection) in each specific treatment case. In a large number of patients, the method is palliative, for example in multimorbid patients and especially in cases of multilocular tumor manifestation or metastases in the spine. In the case of monometastases, a comprehensive, surgically complete resection with a curative approach is more likely to be aimed for. The various score systems for estimating treatment and survival prognosis have only limited informative value and can only be used as a guide (Bartels et al. 2008; Delank et al. 2011; Kreitz 2009; Tokuhashi et al. 1990; Tomita et al. 2001; Ulmar et al. 2007).

Naturally, in many cases it is not possible to completely remove the tumor tissue from the spine intraoperatively, either minimally invasively or as part of a large open ventrodorsal operation. Therefore, radiotherapy must be performed locally immediately after surgery. An exclusively local radiation (with a maximum total dose usually of 30–40 Grey) without prior surgical removal of the tumor tissue does not result in complete elimination of the tumor, especially in the case of large multi-stage osteolyses with a diameter of >2–3 cm. The local radiation dose would then have to be significantly increased, which can cause damage to the skin, subcutaneous and muscle tissue as well as vessels and nerves (Delank et al. 2011; Deutsche Gesellschaft für Nuklearmedizin 2016; Lutz 2011; Moser et al. 2008; Roqué 2011).

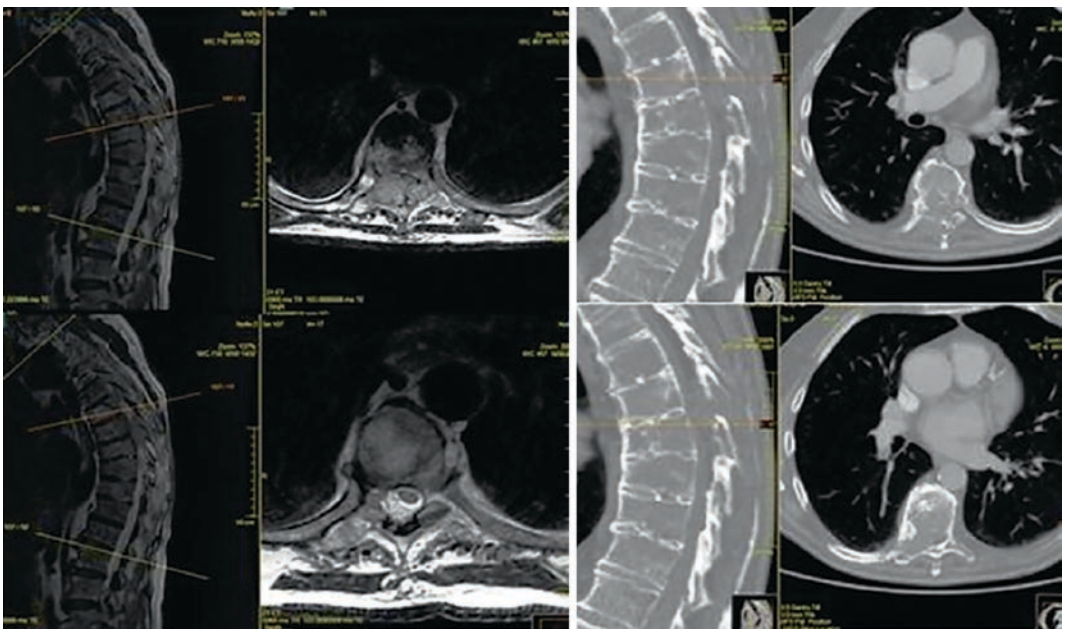
For multimorbid oncological patients with an unfavourable prognosis, in particular also with massive osteolyses or pathological fractures in the area of the spinal column, for whom no adequate therapy (especially no surgical therapy) was possible until recently and who, due to the immobility caused by metastases, suffer from various concomitant diseases correspondingly more quickly (diabetes meitus, renal insufficiency, pneumonia, embolism, cardiovascular disease). The treatment with the cavity coblation method now offers the possibility of regaining a relevant degree

of mobility with the ability to bear weight and to walk, especially for patients with massive osteolysis or pathological fractures in the area of the spine, for whom no adequate therapy (especially no surgical therapy) was possible until recently and who died correspondingly more quickly from various concomitant diseases (diabetes mellitus, renal insufficiency, pneumonia, embolism, cardiac and circulatory failure, etc.) due to the immobility caused by the metastases. This, together with a marked reduction in pain symptoms, significantly improves the quality of life (◘ Figs. 15.8, 15.9 and 15.10).

Survival time in patients with spinal metastases is always dependent on several parameters and aspects, mainly the metastasis or tumor type and number, as well as tumor spread, patient age, concomitant diseases, and the clinical condition of the patient (Delank et al. 2011; Ulmar et al. 2007). Removal of spinal metastases by cavity coblation followed by radiation and chemotherapy significantly improved the clinical condition in every patient in our study. Patients were fully mobile immediately after surgery, pain symptoms were significantly lower, and the stability of the affected spinal segment was significantly better than preoperatively. Therefore, the quality of life and also the survival time were better in patients treated with the cavity coblation method than in patients in whom the multiple metastases from the spine could not be removed. In the latter, mobility was severely limited and patients died often and quickly from concomitant diseases as well as from the metastatic or tumor manifestations.

Like any other therapy method, coblation cavity also has its limits and indication restrictions. These are mainly large extensive metastases with destruction of one or more entire vertebral bodies. Optimal for the application of Coblation-Cavity is when a metastasis is completely within the vertebral body and all 6 or at least 4 vertebral body walls still exist for support or attachment for the bone cement.

In addition, the method has a learning curve that should not be underestimated. It is by no means a beginner's operation and must be performed by a very experienced spine surgeon with very good knowledge of topo-



◘ **Fig. 15.8** Clinical case 1: 72-year-old patient with metastatic prostate carcinoma. Preoperative MRI and CT of the thoracic and lumbar spine show multiple metastases Th6-Th10 with osteolyses and a massive spinal canal stenosis and spinal cord compression in Th7-Th8 (with clinically incomplete paraplegia)

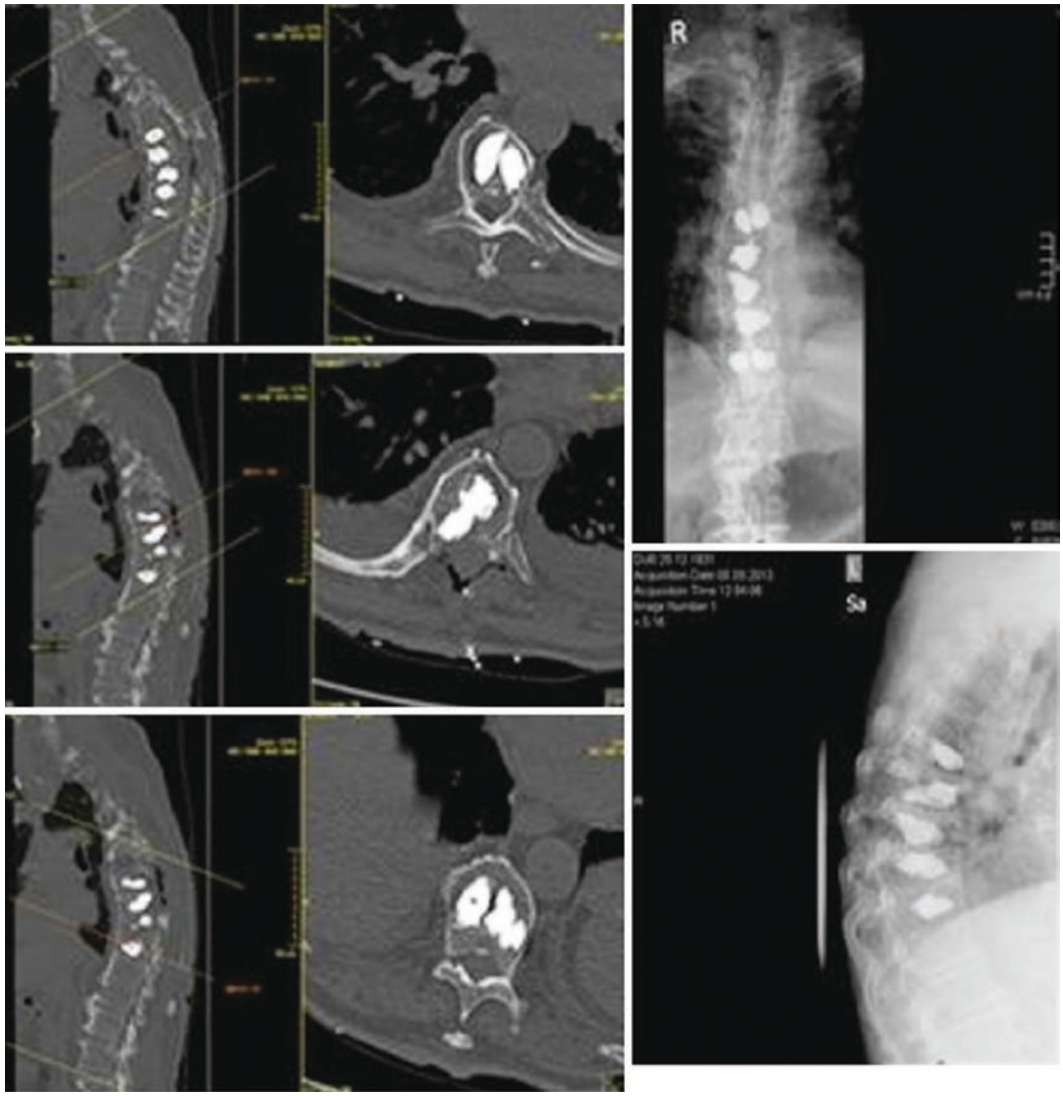


Fig. 15.9 Clinical case 1: Postoperative X-ray and CT after cavity coblation Th6-Th10, microsurgical laminectomy and spinal canal decompression Th7-Th8 in mini-open technique. Postoperative complete regression of the paraplegia, significant pain reduction. Radiological control 12 months postoperatively: no local recurrence, no material loosening

graphic anatomy. The extent of the operation or the indication must be reviewed very precisely and individually for each patient and in each specific case.

In addition to the correct indication, a precise surgical technique is important, whereby the removal of metastases should be as complete as possible.

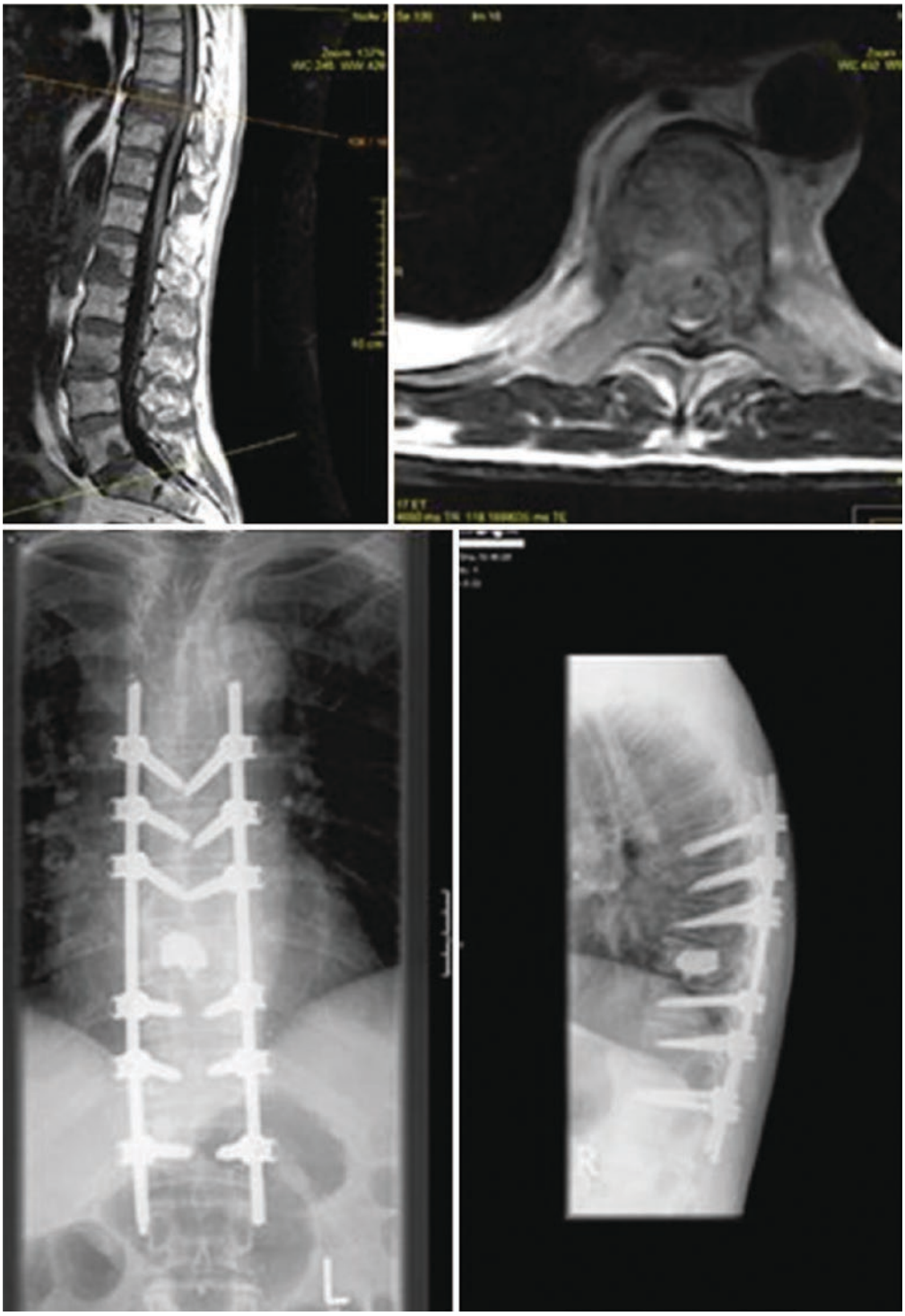


Fig. 15.10 Clinical case 2: 62-year-old patient with multiple metastases of a prostate carcinoma in the thoracic spine, ribs, Th9 with massive defect, stenosis and spinal cord compression. OP: minimally invasive decompression microsurgically with laminectomy Th9 and also with the help of coblation cavity, thereby significant reduction of blood loss, additional stabilization and straightening with fixateur interne percutaneously Th6-Th12. Postoperative: Radiatio BWS and ribs and tumor removal at the prostate. 6 months after surgery no local recurrence

15.8 Reimbursement of Costs

15.8.1 Coding Peculiarities in the DRG for Intravertebral Radiofrequency Ablation and for Cavity Coblation

Since 2014, a specific OPS code for the coding of radiofrequency ablation of intravertebral tumors has been available for the first time: 5-839 h (Destruction of bony tissue by radiofrequency ablation, percutaneous). Here, the bone drilling and imaging procedure are included in the code: .h0 = 1 vertebral body; .h1 = 2 vertebral bodies; .h2 = 3 vertebral bodies; .h3 = 4 or more vertebral bodies.

If radiofrequency ablation is used and coded as monotherapy, this leads to DRG I10F (valuation relevance 1.157; revenue €3906.16; with 2017 federal base rate of €3376.11) regardless of the number of vertebral bodies treated.

If radiofrequency ablation is combined with kyphoplasty, the base DRG I09 is addressed. In this context, radiofrequency ablation is not relevant for assignment to DRG I09. The relevant points for assignment to the individual DRGs within the basic DRG are (Table 15.2):

- Number of vertebral bodies treated with kyphoplasty,
- Age of the patient,
- PCCL score (Complexities and Comorbidities),
- Combination with further interventions on the spine, such as osteosynthesis.

As radiofrequency ablation is not yet relevant for DRG allocation, although it represents a surgical intervention that incurs additional costs, applications to review the mapping of radiofrequency ablation have been submitted since 2014 as part of the "Proposal procedure for the involvement of medical, scientific and other expertise in the further development of the G-DRG system". However, these have not yet been taken into account this year.

Nevertheless, it is indispensable to code the existing OPS code for intravertebral radiofrequency ablation when such an intervention has been performed. Only on the basis of unambiguous, complete and cost-appropriate coding can a realistic further development of the G-DRG system be undertaken. Otherwise, the cost differences that have arisen cannot be identified and mapped by the Institute for the Hospital Remuneration System (InEK).

Table 15.2 Coding based on the G-DRG system 2017 for intravertebral radiofrequency ablation and for cavity coblation

Therapy	PCCL	OPS	DRG	BWR	Proceeds[a] (in €)
BKP 1 Vertebral body + radiofrequency ablation		5-839.a0 + 5-839.h 0-3	109F	1788	6036.48
BKP 2–3 Vertebral body + radiofrequency ablation		5-839.a 1-2 + 5-839.h 0-3	109E	2355	7950.74
BKP >3 vertebral bodies + radiofrequency ablation		5-839.a3 + 5-839.h 0-3	109D	3108	10,492.95
BKP 2–3 Vertebral body + radiofrequency ablation	>3	5-839.a 1-2 + 5-839.h 0-3	109D	3108	10,492.95
BKP >3 vertebral bodies + radiofrequency ablation	>3	5-839.a3 + 5-839.h 0-3	109C	4332	14,625.31

[a]With 2017 federal base rate of € 3376.11

PCCL stands for patient clinical complexity level; *OPS* surgery and procedure code; *DRG* diagnosis-related case groups; *BWR* valuation ratio; *BKP* balloon kyphoplasty

15.8.2 Special Features of the Coding of Diagnoses

If the admission is for treatment of the primary tumour, this is given as the principal diagnosis. If the intravertebral metastases are also treated during the same stay, the ICD code C79.5 "Secondary malignant neoplasm of bone and bone marrow" is additionally coded as a secondary diagnosis. The coding of the primary tumor as the principal diagnosis triggers the assignment of the case to the MDC (Major Diagnosis Group) specific to the primary tumor, e.g., in the case of breast carcinoma, to MDC 09 "Diseases and disorders of the skin, subcutaneous tissue and breast". If the primary tumour is unknown, ICD codes from C80.- "Malignant neoplasms without indication of location" are available.

If, however, the patient is admitted for treatment of the metastases, C79.5 is the principal diagnosis and the primary tumour is coded as a secondary diagnosis. If a vertebral body fracture is present in addition to the metastases, an asterisk code from M49.5-* "Vertebral body compression in diseases classified elsewhere" must be given as a secondary diagnosis. Due to the cross-star system, this code must not be coded alone.

15.9 Conclusion and Clinical Relevance

When treating patients with multiple metastases to the spine, the following aspects must be taken into account in practice:

- Proper indication, patient selection, sober prognostic assessment.
- Comprehensive diagnostics preoperatively: clinical, radiological (always including tumor staging) and, if possible and available, also histological—performance of a biopsy to determine morphological and histological tumor type.
- The indication for surgery or the extent of the operation must be determined individually for each patient and planned precisely.
- Close interdisciplinary cooperation of the orthopedist or spine surgeon with specialists from other fields: with radiologists and nuclear physicians, with radiation therapists, oncologists, histopathologists, with pain therapists, physiotherapists, etc.
- Precise surgical technique, aiming for as complete as possible removal of tumor tissue, deformation correction, fracture reduction and stability restoration of the spine and the individual vertebral body.
- Performing biopsies intraoperatively with sampling from all affected vertebral bodies.
- Postoperative implementation of local radiotherapy and chemotherapy immediately following surgery.
- Particularly important is the co-treatment of the primary tumor and all other tumor derivatives or metastases.
- Regular follow-up: clinical and radiological, including tumour staging, to exclude local recurrences, loosening and fractures, and to assess the patient's condition, pain relief, satisfaction and quality of life.

Multimorbid oncological patients with massive osteolytic metastases in the spine, with instability and pathological fractures and a massive therapy-resistant pain syndrome, for whom no adequate therapy, in particular no surgical therapy, was possible until recently, who were practically no longer mobile and able to bear weight and accordingly died much more quickly from various concomitant diseases (pneumonia, embolism, cardiovascular failure, depression, etc.).), are now given the opportunity to get up again after being treated with the cavity coblation method. They are immediately mobile, able to bear weight and walk again after the operation. The pain syndrome is considerably reduced and the quality of life improves accordingly. These seriously ill patients can now spend the time remaining to them—the last days, weeks and months—actively, pain-free and fully mobile at home with their family and do not have to lie in bed in hospital, as was often the case until recently due to the lack of adequate treatment resources.

The cavity coblation method for the treatment of multiple metastases to the spine in combination with kyphoplasty as well as chemotherapy and local radiotherapy immediately postoperatively represents a safe minimally invasive procedure, which has been proven in our clinic by short- and long-term results. The effectiveness of this method is also confirmed by numerous clinical studies or examples from the other colleagues. Surgical risks, blood loss and surgical times are significantly lower and shorter. This new method is still used in Germany in only a few clinics with lower numbers of operations. In other countries (especially the USA, Japan, France), it is already being used on a larger scale (also on other skeletal segments: pelvis, extremities). In our opinion, the cavity coblation method has promising future potential.

References

Bartels RH, van der Linden YM, van der Graaf WT (2008) Spinal extradural metastasis: review of current treatment options. CA Cancer J Clin 58:245–259

Bludau T, Reis F, Schneider S et al (2015) Kyphoplastie kombiniert mit intraoperativer Radiotherapie (Kypho-IORT). Radiologe 55:859–867

Bortnick DP (2001) Coblation: an emerging technology and new technique for soft-tissue surgery. Plast Reconstr Surg 107:614–615

Buy X, Basile A, Bierry G et al (2006) Saline-infused bipolar radiofrequency ablation of high-risk spinal and paraspinal neoplasms. AJR Am J Roentgenol 186:322–326

Callstrom MR, Charboneau JW, Goetz MP et al (2006a) Image-guided ablation of painful metastatic bone tumors: a new and effective approach to a difficult problem. Skelet Radiol 35:1–15

Callstrom MR, Atwell TD, Charboneau JW et al (2006b) Painful metastases involving bone: percutaneous image-guided cryoablation-prospective trial interim analysis. Radiology 241:572–580

Dabravolski D, Eßer J, Lahm A, Merk H (2017) Treatment of tumors and metastases of the spine by minimally invasive CAVITYcoblation method (plasma field therapy). J Neurosurg Sci 61:565–578. https://doi.org/10.23736/S0390-5616.16.03690-0

Delank K, Wendtner C, Eich H et al (2011) Behandlung von Wirbelsäulenmetastasen. Dt Ärztebl 108:71–80

Deutsche Gesellschaft für Nuklearmedizin e.V. (DGN) (2016) Leitlinie für die Radionuklidtherapie bei schmerzhaften Knochenmetastasen. https://www.nuklearmedizin.de/leistungen/leitlinien/html/radio-nuk_ther.php?navId=53. Accessed on 30.07.2018

Do H, Rippy M (2005) Bone ablation with a plasma-mediated radiofrequency-based device: an in vivo study of temperature and gross effects in tissue. In: Vortrag am congress of neorological surgeons im Okober in Boston

Drees P, Kafchitsas K, Mattyasovszky S et al (2010) Die Radiofrequenz-Kyphoplastie – eine innovative Methode zur Behandlung von osteoporotischen Wirbelkörperkompressionsfrakturen. J Miner Stoffwechs 17:15–19

Dudeney S, Lieberman IH, Reinhardt MK et al (2002) Kyphoplasty in the treatment of osteolytic vertebral compression fractures as a result of multiple myeloma. J Clin Oncol 20:2382–2387

Dupuy D, Hong R, Oliver B et al (2000) Radiofrequency ablation of spinal tumors: temperature distribution in the spinal canal. AJR Am J Roentgenol 75:1263–1266

Efremov NM (2000) Experimental investigation of the action of pulsed electrical discharges in liquids on biological objects. IEEE Trans Plasma Sci 28:224–229

Elgeti F, Gebauer B (2010) Die Radiofrequenz-Kyphoplastie zur Behandlung osteoporotischer und neoplastischer Wirbelkörperfrakturen. J Mineral Stoffwechs 17:5–9

Gangi A, Basile A (2005) Radiofrequency and laser ablation of spinal lesions. Semin Ultrasound CT MR 26:89–97

Gangi A, Buy X (2010) Percutaneous Bone Tumor Management. Semin Intervent Radiol 27:124–136

Georgy BA, Wong W (2006) Plasma-mediated radiofrequency-based ablation in conjunction with percutaneous cement injection for treating painful vertebral compression fractures resulting from metastasized malignancy. In: vortrag am kongress der american society of spine radiology im februar in Las Vegas

Georgy BA, Wong W (2007) Plasma-mediated radiofrequency ablation assisted percutaneous cement injection for treating advanced malignant vertebral compression fractures. AJNR Am J Neuroradiol 28:700–705

Hall DJ, Littlefield PD (2001) Radiofrequency ablation versus electrocautery in tonsillectomy. J Otolaryngol Head Neck Surg 125:211

Hentschel SJ, Burton AW, Fourney DR (2005) Percutaneous vertebroplasty and kyphoplasty performed at a cancer center: refuting proposed contraindications. J Neurosurg Spine 2:436–440

Kreitz N (2009) Operative Behandlung von Knochenmetastasen. Medtropole 17:647–650

Licht AW, Kramer W (2010) Radiofrequenz-Kyphoplastie: Eine neue Methode zur Behandlung osteoporotischer Wirbelkörperkompressionsfrakturen—eine Fallstudie. J Miner Stoffwechs 17:35–37

Lutz S (2011) Palliative radiotherapy for bone metastases: an ASTRO evidence-based guideline. Int J Radiat Oncol Biol Phys 79:965–976

Mathis J, Wong W (2003) Percutaneous vertebroplasty: technical considerations. J Vascular Interv Ref Radiol 14:953–960

Miko L, Szikora I, Grohs J et al. (2009) Initial clinical experience with radio-frequency based vertebral

augmentation in treatment of vertebral compression fractures. In: Vortrag am annual meeting of the society of interventional radiology in San Diego

Moser T, Cohen-Solal J, Bréville P et al (2008) Pain assessment and interventional spine radiology. J Radiol 89:1901–1906

Nussbaum DA, Gailloud P, Murphy K (2004) A review of complications associated with vertebroplasty and kyphoplasty as reported to the food and drug. J Vasc Interv Radiol 15:1185–1192

Reidy D (2003) A biomechanical analysis of intravertebral pressures during vertebroplasty of cadaveric spines with and without simulated metastases. Spine 28:1534–1539

Roqué I (2011) Radioisotopes for metastatic bone pain. Cochrane Database Syst Rev 7

Stadler KR, Woloszko J, Brown IG (2001) Repetitive plasma discharges in saline solutions. Phys Lett 79:4503–4505

Suva L, Washam C, Nicholas RW et al (2011) Bone metastasis: mechanisms and therapeutic opportunities. Nat Rev Endocrinol 7:208–218

Tokuhashi Y, Matsuzaki H, Toriyama S et al (1990) Scoring system for the preoperative evaluation of metastatic spine tumor prognosis. Spine 15:1110–1113

Tomita K, Kawahara N, Kobayashi T et al (2001) Surgical stategy for spinal metastases. Spine 26:298–306

Ulmar B, Huch K, Kocak T et al (2007) The prognostic influence of primary tumour and region of the affected spinal segment in 217 surgical patients with spinal metastases of different entities. Z Orthop Ihre Grenzgeb 145:31–38

Woloszko J (2000) Lasers in surgery: advanced characterization, therapeutics and systems. Spine 3907:306–316

Lumbar Nucleoplasty

L. W. Ackermann

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_16

Chronic low back pain places great demands on the treating physician, so that many minimally invasive decompressive techniques have been developed, including the technique of nucleoplasty. This method is based on the volume reduction of the intervertebral disc by plasmatic current. When well indicated, it represents a possibility to close the gap between intervertebral disc surgery and conservative therapies.

In several studies there is evidence of the positive effect of nucleoplasty in terms of pain reduction and improved mobility for at least 12 months.

16.1 Indication

The range of indications for lumbar nucleoplasty is quite narrow and limited to patients with pain symptoms consisting of at least 50% radiation into the leg in addition to lumbar pain.

The MRI findings should confirm an intervertebral disc protrusion or a subligamentous disc herniation with, at most, a small spatial mass without sequestration. The disc should also have lost no less than 50% of its original height (Mirzai et al. 2007).

Exclusion criteria include mechanical stenosis and segmental instability as well as neurological findings such as sensory or motor paresis in addition to the known red flags.

16.2 Technology

Nucleoplasty uses the technique of creating an electric field which is applied to the nucleus pulposus of the intervertebral disc via a bipolar probe. In the process, the nucleus pulposus is excited as a conductive medium with high-frequency electrical energy. In this way, a "plasma field" is generated. This can dissolve tissue at the molecular level and convert it into predominantly gaseous molecules, which in turn can escape through the probe (Chen et al. 2003; Chen and Lee 2003). The procedure is also known as coblation (shortened from "cold ablation") or plasma disc decompression (PDD).

In contrast to other procedures, the application of nucleoplasty results in rather low temperatures (50–70 °C) (Nau and Diederich 2004).

16.3 Preinterventional Diagnostics

An x-ray of the lumbar spine in two planes in the standing position and an MRI should have been performed for imaging, on the one hand to exclude risks and on the other hand to ascertain the localization and nature of the disc changes.

Conservative therapy should be provided for a period of at least 6–12 weeks, if necessary also supported with targeted injections, before the nucleoplasty procedure is indicated. In case of doubt about the lesion level to be treated, a provocation discography should be performed preoperatively.

A few days before the procedure, it is advisable to have an up-to-date laboratory with blood count, C-reactive protein, erythrocyte sedimentation rate and Quick.

16.4 Necessary Instruments

For a trouble-free procedure, a C-arm with 2 monitors and a table with fluoroscopy capability, which can be adjusted in height by means of pedals and is preferably equipped with a "floating plate", are required. The nucleoplasty procedure requires a room suitable for sterile procedures.

A control unit is also required, such as the "Efficient One" for approx. 2300 € net.

For the disposable electrode with introducer cannula in the set the costs are about 890 € net. A grounding pad is not used because a bipolar electrode is used.

Distribution e. g. via: Lysistech GmbH, Bismarckstr. 5, D-38102 Braunschweig (► www.lysistech.com).

16.5 Pre-Intervention Education

The procedure is performed under local anaesthesia with X-ray vision. It is a fairly low-risk procedure with very rare complications or discomfort (Rathmell et al. 2008).

Despite the greatest care and position control of the probe under the image converter, bleeding, secondary bleeding, nerve irritation or nerve injury can occur in a few cases. The rare main risk is an infection, the development of a diszitis or even spondylodiscitis, abscess formation or even meningitis with subsequent nerve paralysis.

In some cases, local pain, skin irritation and local numbness as well as, very rarely, increased leg pain may occur after the procedure, which disappears after a few days (Bhagia et al. 2006).

The success of nucleoplasty can still be seen in a period up to 8 weeks after the procedure (Gerszten et al. 2010).

16.6 Implementation of the Intervention

The patient is positioned on the radiolucent table in the prone position with slight delordosis. The patient is awake and must therefore lie comfortably. The image converter is aligned centrally in the a.p. direction on the target disc level so that the cover and base plates appear parallel. The BV is then rotated sideways to the painful side by about 30–35 ° until the small vertebral joint can be seen clearly, or it is projected approximately over the centre of the displayed cover plate.

The anterior portion of the disc is now presented ventrally from the superior process of the lower vertebra. The approach via the "Kambin's triangle" corresponds to that of the discography (Fig. 16.1). This provides the so-called tunnel view for the desired target of the intervention.

After brief disinfection of the skin, a generous skin quaddle is placed. Subsequently, using a 10 mm needle, the puncture canal infiltration is carried out gradually up to the ventral part of the superior process by means of a short-acting local anaesthetic (Fig. 16.2).

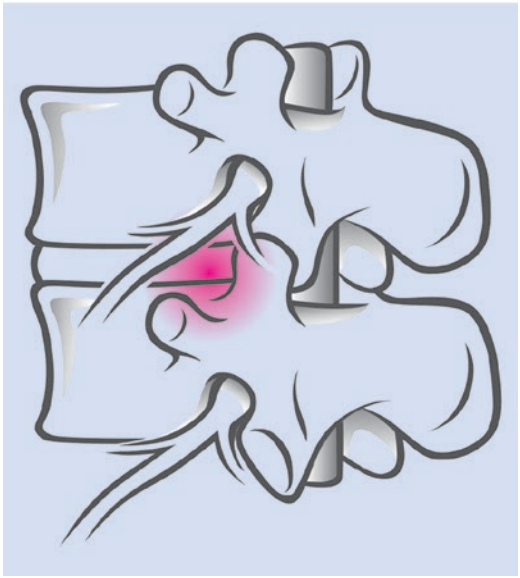


Fig. 16.1 Pink marked Cambin triangle as target zone

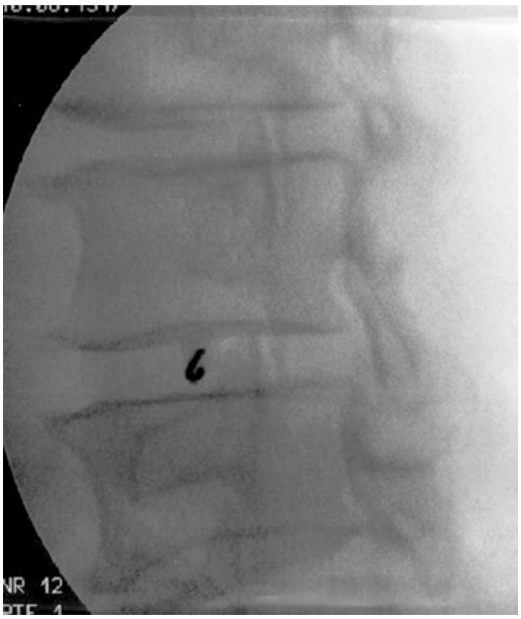


Fig. 16.2 Nucleoplasty trocar in tunnel view L4/5 from the left

Sterile washing and covering as usual and perioperative intravenous antibiosis. The introducer needle is then inserted in the tunnel view onto the target in the intervertebral disc directly in front of the superior process until the resistance of the intervertebral disc is felt.

Then check in a.p. and lateral view. The introducer tip should be centered over the intervertebral disc, i.e. not too close to the cover plate or base plate, and directly in front of the superior articular process of the lower vertebra. Then advance the introducer needle further so that the tip is directly medial to the pedicle line in the a.p. view (Fig. 16.3). In the lateral view, the introducer tip should now be located approximately at the transition of the posterior third to the middle third of the disc.

Then remove the stylet and insert the nucleoplasty probe into the introducer sheath, carefully advance under fluoroscopy in lateral view until a slight resistance is created. This is generated by the ventrolateral annulus fibrosus of the intervertebral disc. This must not be penetrated under any circumstances. In this distal position, a limiter spring ring is fixed to the upper end of the probe to prevent accidental injury to the fibrous ring during further maneuvers. Here again, securing is done by X-ray control in 2 planes. The probe tip should be centered in the disc and not touch the base or cover plate (Fig. 16.4). Then retract the probe while fixing the introducer cannula with the other hand until the grey marking (proximal limit) appears on the probe. The distance between the limiter spring ring and the grey mark on the probe represents the treatment distance, which is usually between 25 mm and 40 mm. Under application of current, the probe is slowly advanced over the treatment distance within 10 s until the limiter spring ring is reached. Then retract the probe without applying current, rotate the probe by approx. 60 ° and reenter under current for 10 s. This procedure should be done about 6 times. Thanks to the slightly curved tip of the probe, small divergent channels are created in the disc.

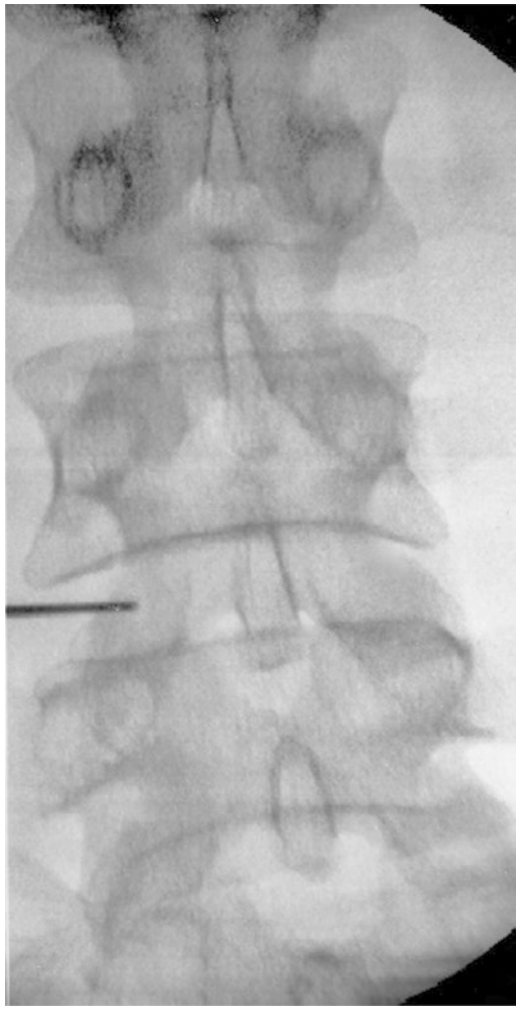


Fig. 16.3 a.p. radiograph of the L4/5 nucleoplasty trocar with its tip at the medial pedicle line

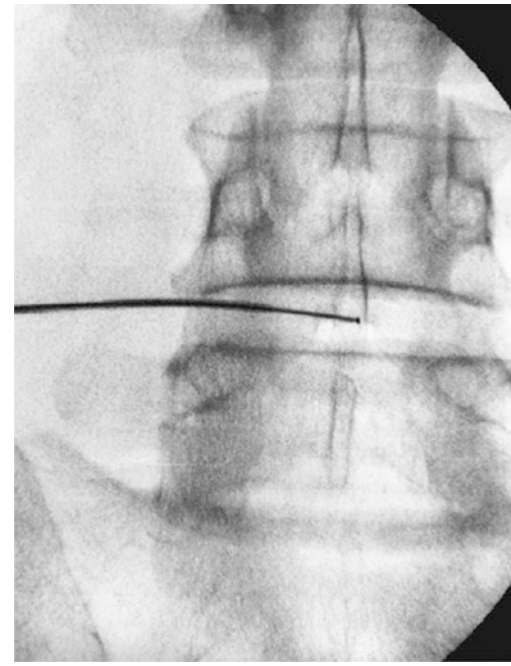


Fig. 16.4 a.p. X-ray image of the nucleoplasty probe in target area L4/5

Then withdraw first the probe, then also the introducer cannula.

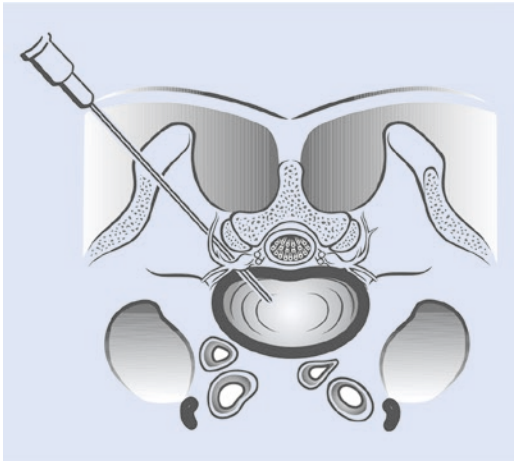
After the intervention, the patient is monitored for 2 h. Full motor and sensory abilities are checked, after which the patient is mobilized. In the further course, control after 1 week and 4 weeks. One week of sports prohibition and wearing of a lumbar bariatric brace as well as general physical rest. After that, there are no more restrictions.

16.7 Possible Complications

It seems opportune to perform the nucleoplasty in awake patients under local anesthesia, at most under light analgesia. In this way, nerve injuries are prevented even in the case of incorrect positioning of the probe or anatomical variations. If the above-mentioned anatomical structures cannot be safely visualized (often difficult at the L5/S1 level), do not proceed. If the approach is too ventral, the large blood vessels are at risk (◘ Fig. 16.5).

At the level of LWK1-LWK3, the rotation should not exceed 25°, as otherwise the kidneys could be endangered. In this case, it is advisable to clarify the position in advance by CT or MRI.

If a preoperative discography is necessary, this should not be done immediately before the procedure, because on the one hand the electrical field is changed and on the other hand the contrast medium can cover the electrode tip.



◘ **Fig. 16.5** Position of the nucleoplasty probe in axial view

16.8 Results in the Literature

In several studies, nucleoplasty showed a positive therapeutic effect that was better than that of conservative therapy (El-Zain et al. 2008; Mirzai et al. 2007; Alexandre et al. 2005).

Compared to transforaminal epidural corticosteroid injection (TFESI), the effect was also better in a controlled prospective study over 24 months (Gerszten et al. 2010).

In a large systematic review, 22 prospective and 5 retrospective studies on a total of 3211 patients after nucleoplasty were evaluated. Overall, it was possible to demonstrate that this intervention significantly reduces pain (VAS was still reduced by more than 3 points after 12 months) and increases mobility (Oswestry Disability Index was still reduced from 58.95 to 24.43 after 12 months) (Eichen et al. 2014).

The complication rate is low compared to many other intradiscal procedures and was reported to be 0.8% for cervical use and 1.8% for lumbar nucleoplasty in 3069 patients in the aforementioned review study (Eichen et al. 2014).

16.9 Reimbursement of Costs

The nucleoplasty procedure has its own operation and procedure code, OPS 2018, and can be performed on an outpatient basis:

5-831.8 Percutaneous volume reduction of intervertebral disc.

- Including: Percutaneous laser disk decompression, chemonucleolysis, coblation.
- Info: The access is not to be coded separately here.

According to EBM number 31133, this corresponds to a D3 procedure.

The costs for the probe are usually reimbursed by the health insurance fund (KV) after presentation of the invoice.

References

Alexandre A, Coro L, Azuelos A, Pellone M (2005) Percutaneous nucleoplasty for discoradicular conflict. Acta Neurochir Suppl 92:83–86

Bhagia SM, Slipman CM, Nirschl M et al (2006) Side effects and complications after percutaneous disc decompression using coblation technology. Am J Phys Med Rehabil 85:6–13

Chen YC, Lee SH (2003) Intradiscal pressure study of percutaneous disc decompression with nucleoplasty in human cadavers. Spine (Phila Pa 1976) 28:661–665

Chen YC et al (2003) Histologic findings of disc, end plate and neural elements after coblation of nucleus pulposus: an experimental nucleoplasty study. Spine J 3:466–470

Eichen PM, Achilles N, Konig V et al (2014) Nucleoplasty, a minimally invasive procedure for disc decompression: a systematic review and meta-analysis of published clinical studies. Pain Physician 17:E149–E173

El-Zain F, Lemcke J et al (2008) Minimally invasive spinal surgery using nucleoplasty: a 1-year-follow-up study. Acta Neurochir 150:1257–1262

Gerszten PC, Smuck M, Rathmell JP et al (2010) Plasma disc decompression compared with fluoroscopy-guided transforaminal epidural steroid injections for symptomatic contained lumbal disc herniation: a prospective randomized controlled trial. J Neurosurg Spine 12:357–371

Mirzai H, Tekin I, Yaman O, Bursali A (2007) The results of nucleoplasty in patients with lumbar herniated disc: a prospective clinical study of 52 consecutive patients. Spine J 7:88–93

Nau WV, Diederich CJ (2004) Evaluation of temperature distributions in cadaveric lumbal spine during nucleoplasty. Phys Med Miol 49:1583–1594

Rathmell JP, Saal JS, Saal J (2008) Discography, IDET, percutaneous discectomy, and nucleoplasty: complications and their prevention. Pain Med 9(S1):S73–S81

Cervical Nucleoplasty

K. Birnbaum

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_17

17.1 Indication

The indication for nucleoplasty of the cervical spine is clear. This includes a monoradicular radiation of pain from the cervical spine into the right or left arm depending on the form of the disc protrusion or prolapse.

An exclusion criterion is acute nerve root compression with motor paresis.

Pain in the cervical spine alone is not an indication for nucleoplasty, since in the majority of cases it reflects pain originating in the facet joints. An MRI of the cervical spine is used preoperatively to confirm the indication for surgery. The clear indication is disc protrusion and non-sequestered disc prolapse with matching clinical symptoms of discomfort.

In many cases, floor diagnostics can help to determine the indication. This means that if the practitioner is unable to establish an unambiguous indication, floor diagnostics can make a significant contribution to the decision on therapy. This includes the repeated clinical-neurological examination in the course of at least 6 weeks of intensive conservative therapy, which would precede the nucleoplasty.

Conservative therapy primarily includes treatment with nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics and, if necessary, muscle relaxants in combination with intensive physiotherapeutic exercise treatment (KG) with training of the cervical spine-stabilizing muscles and acupuncture. If necessary, physical therapy measures with massages, electrotherapy and thermal baths are also used.

If these therapeutic measures do not show any improvement in the symptoms, the next step is targeted injections in the cervical spine, which may be performed during the course of the ongoing KG. In the first step, these include facet infiltrations and subsequently nerve root infiltrations of the cervical spine or the affected disc levels and nerve roots. The targeted injections should be performed under C-arm control or under computed tomographic control. This allows a safe floor diagnosis and at the same time a clear documentation. If the targeted C-arm-assisted nerve root infiltration—matching the affected disc floor or matching the disc protrusion or prolapse—contributes to a passive pain reduction, the indication for disc decompression (nucleoplasty) is clear.

If the pain persists despite the exhaustion of conservative treatment measures, nucleoplasty may be indicated.

17.2 Disc Decompression (Nucleoplasty): What Is it?

Nucleoplasty is a low-temperature plasma excision and thus a controlled, non-heat-controlled procedure. This allows temperatures that are at a maximum of 50 °C at the probe tip of the nucleoplasty catheter, thus making damage to the surrounding tissue, especially nervous structures, almost impossible.

Bipolar radiofrequency energy is directed to a conductive medium—in this case disc tissue or nucleus pulposus. This generates a precisely focused plasma field which breaks the molecular bonds in the tissue and thus enables volumetric ablation of the intervertebral disc tissue.

High voltage is applied to the conductive liquid—in this case intervertebral disc tissue. The intervertebral disc tissue is thereby transformed into an ionized vapor layer (plasma). The plasma field contains ions that hit the tissue at high speed and break molecular bonds. The tissue is transformed into predominantly gaseous molecules, which can escape through the trocar of the nucleoplasty probe (Chen 2003).

This technique, which has been used in minimally invasive disc therapy for more than two decades, allows controlled and localized ablation of disc tissue at low temperatures. It involves effective pressure relief of the disc and promotes the scientifically proven self-healing process by initiating an anti-inflammatory, interleukin-mediated biochemical process (O'Neill et al. 2004).

17.3 Preoperative Diagnostics

A conventional x-ray of the cervical spine in 3 planes should be performed on the one hand to assess foraminal narrowing and facet joint arthrosis and on the other hand to exclude

inflammatory or tumorous changes. In addition, an MRI of the cervical spine should be obtained to assess the intervertebral discs and exclude cervical myelopathy.

If there are possible disc changes over several motion segments, a few days before the actual surgery planned discography of the disc floors for the surgeon and the patient can provide clarity about the floor to be treated.

17.4 Reconnaissance

The minimally invasive surgical procedure of nucleoplasty of the intervertebral discs of the cervical spine has a very low surgical risk.

As with any surgical procedure, the possibility of infection and injury to nerves, vessels and adjacent structures must be explained.

17.5 Surgical Technique

The best possible preparation guarantees a safe success of the surgical procedure.

The first step is good positioning that is comfortable for the patient. The patient lies supine on a radiolucent table. Establishment of an i.v. line, pulse oximetry and ECG for monitoring. If necessary, supplementary stand-by by the anaesthesiology department of the hospital as well as supplementary sedation of the patient if necessary. Intubation anaesthesia is not indicated in any case.

Subsequently, the X-ray image intensifier (intensifier) should be precisely adjusted to the cervical spine motion segment to be treated and the tilt (gentry) of the intensifier should be marked. The surgical risk decreases all the more significantly, the more the surgeon observes a safe radiographic setting of the disc level to be treated intraoperatively. This includes the clear line-shaped adjustment of the cover or base plate of the adjacent vertebral bodies in the X-ray image of the monitor located at the foot end or opposite.

Now retract the BV and sterilely cover the surgical site. It is important to maintain continuous contact with the patient, as the sterile covering of the surgical site significantly restricts the awake patient's field of vision during the minimally invasive surgical procedure.

The next step is to set the operating table. A sterile pen, another skin disinfection, a local anaesthetic for the stitch canal anaesthesia as well as the nucleoplasty catheter and the nucleoplasty needle (needle trocar) are required.

Now mark the anatomical landmarks—in particular the common carotid artery laterally and the trachea and oesophagus medially (Fig. 17.1). Medial to the artery, one senses a gap between the trachea and the vessel. In this natural low-resistance area, the needle trocar should be positioned at the level of the disc level to be treated (Fig. 17.2).

The hand position of the trocar needle and the nucleopasty catheter are as follows for the minimally invasive intervention: The trocar needle is clamped between the second and third finger and inserted into the disc space under continuous BV control.

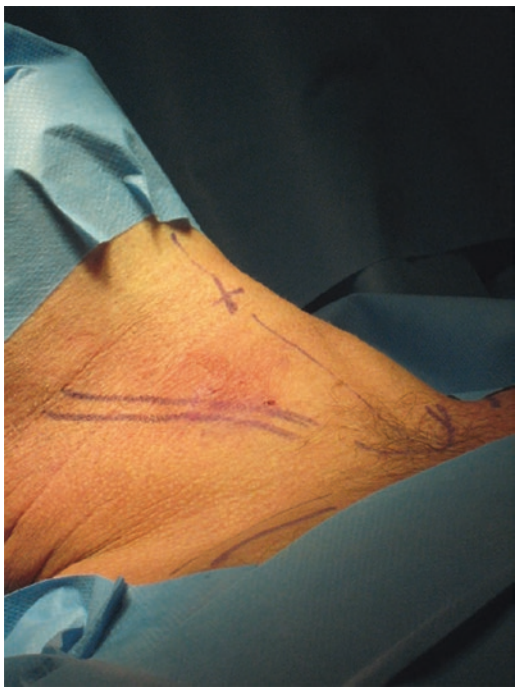


Fig. 17.1 Intraoperative view of the surgical site of the cervical spine from ventral with sterile draping at the level of the mandible and rib cage. Marking of the anatomical landmarks: Midline with underlying trachea and esophagus and common carotid artery

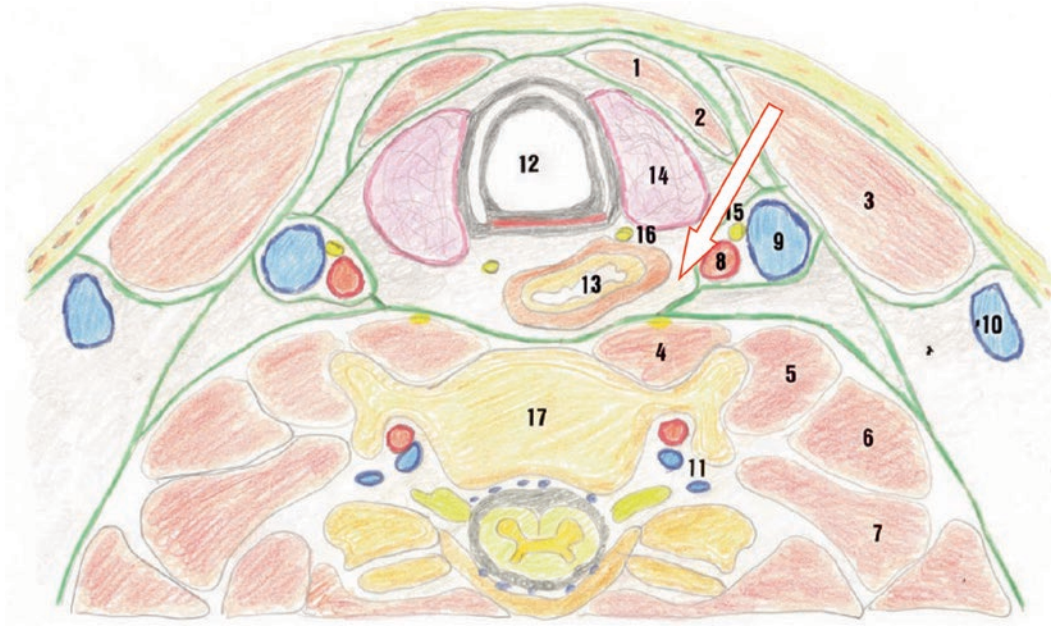


Fig. 17.2 Drawing of the cervical spine in cross-section showing the important anatomical structures and illustrating the ideal percutaneous access route (*arrow*) between the trachea medially and the common carotid artery laterally. *1* Sternohyoid muscle; *2* Sternothyroid muscle; *3* Sternocleidomastoid muscle; *4* Longus colli muscle; *5* Anterior scalenus muscle; *6* Medial scalenus muscle; *7* Posterior scalenus muscle; *8* *Common carotid artery;* *9* Common carotid artery. Carotis communis; *9* V. jugularis interna; *10* V. jugularis externa; *11* Vasa vertebralia; *12* Trachea; *13* Esophagus; *14* Glandula thyroidea. *Arrow* = optimal angle of entry of the trocar needle into the intervertebral disc

The following **surgical steps** are performed:

Search of the puncture site under C-arm control in p.a. and lateral view: in a.p.-centre position fine-line drawing of the base and cover plates of the disc to be treated visible; in lateral view disc also clearly visible in the area of the cervicothoracic transition.

Asking the patient to bring his arms down.

Subcutaneous instillation of local anesthetic (Fig. 17.3).

Insertion site between artery and trachea anterolaterally: Depending on the position of the trocar needle, the surgeon can enter the disc space either ipsilaterally, medially or contralaterally. The entry angles of the insertion needle in relation to the midline of the cervical spine motion segments (Fig. 17.4) are as follows

- 10–15° for the ipsilateral side of the disc,
- 15–20° for the mediodorsal region of the disc,
- 20–25° for the contralateral side of the disc.

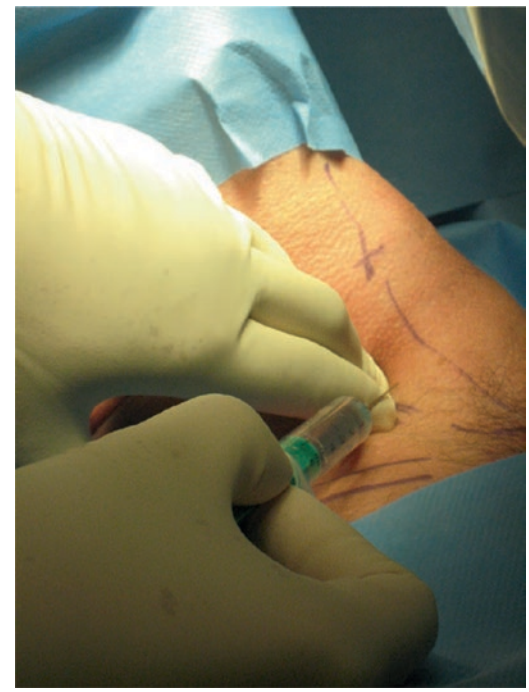


Fig. 17.3 Subcutaneous instillation of local anaesthetic between the medial trachea and the lateral common carotid artery prior to trocar insertion

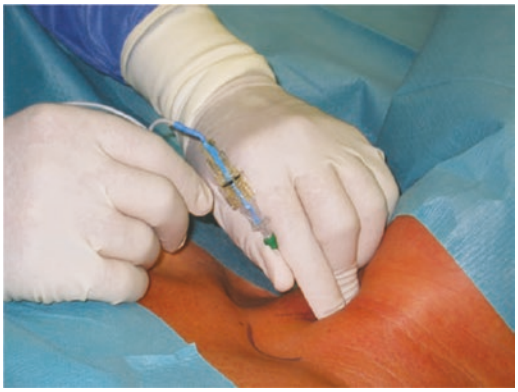


Fig. 17.4 Intraoperative hand position of the trocar with the nucleoplasty catheter. The needle trocar is inserted into the disc under lateral X-ray control. In the next step, with the needle correctly positioned intradiscally in the posterior third of the disc space in the lateral radiographic projection of the motion segment, the needle is withdrawn into the middle third of the disc space. In the following step, the nucleoplasty catheter is inserted under continuous lateral X-ray control in order to prevent the catheter tip from entering the spinal canal in any case

17.5.1 Intradiscal Section

First, the intradiscal placement of the trocar needle is performed under continuous radiographic control in a.p. (anteroposterior) and lateral projection. Orthograde radiographic visualization of the intervertebral disc space in the ventral and lateral beam paths is important for accurate positioning of the needle. The base plate of the upper vertebral body and the cover plate of the lower vertebral body must be visible as a line-like boundary in the radiograph (Fig. 17.5a, b).

After correct positioning of the trocar needle tip in the posterior third of the intervertebral disc in lateral X-ray projection and projection of the needle tip in the middle third of the intervertebral disc in ventral X-ray, the needle is retracted to the middle of the intervertebral disc. This must be done because when the nucleoplasty catheter is inserted and locked via the Luer lock of the

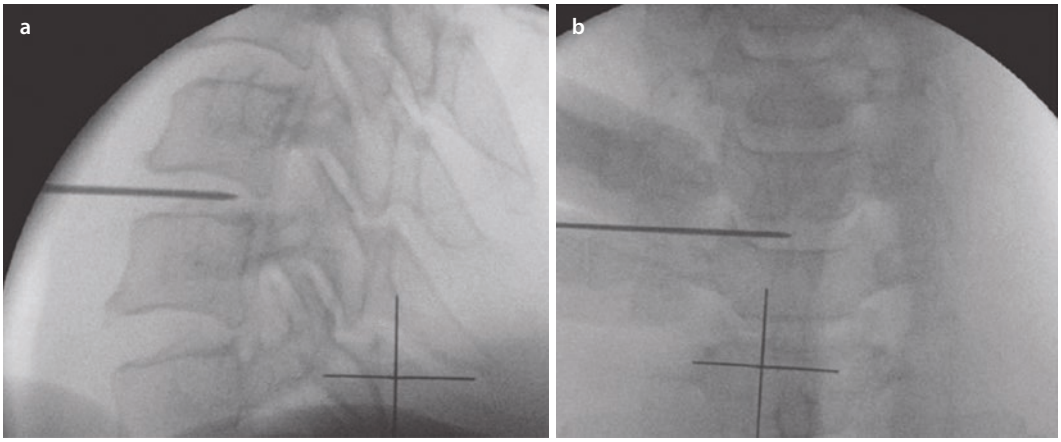


Fig. 17.5 **a** Lateral X-ray of the cervical spine showing the needle trocar in the posterior third of the disc space to be treated. **b** X-ray of the cervical spine from ventral (a.p. projection) showing the needle trocar in the middle of the disc space to be treated. For the correct position of the needle trocar, it is important that the needle tip is in the posterior third of the disc space in the lateral X-ray projection. At the same time, a central projection of the needle tip should be visible in the ventral X-ray projection

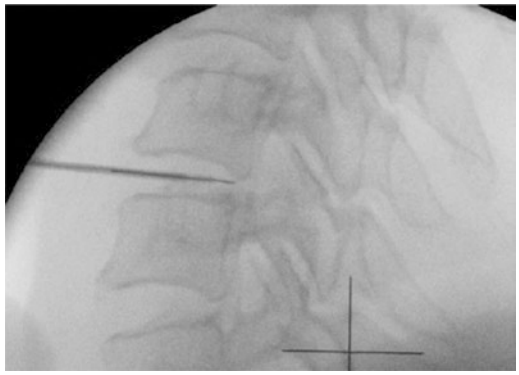


Fig. 17.6 Lateral X-ray with intradiscal visible connected nucleoplasty catheter in the posterior third of the disc to be treated. In this position, the **first** coblation is performed with the controller set to level 2 for 2–3 s with simultaneous rotation of the nucleoplasty catheter by 360°

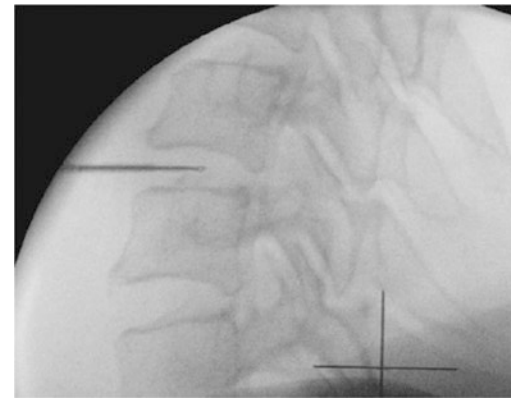


Fig. 17.7 Lateral X-ray with intradiscal visible connected nucleoplasty catheter in the middle third of the disc to be treated. In this position, the **second** coblation is performed with the controller set to level 2 for 2–3 s with simultaneous rotation of the nucleoplasty catheter by 360°

trocar needle, the tip protrudes 7 mm beyond the trocar needle (Fig. 17.6).

After insertion of the nucleoplasty catheter, the controller unit is connected, which activates the plasma field. After connecting the controller, the short stimulation with the coagulation mode is carried out for a maximum of 1 s in order to exclude possible nerve irritation during the subsequent coblation mode (generation of the plasma field). If the patient does not complain of any discomfort, the coblation can be performed.

Coblation (generation of the plasma field) is performed with the Level 2 controller for 2–3 s in the posterior and middle thirds of the disc space with simultaneous 360 ° rotation of the nucleoplasty catheter (Figs. 17.6 and 17.7).

When activating the plasma field (coblation), the catheter should not be advanced, as this may result in bending and possibly shearing of the tip. In any case, contact of the vertebral body end plates with the tip of the nucleoplasty catheter should be avoided, as otherwise a thermal influence on the base and cover plate of the adjacent vertebral bodies may result.

All steps should be performed under C-arm control and documented step by step. After coblation of the intervertebral disc, first the nucleoplasty catheter and then the trocar needle are removed. The final skin disinfection and the sterile dressing complete the operation.

17.5.2 Postoperative

Perioperative antibiotic prophylaxis is given. The hospital stay usually lasts 4–5 h. An anatomical neck brace should be worn by the patient for 1 week at night (Dunning bandage). The inability to work is 4–5 days.

17.6 Results

Cervical nucleoplasty is an outstanding procedure for the sufficient treatment of disc protrusion and non-sequestered disc prolapse after conservative therapy measures have been exhausted. With the correct indication, it represents a successful alternative to monosegmental spondylodesis.

In-house results in 86 patients who had a mean baseline pain score of 8.6 on the visual analog scale (VAS) at baseline showed a pain reduction of 1.8 on the VAS at follow-up 2 years after cervical nucleoplasty compared with physical therapy and nerve root injections.

Overall, the data base of publications on the topic of cervical nucleoplasty is very manageable and the value of the publications is moderate.

A study by Yan et al. (2010) compared the treatment of non sequestered cervical disc hernia with nucleoplasty (n = 81) versus nucleotomy (n = 95). Pain severity was evaluated by VAS 2 weeks postoperatively and 1, 3, 6, and 12 months postoperatively. Thereby, 12 months postoperatively showed a comparable pain reduction in both surgical procedures: In the nucleotomy patients, the pain score was on average still 2.74 (preoperative 7.12), in the nucleoplasty patients 2.71 (preoperative 7.18).

References

Chen YC (2003) Histologic findings of disc, end plate and neural elements after coblation of nucleus pulposus: an experimental nucleoplasty study. Spine J 3:466–470

O'Neill CW et al (2004) Percutaneous plasma decompression alters cytokine expression in injured porcine intervertebral discs. Spine J 4:88–98

Yan et al (2010) Percutaneous cervical nucleoplasty and percutaneous discectomy treatment of the contained cervical disc herniation. Arch Orthop Trauma Surg 130(11):1371–1376

Endoscopic Decompression of the Lumbar and Cervical Spine

S. Ruetten and M. Komp

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_18

Conventional spinal decompressions show good results (Annertz et al. 1995; Ebeling et al. 1986; Epstein and Adler 2000; Ferrer et al. 1988; Gore and Sepic 1998; Grieve et al. 2000; Harrop et al. 2003; Hermantin et al. 1999; Jodicke et al. 2003; Johnson et al. 2000; Kotilainen and Valtonen 1993; Laing et al. 2001; Papadopoulos et al. 2006; Villavicencio et al. 2007). Nevertheless, surgery-related scarring of the epidural space can occur (Annertz et al. 1995; Fritsch et al. 1996; Lewis et al. 1987; Schoeggl et al. 2002), which can also become clinically symptomatic (Fritsch et al. 1996; Ruetten et al. 2002). In addition, they complicate reoperations, which can never be ruled out in the spine due to the progressive degenerative process. Available study results indicate the possibility of surgery-induced instabilities due to the necessary resection of structures of the spinal canal (Abumi et al. 1990; Haher et al. 1994; Hopp and Tsou 1988; Kaigle et al. 1995; Kato et al. 1998; Kotilainen and Valtonen 1993; Kotilainen 2001; Sharma et al. 1995). The access route in the innervation area of the dorsal branch of the spinal nerve may adversely affect the stabilizing and coordinating systems (Cooper et al. 1991; Lewis et al. 1987; Waddell et al. 1988). Access-related and surgery-specific complications and problems may occur. The combination of these parameters may explain unsatisfactory outcomes of revision surgery (Aydin et al. 2002; Epstein 2002; Kawaguchi et al. 1996; Pedram et al. 2003; Sihvonen et al. 1993; Wang et al. 2007). Because of these problems, attempts have been made to modify existing surgical procedures from the very beginning of spine surgery. The focus here is on reducing invasiveness and improving intraoperative visibility with appropriate illumination and visualization of the structures.

The open interlaminar approach to the spine has been described since the early twentieth century (Abumi et al. 1990; Brayda-Bruno and Cinnella 2000; Mixter and Barr 1934; Putti 1927; Stookey 1928). Thirty years after its introduction, alternative methods for surgery of disc pathology developed (Hult 1951). The posterolateral approach for biopsies from vertebral bodies was described in the late 1940s (Valls et al. 1948). Percutaneous surgery was used from the early 1970s (Gottlob et al. 1992; Hijikata 1975; Maroon et al. 1989; Smith et al. 1963). In the late 1970s, the microsurgical approach via the interlaminar approach using a microscope was developed (Caspar et al. 1991; Goald 1978, 1980; Wilson and Kenning 1979). Endoscopes have been used since the early 1980s, initially to inspect the intervertebral space after open surgery was completed (Forst and Hausmann 1983). This evolved into full-endoscopic transforaminal surgery with posterolateral access (Kambin and Sampson 1986; Kambin et al. 1996, 1998; Knight et al. 1998; Mathews 1996; Mayer and Brock 1993; Savitz 1994; Stücker 2005). Endoscopic-assisted interlaminar techniques were described in the literature in the late 1990s (Brayda-Bruno and Cinnella 2000; Destandau 1999; Nakagawa et al. 2003; Perez-Cruet et al. 2002; Schick et al. 2002). The lateral approach for full-endoscopic transforaminal surgery improved access to the spinal canal under continuous visualization since the late 1990s (Fig. 18.1) (Ruetten et al. 2005, 2007b, 2008b). The development of the full-endoscopic interlaminar approach occurred at the same time (Fig. 18.2) (Ruetten 2005; Ruetten et al. 2006, 2007b, 2008b).

In the cervical spine, the dorsal approach was described in the 1940s and surgical procedures with a ventral approach in the 1950s (Cloward 1958; Frykholm 1951; Semmes and Murphey 1943). The ventral decompression and fusion that evolved from this is now considered the gold standard for decompression surgery. Various modifications have been described, such as ventral decompression without fusion (Aydin et al. 2005; Dowd and Wirth 1999; Savolainen et al. 1998; Sonntag and Klara 1996; Thorell et al. 1998), ventral foraminotomy in various techniques (Choi et al. 2007; Hakuba 1976; Jho 1996; Johnson et al. 2000; Lee et al. 2006; Pechlivanis et al. 2006; Saringer et al. 2003) or ventral endoscopic transdiscal decompression (Fig. 18.3) (Ahn et al. 2005; Chiu et al. 2000; Kotilainen 1999, Lee et al. 2006; Wang et al. 2001; Zhou et al. 1994). Disc prosthesis attempts to reconstruct the intervertebral space while preserving segmental mobility (Mummaneni et al. 2007; Nabhan et al. 2007; Pickett et al. 2006). All

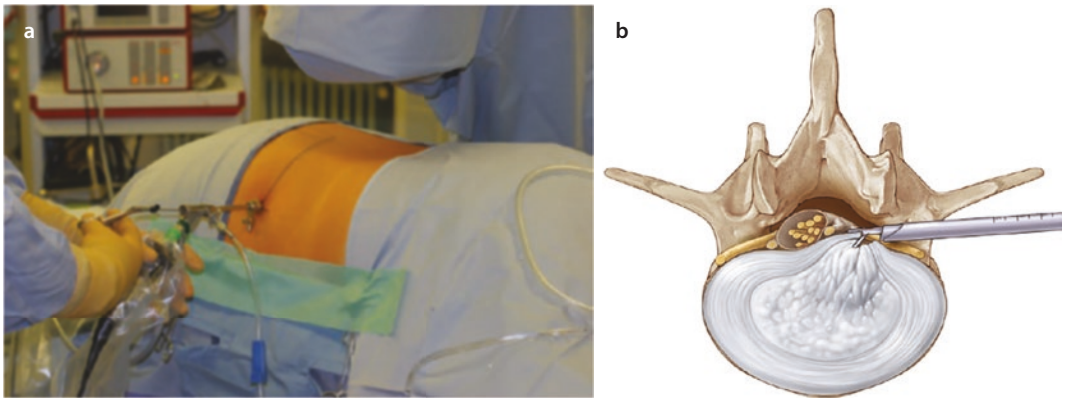


Fig. 18.1 **a**, **b** Lumbar lateral transforaminal approach

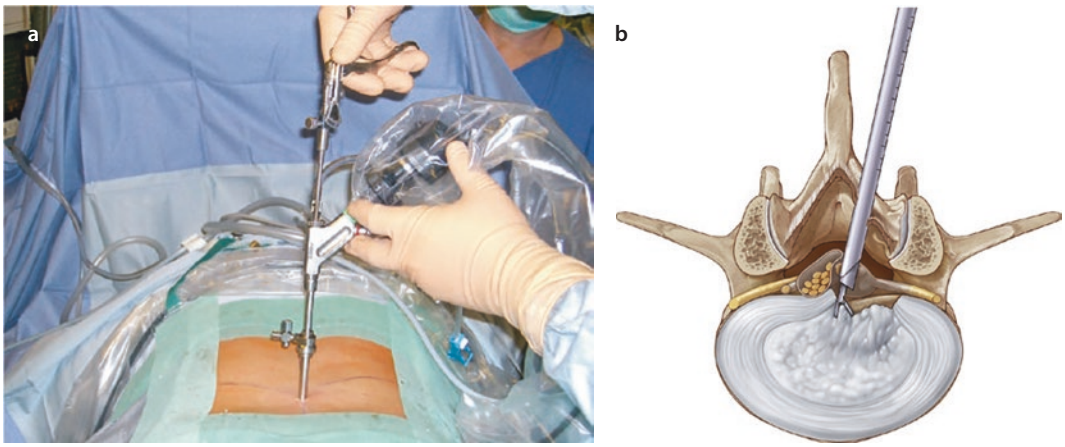


Fig. 18.2 **a**, **b** Lumbar interlaminar approach

alternative ventral techniques, with the exception of disc prosthesis, involve decompression without fusion, i.e., reconstruction of the intervertebral space. The dorsal technique is the most common alternative procedure for decompression surgery (Adamson 2001; Aldrich 1990; Clarke et al. 2007; Epstein and Adler 2000; Grieve et al. 2000; Harrop et al. 2003; Jodicke et al. 2003; Riew et al. 2007; Woertgen et al. 1997). Microscopic-assisted and endoscopic-assisted techniques have been described to reduce invasiveness and are nowadays referred to as keyhole foraminotomy (Adamson 2001; Burke and Caputy 2000; Fessler and Khoo 2002; Hilton Jr. 2007; Roh et al. 2000). Endoscopic ventral techniques have also been reported since the late 1980s (Ahn et al. 2005; Chiu et al. 2000; Kotilainen 1999; Ruetten et al. 2009b; Wang et al. 2001; Zhou et al. 1994). The full-endoscopic dorsal approach was developed in 2008 (Fig. 18.4) (Ruetten et al. 2007b, 2008b).

Minimally invasive techniques can reduce tissue damage and its consequences (Parke 1991; Schick et al. 2002; Weber et al. 1997). Endoscopic surgery is considered standard in many fields. In the musculoskeletal system, arthroscopic surgery with rod-lens optics under continuous fluid flow shows the advantages of less invasiveness and improved intraoperative visibility, outweighing the disadvantages for many indications. For fully endoscopic operations on the lumbar spine, the trans/extraforaminal and the interlaminar approach are available nowadays, on the cervical spine the ventral and dorsal approach.

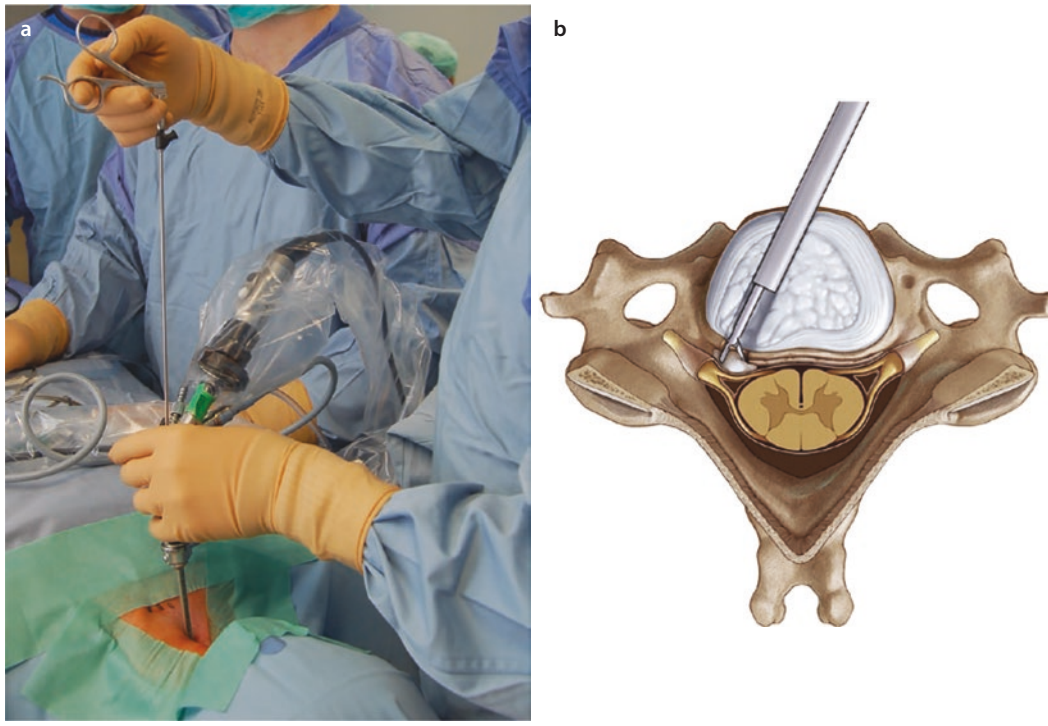


Fig. 18.3 **a**, **b** Cervical contralateral ventral approach

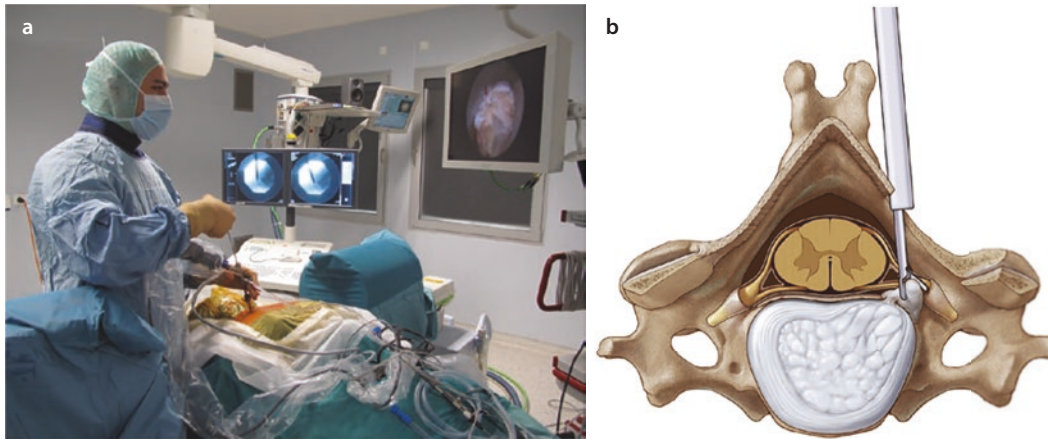


Fig. 18.4 **a**, **b** Cervical dorsal approach

18.1 Indication

The main indications for surgery correspond to the standards valid today (Andersson et al. 1996; McCulloch 1996). They relate to radicular symptoms and/or neurogenic claudication and, in the cervical spine, also to central symptoms. Isolated back or neck pain is usually not improved by decompression surgery. Concomitant pathologies, such as instabilities or deformities, may need additional treatment with other procedures.

18.1.1 Lumbar Spine

The following pathologies are considered indications for full-endoscopic trans/extraforaminal or interlaminar surgery of the lumbar spine:

- sequestered or non-sequestered intra- and extraforaminal disc herniations,
- sequestered or non-sequestered recurrent disc herniations of any localization,
- lateral spinal stenosis (foraminal and recess stenosis),
- central spinal stenosis,
- lateral spinal canal stenosis due to cysts of the zygoapophyseal joints (foraminal stenosis).

Indication Trans–/Extraforaminal Access

In the case of herniated discs within the spinal canal, the following indication criteria must be taken into account due to the pelvis and/or the limited mobility of the endoscope:

- Localization of the herniated disc in the craniocaudal direction between the middle of the caudal and the beginning of the cranial pedicle,
- In the orthograde, lateral beam path, radiological coverage of the corresponding intervertebral disc maximally up to the middle of the cranial pedicle.

All pathologies that are localized intra–/extraforaminal are operated on primarily with the trans–/extraforaminal approach, since they cannot be reached directly with the interlaminar approach. There are no restrictions for disc herniations and foraminal stenoses, including those caused by intra/extraforaminal cysts. In the case of recess stenoses, the craniocaudal extension may extend at most from the upper edge of the underlying pedicle to the lower edge of the overlying pedicle of the respective floor.

When using the usually necessary lateral access technique, an obstruction of the access path by abdominal structures must be excluded. This must be considered especially in the floors cranial to L4/5. If a clear assessment is not possible with the available imaging, a single CT scan with abdominal window through the corresponding disc in the normal supine position can be performed for preoperative planning.

Indication Interlaminar Access

Indications for interlaminar access are all pathologies localized within the spinal canal that cannot be technically operated on transforaminally due to the criteria mentioned.

- All primary disc herniations or recurrent disc herniations with localization in the spinal canal that are outside the inclusion criteria for the transforaminal approach (extent of sequestration, height of the iliac crest, abdominal organs) must be operated on using the interlaminar technique.
- All primary disc herniations or recurrent disc herniations with localization in the spinal canal that are within the inclusion criteria for the transforaminal approach can alternatively be operated on using the interlaminar technique.
- Recess stenosis and central spinal stenosis.
- Recess stenosis and central spinal stenosis due to cysts of the zygoapophyseal joints.

In summary, pathologies within the spinal canal can be partially operated on transforaminally, taking into account the appropriate criteria, or must otherwise be operated on interlaminally. As an alternative, the interlaminar approach can be used for all pathologies within the spinal canal. All intra/extraforaminal pathologies must be operated on using the trans/extraforaminal approach.

18.1.2 Cervical Spine

The following pathologies are considered indications for full-endoscopic dorsal or ventral surgery of the cervical spine:

- non-sequestered medial disc herniations,
- sequestered or non-sequestered lateral and foraminal disc herniations,
- Stenosis of the foramen and recessus,
- Spinal stenosis due to dorsal pathology,
- Spinal stenosis due to cysts of the zygoapophyseal joints.

Compression of the myelon from ventrally by hard tissue, such as bone, annulus, or ligamentous tissue, and medial sequestered disc herniations are not indications.

Indication Dorsal Access

The dorsal approach is preferred by the authors. The prerequisite is to avoid manipulation of the myelon medially, so that no medial ventral pathologies can be operated from dorsally. Thus, the following indication criteria apply:

- sequestered or non-sequestered lateral disc herniations, which are localized with their main mass lateral to the myelon,
- sequestered or non-sequestered foraminal disc herniations,
- Foraminal stenosis,
- Spinal nerve compression from ventral in the recessus,
- Spinal stenosis with spinal nerve or myelon compression due to dorsal pathology.

Indication Ventral Access

A prerequisite for safe access is clear palpation of the ventral spine between the esophagus/trachea and the vascular-nerve cord. Additionally, previous surgery in the access or surgical area due to scarring may increase the risk of injury to adjacent structures (esophagus, arteries, veins, etc.) or may be uncontrollable. The following indications apply to the ventral approach:

- non-sequestered medial and lateral disc herniations,
- in special cases spinal nerve compression from ventral in the recessus and foramen,
- ventral minimum height of the intervertebral space of 4 mm to avoid access-related damage to the end plates.

18.1.3 Contraindications

In addition to the indications and limitations mentioned, the contraindications correspond to the criteria generally applicable to decompressive surgery, taking into account the specific technical possibilities and the inclusion criteria of the surgical procedure in question.

18.2 Preinterventional Diagnostics

As with conventional procedures, the entire spectrum of clinical and technical examinations must be taken into account diagnostically. As with all microsurgical techniques, technical surgical planning is based on preoperative imaging. The aim is to traumatize or resect structures of the spinal canal as sparingly as possible, depending on the pathology involved.

X-rays of the lumbar spine in 2 planes and, if possible, an MRI with sagittal and transverse reconstruction are required. When using the lateral, transforaminal approach, an obstruction of the access path by abdominal structures must be excluded. This should be considered especially in the floors cranial to L4/5. If a clear assessment is not possible with the available imaging, at least a single CT scan with abdominal window through the corresponding disc in the normal supine position can be performed for preoperative planning.

Further examinations specific to endoscopic surgery are not necessary.

18.3 Necessary Instruments

A radiolucent, electrically adjustable operating table, a C-arm and, if necessary, specific positioning aids (e.g. Mayfield clamp for operations on the cervical spine, etc.) are required. In addition to the surgical instruments and optics, general equipment for endoscopic surgery under fluid flow is required, such as a monitor, camera unit, light source, documentation system, fluid pump, shaver system or radio frequency generator. Existing equipment from arthroscopy or endoscopy can be used.

For the techniques presented here, optics and instrumentation from RIWOspine GmbH, Knittlingen, Germany, are necessary, as these enable the operation including sufficient bone resection to be performed under visual control. The rod lens optics include an eccentric working channel. The viewing direction is 25°. The surgical sleeves have a beveled opening that creates a field of view and working area in an area without a clearly anatomi-

cally preformed cavity. Various instruments with outer diameters of 2–4 mm are available. All instruments can be used through the intraendoscopic working channel, i.e. under continuous vision.

Cost:

- Monitor: approx. 3800 €,
- Camera unit: approx. 19,000 €,
- Light source: approx. 2700 €,
- Shaver system: approx. 9500 €,
- Documentation system: approx. 11,500 €,
- Pump: approx. 4500 €,
- Radio frequency device: approx. 12,000 €,
- Optics: approx. 4800 €,
- Instrument set: approx. 7000 €,
- additional costs for consumables: approx. 350 € per procedure.

Order address: RIWOspine GmbH, Pforzheimer Straße 32, D-75438 Knittlingen (Email: info@riwospine.com; ► www.riwospine.com).

18.4 Pre-Intervention Education

Patients must be informed and educated about their disease, its possible long-term course and consequences, and, despite the minimally invasive nature and associated advantages of the surgical procedure, about all known side effects, complications, therapeutic options and treatment alternatives, as is the case with conventional procedures (Hopp and Tsou 1988).

With regard to the fully endoscopic procedure, it should be noted that even with minimally invasive procedures, depending on the necessary extent of the surgical procedure, scarring, surgery-induced instability, etc. cannot be completely avoided. In the case of long operation times and unnoticed obstruction of the outflow of the irrigation fluid, the consequences of an increase in pressure within the spinal canal and the connected and adjacent structures cannot theoretically be completely ruled out. In addition, it should be emphasized that for the treatment of a complication, it may be necessary to switch to an open procedure once or twice.

18.5 Implementation of the Intervention

As with all microsurgical techniques, the intraoperative procedure must be planned preoperatively on the basis of the imaging findings. The goal is to resect structures of the spinal canal as sparingly as possible, depending on the pathology. Full endoscopic surgery can be performed under general anesthesia. This is more comfortable for the patient and surgeon, allows for positioning as needed, and also allows for extended work within the spinal canal. The surgical cover includes the possibility of collecting irrigation fluid. The positioning of the monitor, basic devices and instruments is carried out in accordance with the procedure for arthroscopic or endoscopic operations and may have to be adjusted depending on the side of the operation.

Operations on the lumbar spine are performed in the prone position on a radiolucent table under image converter control in 2 planes. The patient should be positioned, for example, on a hip and thoracic roll to relieve the abdominal and thoracic organs. The possibility of variable adjustment of the operating table is helpful.

The dorsal approach to the cervical spine is performed in the prone position, the ventral approach in the supine position, also under image converter control. The head is fixed, the shoulder is pulled down if necessary, in order to be able to work in the lower levels under radiographic control. Holding the head, e.g. in the Mayfield clamp, provides good fixation and also allows immediate changeover to an open procedure in the event of unexpected complications. The cervical spine is positioned neutrally, i.e. in a lordotic manner.

18.5.1 Lumbar Spine

- **(Lateral) Transforaminal Approach (Ruetten et al. 2005, 2007b, 2008b)**

At the beginning, the skin incision is localized. The aim is to reach the spinal canal as tangentially as possible. In the caudal levels, the dorsal line of the inferior articular process normally serves as the boundary in the lateral beam path, depending on the preoperative diagnosis, which is not crossed ventrally. Through the skin incision, a spinal cannula is inserted orthograde to the disc space in the target area. After insertion of a target wire and removal of the cannula, the cannulated dilator is inserted (Fig. 18.5). The target wire is removed and the surgical sleeve is advanced over the dilator, in the final position with the bevelled opening dorsally towards the neural structure (Fig. 18.6). From here, decompression is performed under visualization and continuous irrigation with isotonic saline. Further necessary entry into the epidural space is performed under visualization. The exact decompression procedure depends on the respective findings (Fig. 18.7).

If the bony diameter of the foramen does not allow passage, the foramen is bony dilated. If the position of the exiting nerve is not clear, such as in the case of intraforaminal or extraforaminal herniated discs or foraminal stenosis, an extraforaminal approach is made to the caudal pedicle.

- **Extraforaminal Access (Ruetten et al. 2007b; Ruetten 2011)**

The spinal cannula is advanced towards the foramen at the level of the intervertebral space under orthograde, p.a. X-ray control. Shortly before reaching the foramen, the direction is changed caudally to the pedicle of the underlying vertebral body. The endpoint should be in the middle of the lateral wall of the caudal pedicle. This is a safe zone where the exiting spinal nerve is not injured. The dilator and the surgical sleeve are inserted over the target wire and fixed to the bone of the pedicle under

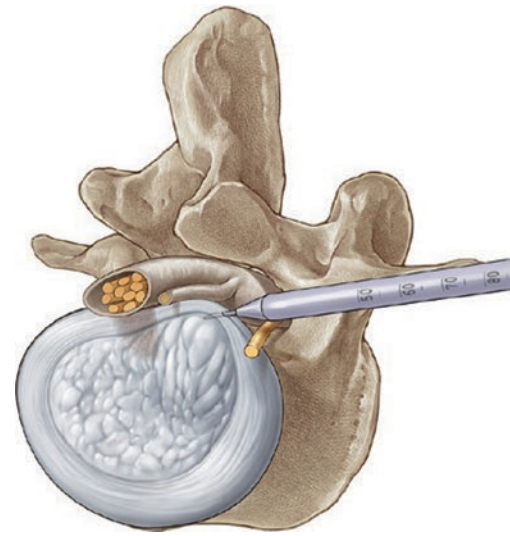


Fig. 18.5 Target wire and dilator for transforaminal access

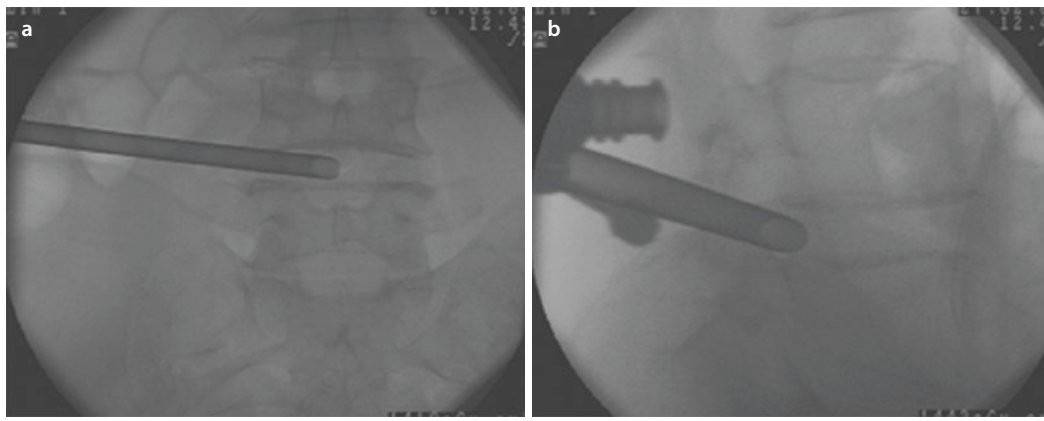


Fig. 18.6 **a**, **b** Exemplary final position of the surgical sleeve in the spinal canal during the lateral transforaminal approach, the opening of the sleeve is in the epidural space

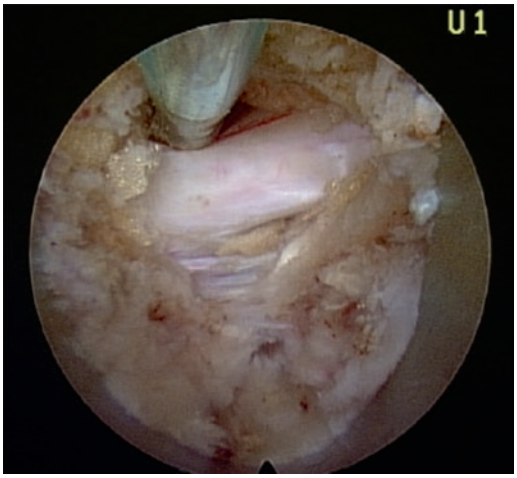


Fig. 18.7 Intraoperative view of the decompressed dural sac

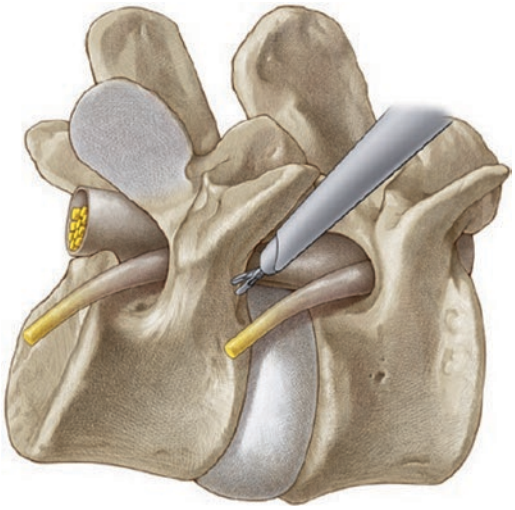


Fig. 18.8 Lumbar extraforaminal approach to caudal pedicle

continuous pressure. The remainder of the procedure is performed after insertion of the endoscope under continuous vision and pressure-controlled irrigation with isotonic saline. The bony, lateral wall of the pedicle is prepared and subsequently the foramen. For this purpose, the ascending facet is exposed cranially from the pedicle and the intervertebral disc is exposed ventrally. With the electrode the entrance into the foramen can be checked. Care must be taken that the exiting nerve does not slip in front of the opening of the sheath. The sheath itself is used as a nerve hook, holding the nerve cranially and ventrally. From this position, further intra/extraforaminal preparation is performed if pathology is localized here, or entry into the spinal canal through the foramen, if necessary after prior bone resection (Figs. 18.8 and 18.9).

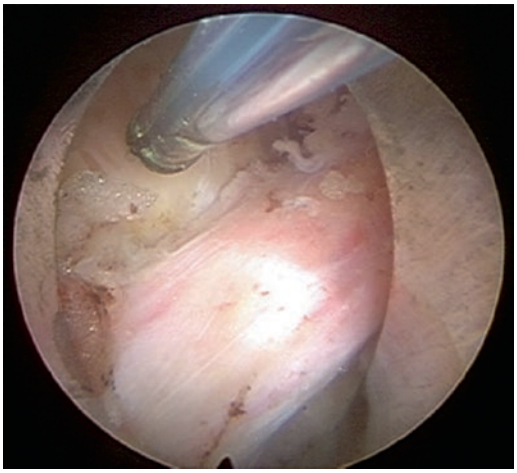


Fig. 18.9 Intraoperative view of the decompressed exiting spinal nerve

Interlaminar Access (Ruetten 2005; Ruetten et al. 2006, 2007b, 2008b)

The skin incision is made as medially as possible over the interlaminar window. The craniocaudal localization depends on the findings of the respective pathology. Under p.a. image converter control, the dilator is introduced bluntly onto the lateral edge of the ligamentum flavum or onto the descending facet of the zygoapophyseal joints. The further procedure is performed in the lateral beam path. The surgical sleeve with beveled opening is advanced medially in the direction of the ligamentum flavum via the dilator (Fig. 18.10). From here on, the rest of the procedure is performed under visualization and continuous irrigation with isotonic saline solution. To reach the spinal canal, the ligamentum flavum is incised laterally to approx. 3–5 mm. Further incision is made possible by the elasticity of the ligament. The surgical sleeve with bevelled opening can be used as a second instrument by rotation and serves as a nerve hook, e.g. by displacing the neural structures medially.

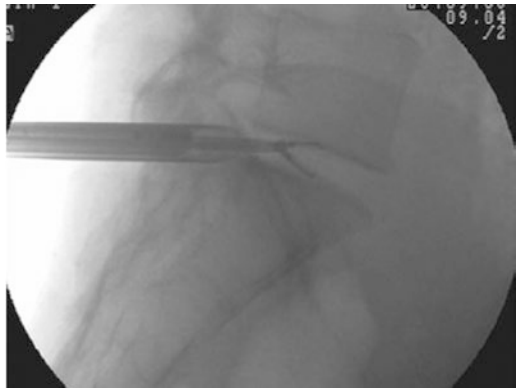


Fig. 18.10 Inserted surgical sleeve and endoscope for interlaminar surgery

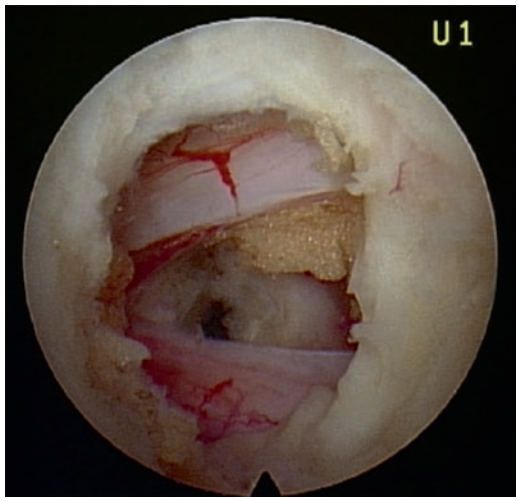


Fig. 18.11 Intraoperative view of decompressed axilla and annulus defect

If the bony diameter of the interlaminar window does not permit passage during surgery for spinal canal stenosis or in the case of clearly dislocated sequestra, the window is widened bony. The exact decompression procedure depends on the respective findings (Fig. 18.11).

18.5.2 Cervical Spine

Dorsal Approach (Ruetten et al. 2007b, 2008b)

Under p.a. image converter control, the line of the massa laterales is marked on the skin. The further procedure takes place in the lateral beam path. Determination of the disc segment with a cannula on the line of the massa laterales and execution of the skin incision. The dilator is inserted bluntly on the massa lateralis or the zygoapophyseal joint. Over the dilator, the surgical sleeve with beveled opening is advanced medially toward the ligamentum flavum and the dilator is removed. From here on the further procedure is performed under visualization and continuous irrigation with isotonic saline solution. After preparation of the anatomical structures, start of the foraminotomy on the medial joint parts as well as the cranial and caudal lamina. After exposure of the ligamentum flavum, the ligamentum is incised laterally to 3–5 mm and the lateral epidural space is dissected. The lateral border of the cervical myelon as well as the exit of the spinal nerve must be clearly visualized. The exact execution of the decompression depends on the respective findings (Figs. 18.12 and 18.13).

Ventral Approach (Ruetten et al. 2009b)

The approach is from the contralateral side. This requires less manipulation of the soft tissues and allows a right-handed surgeon to work with the instruments forward rather than backward. The ventral spine is palpated, with trachea and esophagus manipulated medially and the vascular-nerve cord with internal carotid artery and internal jugular

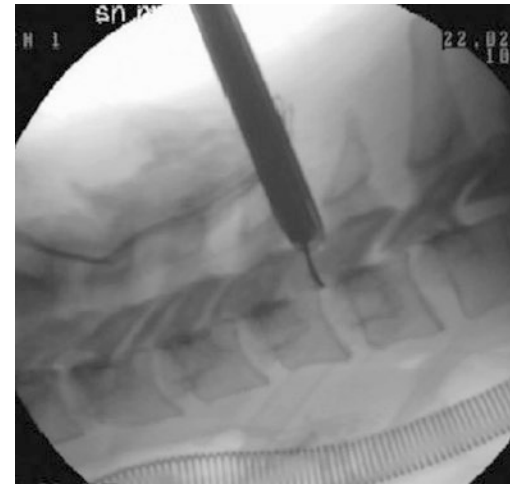


Fig. 18.12 Inserted surgical sleeve and endoscope for cervical dorsal surgery

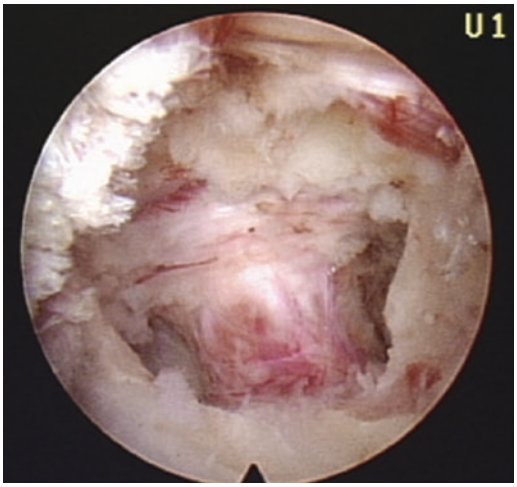


Fig. 18.13 Intraoperative view of the decompressed spinal nerve

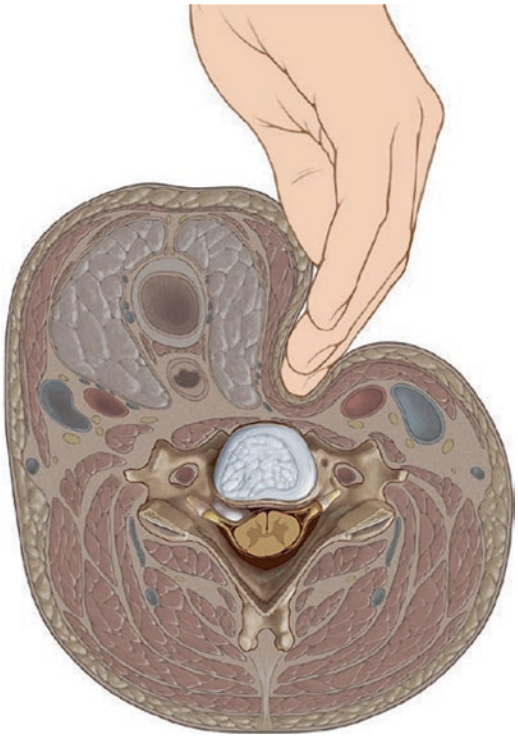


Fig. 18.14 Palpating the ventral cervical spine for the contralateral ventral approach

vein manipulated laterally (Fig. 18.14). If this is not clearly possible, there is an increased risk of injury to the surrounding structures.

Under lateral image converter control, the corresponding intervertebral space is marked and the skin incision is made at the medial edge of the sternocleidomastoid muscle. Under continuous palpation of the spine, the initial dilator is inserted into the intervertebral space. Alternatively, puncture can be performed here first with a spinal cannula and subsequently with the dilator. The intradiscal position is checked in the p.a. beam. The further procedure is performed under lateral image converter control. The combined surgical sleeve-dilator system is pushed into the intervertebral space via the initial dilator. The dilators are removed, the surgical sleeve remains with the opening dorsal in the intervertebral space. From here on, further surgery is performed under visualization and continuous irrigation with isotonic saline solution (Fig. 18.15). On the pathology side, the dorsal annulus, dorsal areas of the vertebral bodies or end plates and the uncinate process are prepared. Subsequently, depending on the pathology and anatomy, the sequestered disc material is visualized. This may require opening of the dorsal annulus and the posterior longitudinal ligament. Resection of bone in the dorsal region of the caudal vertebral body or the uncinate process may also be necessary. The exact decompression procedure depends on the respective findings.

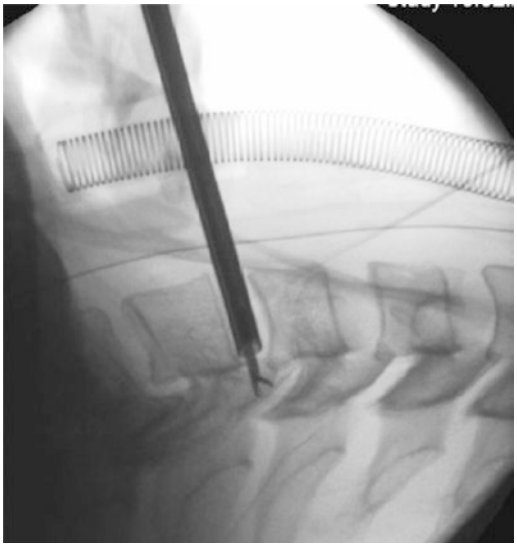


Fig. 18.15 Inserted surgical sleeve and endoscope for cervical ventral surgery

18.6 Possible Complications

Possible complications in the context of microsurgical procedures are well known and numerous have been published (Mayer 2005; Ramirez and Thisted 1989; Rompe et al. 1999; Stolke et al. 1989). A minimally invasive approach can reduce the complication rate (Parke 1991; Schick et al. 2002; Weber et al. 1997), but will not avoid them completely. In principle, all complications can occur as in known conventional surgery, even taking into account the respective surgical technique.

With regard to the fully endoscopic procedure, it should be emphasized that the treatment of a complication may require a one- or two-stage switch to an open procedure. In particular, the endoscopic suture of a dura injury is technically limited. In the case of long operation times and unnoticed obstruction of the outflow of the irrigation fluid, the consequences of an increase in pressure within the spinal canal and the connected and adjacent structures cannot theoretically be completely ruled out.

In the lumbar spine, a prolonged and uninterrupted excessive retraction of the neural structures with the working sleeve medially must be avoided or performed intermittently during the interlaminar approach to avoid the risk of neurological damage. In transforaminal surgery, there may be a risk of injury to the exiting nerve, especially when performing the approach. To avoid it, it is necessary to stay exactly in the caudal region of the foramen. Alternatively, or if the foramen is narrowed, the extraforaminal approach can be used. When using the lateral approach, it must be excluded that abdominal organs obstruct the access path.

At the cervical spine, there is an increased risk of injury to surrounding structures when performing ventral access if the ventral cervical spine cannot be clearly palpated between the esophagus/trachea and the vascular nerve cord or due to scarring changes from previous surgery.

Experience has shown that, as with all new techniques, there is an increased risk of complications occurring, particularly during the learning curve.

18.7 Results in the Literature

18.7.1 Lumbar Spine

The development of new rod lens optics with a large intraendoscopic working channel and corresponding instrumentation has technically enabled the fully endoscopic surgery of all lumbar primary disc herniations and recurrent disc herniations inside and outside the spinal canal as well as spinal stenoses. In combination with the newly developed surgical approaches, parameters such as bony diameter of the interlaminar window and the foramen intervertebrale or extent of sequestration of the disc material are no longer contraindications (Komp et al. 2011, 2014; Ruetten et al. 2005, 2006, 2008b, 2009a, c).

To safely achieve complete decompression, disc herniations and spinal stenosis must be operated on under continuous visualization, even when using a full-endoscopic technique. With reference to the posterolateral transforaminal approach, various authors have described the removal of sequestra from the epidural space in terms of retrograde resection from intradiscal through the existing annulus defect (Kambin and Sampson 1986; Kambin et al. 1996, 1998; Stücker 2005; Yeung and Tsou 2002). Some publications present resection of all types of disc herniation (Hoogland et al. 2006; Yeung and Tsou 2002). Nevertheless, surgery is limited especially from pathologies localized within the spinal canal (Kambin et al. 1998; Lee et al. 2006; Ruetten et al. 2005, 2006, 2007a, 2008b, 2009c). The development of the lateral transforaminal approach optimizes and allows access to the spinal canal and working under continuous visualization (Ruetten et al. 2005, 2007a, 2008b, 2009c). Problems of the posterolateral approach are hereby eliminated. Nevertheless, even with the lateral approach, there are clear inclusion and exclusion criteria and thus limitations (Ruetten et al. 2005, 2007a, 2008b, 2009c). In cases that are technically not operable transforaminal, the interlaminar approach can be used nowadays (Komp et al. 2011, 2014; Ruetten et al. 2006, 2007a, 2008b, 2009a, c).

Microscopic-assisted decompressions achieve good clinical results between 75% and 100% (Andrews and Lavyne 1990; Ebeling et al. 1986; Nystrom 1987; Williams 1986). Nowadays, with the developed full-endoscopic techniques, clinically consistent results can be achieved as with the conventional microsurgical approach. The clinical improvements are significant and constant over the follow-up periods for all indications mentioned (Komp et al. 2011, 2014; Ruetten et al. 2008b, 2009a, c).

Indication Primary Herniated Disc

Possible negative consequences of conventional operations on the lumbar spine are well known and have been described in numerous studies (Abumi et al. 1990; Annertz et al. 1995; Cooper et al. 1991; Fritsch et al. 1996; Haher et al. 1994; Kato et al. 1998; Kotilainen and Valtonen 1993; Schoeggl et al. 2002). By means of the full-endoscopic approach, surgical times, tissue trauma and complications can be reduced in the literature comparison and in the underlying studies (Rantanen et al. 1993; Rompe et al. 1999; Ruetten et al. 2008b). This is consistent with the published advantages of a minimally invasive intervertebral and epidural approach. The possibility of reducing or omitting osseous and ligamentous resection as well as the more atraumatic clearing of the intervertebral space can avoid surgery-induced instabilities according to current knowledge. The minimization of the annulus defect, which is possible by means of a fully endoscopic technique, seems to have a protective influence (Abumi et al. 1990; Aydin et al. 2002; de Divitiis and Cappabianca 2002; Ebara et al. 1992; Faulhauer and Manicke 1995; Goel et al. 1986; Iida et al. 1990; Kotilainen 1999; Natarajan et al. 1999; Schoeggl et al. 2002; Zander et al. 2003; Zollner et al. 1999).

Surgery-related rehabilitative measures are not required. There is a comparatively high return to occupational and sporting activity levels (Donceel and Du Bois 1998). Known increased morbidity with concomitant factors could not be found (Ramirez and Thisted 1989; Rompe et al. 1999; Stolke et al. 1989). The recurrence rate shows no significant differences compared to the literature and within studies compared to the conventional approach (Boyer et al. 1994; Carragee et al. 2003; Hirabayashi et al. 1993; Wenger et al. 2001). Revisions can be performed using the same technique. The type of disc herniation and annulus defect appear to have greater influence on the recurrence rate than the extent of intervertebral space clearance (Carragee et al. 2003; Yorimitsu et al. 2001).

Overall, no relevant disadvantages for the application of the full-endoscopic technique for the surgery of herniated discs could be found (Ruetten et al. 2005, 2006, 2007a, 2008b). At the same time, advantages in surgical technique and reduced traumatization in the area of the access path and the structures of the spinal canal were shown. Due to reduced osseous and ligamentous resection, the transforaminal approach is considered less traumatizing and thus the approach of first choice. Due to the anatomical and pathological conditions, however, there are clear limitations, so that the interlaminar approach has the greater spectrum.

Indication Recurrent Herniated Disc

Recurrent disc herniations after discectomies can never be completely ruled out. The recurrence rate is reported in the literature to range from 5% to over 20% depending on fragment type and annulus defect (Boyer et al. 1994; Carragee et al. 2006; Hirabayashi et al. 1993; Stambough 1997; Wenger et al. 2001). During surgery for recurrent disc herniation after conventional pre-surgery, the risk of dura and nerve injury is increased due to existing epidural scarring (Kim and Michelsen 1992; Stolke et al. 1989). In order to reduce this risk, the surgical field usually has to be prepared more extensively and thus increased trauma has to be accepted (Abumi et al. 1990; Hopp and Tsou 1988; Kato et al. 1998; Sharma et al. 1995). This may result in, for example, surgery-induced segmental instability, progressive degeneration, increased epidural scarring, or arachnoiditis (Connolly 1992; Ebeling et al. 1989; Fandino et al. 1993; Jonsson and Stromqvist 1993). These secondary problems

may become clinically symptomatic and further complicate repeat revisions. The scarring connection between the dura and paravertebral musculature can result in the so-called tethering of the cauda equina (Katz et al. 1991; LaRocca and Macnab 1974). Increasing resection of stabilizing structures favors surgery-induced instability (Abumi et al. 1990; Haher et al. 1994; Hopp and Tsou 1988; Kaigle et al. 1995; Kato et al. 1998; Kotilainen and Valtonen 1993; Sharma et al. 1995). Trauma caused by the access route in the innervation area of the dorsal branch of the spinal nerve can have a negative effect on the stabilizing and coordinating systems (Cooper et al. 1991; Lewis et al. 1987). Therefore, tissue-sparing techniques should be sought, especially in revisions as well as in primary surgeries (Isaacs et al. 2003; Ruetten et al. 2009c). When using the full-endoscopic approach, the outcome parameters and advantages were comparable to those in the indication of primary disc herniation with regard to reduced operation times, tissue trauma and complications (Mayer 2005; Ramirez and Thisted 1989; Rompe et al. 1999; Ruetten et al. 2009c; Stolke et al. 1989). Again, no relevant disadvantages were found compared to the conventional microscopic-assisted technique (Ruetten et al. 2009c). The same inclusion and exclusion criteria apply. The transforaminal approach is of particular importance as it completely bypasses the epidural scarring caused by the previous operation.

- **Indication Spinal Stenosis**

The same problems are discussed for surgery of spinal stenosis as for discectomy (Abumi et al. 1990; Cooper et al. 1991; Fritsch et al. 1996; Haher et al. 1994; Kotilainen and Valtonen 1993; Waddell et al. 1988). Resection of joint components and soft tissue structures in the lateral and ventral regions is usually more pronounced due to pathology; thus, possible surgery-induced instability must always be considered (Abumi et al. 1990; Haher et al. 1994; Kaigle et al. 1995; Kato et al. 1998; Kotilainen and Valtonen 1993; Sharma et al. 1995). Extensive decompression or additional instability and deformity may require additive fusion. Various tissue-sparing techniques have been used in an attempt to reduce trauma (Frank and Hsu 2002; Getty et al. 1981; Guiot et al. 2002; Khoo and Fessler 2002; Mayer 2005; Sanderson and Getty 1996; Young et al. 1988). An essential prerequisite for the use of fully endoscopic techniques was the development of appropriate burrs that ensure bone resection under visual control. With this, the sufficient decompression of lateral spinal canal stenosis is technically possible (Komp et al. 2011, 12,014; Ruetten et al. 2009a).

When the full-endoscopic approach was used, the outcome parameters and advantages were found to be comparable to those for the indication of primary disc herniation or recurrent disc herniation in terms of complications, tissue traumatization, and reduced surgical times (Komp et al. 2011, 2014; Mayer 2005; Ramirez and Thisted 1989; Rompe et al. 1999; Ruetten et al. 2009a). Again, no relevant disadvantages were found compared to the conventional microscopic-assisted technique (Komp et al. 2011, 2014; Ruetten et al. 2009a). Due to the anatomical and pathological requirements, only a few of these stenoses meet the inclusion criteria for a transforaminal approach, which is, however, technically feasible in these cases. Transforaminal decompression with posterolateral approach has been described (Kambin et al. 1996). However, the patient population included cases with additional disc herniation and the decompression was not performed under vision in terms of a necessary resection of the medial edge of the ascending articular facet and the ligamentum flavum. Another indication is in pure foraminal stenosis when no reconstruction of the motion segment is required.

18.7.2 Cervical Spine

Also in the cervical spine, the development of new and different rod lens optics and instrumentation has technically enabled the fully endoscopic resection of herniated discs. Sufficient bone resection has been a prerequisite for the dorsal approach in particular. When using the ventral approach, the modified system with oval surgical sleeve protects

the base and cover plates of the vertebral bodies. As in the area of the lumbar spine, each step can be performed under the required continuous visualization.

Indication Primary Herniated Disc

Potential problems of the standard procedure for surgery of cervical disc herniations, ventral decompression and fusion, are well known and numerous described (Epstein 2002; Kulkarni et al. 2004; Pedram et al. 2003; Tureyen 2003; Wang et al. 2007). The same is true for the most common alternative, dorsal keyhole foraminotomy (Adamson 2001; Sihvonen et al. 1993; Woertgen et al. 1997). The good clinical results of microsurgical ventral decompression and fusion, which is considered the gold standard, and dorsal foraminotomy can be achieved with the fully endoscopic techniques nowadays (Adamson 2001; Aldrich 1990; Clarke et al. 2007; Epstein 2002; Jodicke et al. 2003; Riew et al. 2007; Woertgen et al. 2000). They are significant and constant throughout the follow-up periods (Ruetten et al. 2007b, 2008a, 2009b). At the same time, surgical times, tissue trauma and complications are reduced (Adamson 2001; Clarke et al. 2007; Epstein 2002; Grieve et al. 2000; Harrop et al. 2003; Jodicke et al. 2003; Riew et al. 2007; Ruetten et al. 2007b, 2008a, 2009b). This is consistent with experience with minimally invasive intravertebral and epidural procedures in the lumbar spine (Aydin et al. 2002; de Divitiis and Cappabianca 2002; Faulhauer and Manicke 1995; Natarajan et al. 1999; Wenger et al. 2001; Zander et al. 2003; Zollner et al. 1999). Surgery-induced neck pain or instability was not noted. With the dorsal endoscopic approach, the joint portions are almost completely preserved. No increase in segmental kyphosis occurred with the ventral endoscopic approach either. The mean decrease in the height of the intervertebral space was significant here. However, this was also true for the control group with fusion. Higher values for these parameters are described in the literature for ventral decompression procedures without fusion (Brigham and Tsahakis 1995; Hauerberg et al. 2008; Oktenoglu et al. 2007). However, in contrast to the endoscopic procedure, endplate shortening is performed here (Hauerberg et al. 2008). This may also explain the higher spontaneous fusion rates that did not occur with the endoscopic technique. Overall, no correlation was found between the above parameters and clinical outcome. Also in the literature, the questions regarding progressive kyphosis or instability cannot be answered uniformly according to EBM criteria (Abd-Alrahman et al. 1999; Dowd and Wirth 1999; Hauerberg et al. 2008; Martins 1976; Nandoe Tewarie et al. 2007; Oktenoglu et al. 2007; Savolainen et al. 1998; Sonntag and Klara 1996; van den Bent et al. 1996). The recurrence rate is within the results of published conventional procedures without fusion (Adamson 2001; Henderson et al. 1983; Jodicke et al. 2003). Revisions can be performed using the same technique. In contrast to procedures with reconstruction of the intervertebral space, recurrent disc herniations cannot be technically excluded. To date, one paper has been presented in the literature reporting dorsal endoscopic techniques in combination with ventral access (Fontanella 1999). Further precise specifications or information on bone resection are not mentioned. In described ventral techniques, some steps were performed only under radiological control, and the viewing conditions were often reduced due to the small optics. The new rod lens optics provide excellent viewing conditions. Bone resection is possible under continuous visualization, which is always required for the dorsal approach and may be necessary for the ventral approach. The problem of epidural bleeding known from conventional surgery is avoided by continuous irrigation (Ruetten et al. 2007b, 2008a, 2009b). The 25° viewing direction provides an extended field of view, which allows a view under the myelon, which must not be manipulated, especially for the dorsal approach. The dorsal endoscopic approach offers no special problems. It is therefore the access of first choice, but only indicated for lateral pathologies. However, most disc herniations with radicular symptoms are localized in this area. The ventral approach is performed close to structures that are susceptible to injury. Direct palpation of the ventral spine is required during the approach. This may be more difficult in patients who are muscular in the caudal floors.

18.8 Conclusion and Clinical Relevance

The goal in the development of surgical therapy of radicular compression syndromes caused by herniated discs or spinal canal stenosis is the sufficient decompression under optimized visual conditions with minimized surgery-induced traumatization and its negative consequences. The development of surgical accesses as well as new rod lens optics and corresponding instrumentation has technically enabled the fully endoscopic surgery of all primary and recurrent disc herniations inside and outside the spinal canal as well as spinal canal stenoses in the area of the lumbar spine. In the area of the cervical spine, the focus is on the resection of soft disc herniations. Parameters such as bony diameter of the access path or extent of sequestration are not contraindications. The use of each approach depends on anatomic and pathologic inclusion and exclusion criteria. The clinical results of standard procedures are achieved, which must be considered a minimum criterion when introducing new techniques (Maroon 2002). At the same time, there are advantages in operative technique and clinical variables.

Based on surgical experience and clinical studies, the following advantages of fully endoscopic techniques in the lumbar and cervical spine can be cited:

- Facilitation for the surgeon through good visualization, illumination and extended field of view through 25° optics,
- Cost-effective procedure due to short operation times, fast rehabilitation and low postoperative follow-up costs,
- reduced traumatisation of the surrounding tissue, stabilising structures and epidural space,
- facilitated revision surgery (lumbar transforaminal bypass of epidural scarring),
- Monitor image as a basis for training medical staff,
- high patient acceptance,
- in the case of cervical approaches, preservation of mobility.

The following is considered to be a detriment:

- Inclusion criteria for the different accesses must be met,
- limited possibilities to increase access in case of problems,
- challenging learning curve,
- lumbar transforaminal theoretical risk of injury to the exiting nerve,
- for cervical approaches, only direct decompression and no indirect decompression by reconstruction of the intervertebral space.

Based on prospective randomized and controlled studies, it can be summarized, also taking into account EBM criteria, that by means of full-endoscopic techniques in the abovementioned indications, sufficient decompression equivalent to standard procedures is achieved with reduced traumatization, improved visual conditions and a positive cost relationship. Thus, full-endoscopic surgery can be classified today as an extension and alternative within the overall concept of spine surgery. Special attention must be paid to the respective indication as well as the difficult learning curve, which, as with many new procedures, can involve an increased potential for problems and risks at the beginning.

18.8.1 Other Fields of Application

The incidence of thoracic disc herniations and spinal stenosis is low. Only up to 4% of all decompressions are performed on the thoracic spine. These are surgically challenging pathologies that are frequently calcified. The indication is symptoms of thoracic myelopathy, less frequently therapy-resistant radicular syndromes. Each case requires individual preoperative planning of the surgical technique and a risk-benefit assessment. If indicated, full-endoscopic surgery is also used for decompression. A special situation in the indication concerns the compression of the spinal nerve Th1 by a herniated disc of the level Th1/2, which can lead to neurological deficits in the upper extremity due to the interconnection in the brachial plexus.

To avoid manipulation of the myelon, a range of surgical approaches must be available, taking into account the localization of the pathology, as in the conventional approach, from which the appropriate procedure is determined after preoperative planning. Full endoscopic coverage of the area is from the interlaminar (dorsal to dorsolateral) to the transforaminal (dorsolateral area) to the transthoracic (retropleural, transpleural) approach (Figs. 18.16, 18.17, and 18.18). The type and localization of the pathology determine the respective procedure. Due to the low incidence, clinical and technical experience is limited. In the case of extensive findings and borderline cases with regard to anatomy, pathology or symptomatology, surgery using a conventional approach may be the only suitable option.

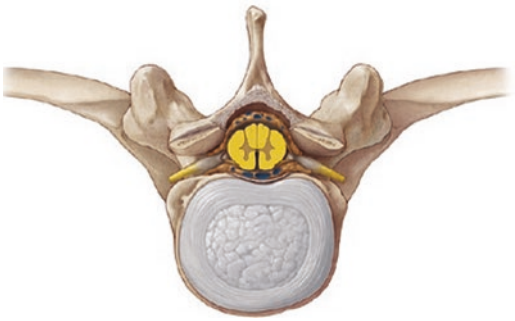


Fig. 18.16 Various approaches may be required to avoid manipulation of the myelon

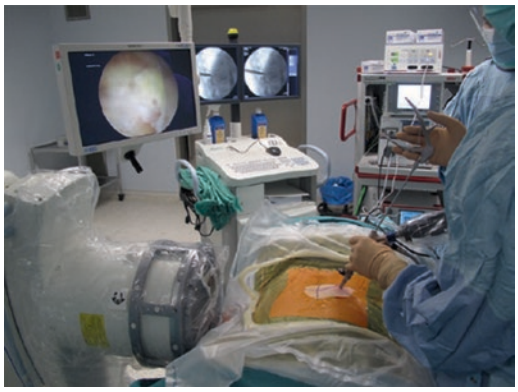


Fig. 18.17 Transthoracic retropleural approach in lateral position

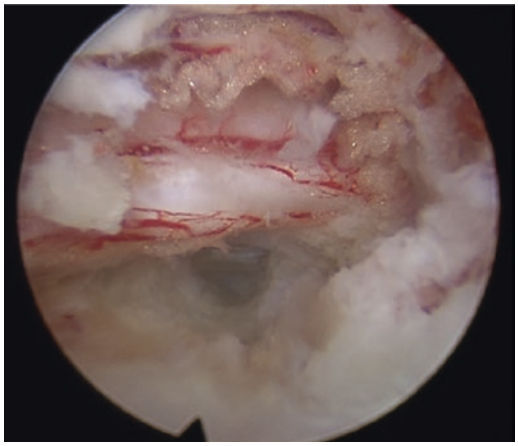


Fig. 18.18 Intraoperative view of decompressed myelon with thoracic transforaminal approach

References

Abd-Alrahman N, Dokmak AS, Abou-Madawi A (1999) Anterior cervical discectomy (ACD) versus anterior cervical fusion (ACF), clinical and radiological outcome study. Acta Neurochir 141:1089–1092

Abumi K et al (1990) Biomechanical evaluation of lumbar spinal stability after graded facetectomies. Spine (Phila Pa 1976) 15:1142–1147

Adamson TE (2001) Microendoscopic posterior cervical laminoforaminotomy for unilateral radiculopathy: results of a new technique in 100 cases. J Neurosurg 95:51–57

Ahn Y, Lee SH, Shin SW (2005) Percutaneous endoscopic cervical discectomy: clinical outcome and radiographic changes. Photomed Laser Surg 23:362–368

Aldrich F (1990) Posterolateral microdisectomy for cervical monoradiculopathy caused by posterolateral soft cervical disc sequestration. J Neurosurg 72:370–377

Andersson GB et al (1996) Consensus summary of the diagnosis and treatment of lumbar disc herniation. Spine (Phila Pa 1976) 21:75S–78S

Andrews DW, Lavyne MH (1990) Retrospective analysis of microsurgical and standard lumbar discectomy. Spine (Phila Pa 1976) 15:329–335

Annertz M et al (1995) No relationship between epidural fibrosis and sciatica in the lumbar postdiscectomy syndrome. A study with contrast-enhanced magnetic resonance imaging in symptomatic and asymptomatic patients. Spine (Phila Pa 1976) 20:449–453

Aydin Y et al (2002) Clinical and radiological results of lumbar microdiskectomy technique with preserving of ligamentum flavum comparing to the standard microdiskectomy technique. Surg Neurol 57:5–13. discussion 13–14

Aydin Y et al (2005) Minimally invasive anterior contralateral approach for the treatment of cervical disc herniation. Surg Neurol 63:210–218. discussion 218–219

Boyer P et al (1994) Lumbar disk hernia. Excision of hernia with or without complementary diskectomy? Neurochirurgie 40:259–262

Brayda-Bruno M, Cinnella P (2000) Posterior endoscopic discectomy (and other procedures). Eur Spine J 9(Suppl 1):S24–S29

Brigham CD, Tsahakis PJ (1995) Anterior cervical foraminotomy and fusion. Surgical technique and results. Spine (Phila Pa 1976) 20:766–770

Burke TG, Caputy A (2000) Microendoscopic posterior cervical foraminotomy: a cadaveric model and clinical application for cervical radiculopathy. J Neurosurg 93:126–129

Carragee EJ et al (2003) Clinical outcomes after lumbar discectomy for sciatica: the effects of fragment type and anular competence. J Bone Joint Surg Am 85-A:102–108

Carragee EJ et al (2006) A prospective controlled study of limited versus subtotal posterior discectomy: short-term outcomes in patients with herniated lumbar intervertebral discs and large posterior anular defect. Spine (Phila Pa 1976) 31:653–637

Caspar W et al (1991) The Caspar microsurgical discectomy and comparison with a conventional standard lumbar disc procedure. Neurosurgery 28:78–86. discussion 86–87

Chiu JC et al (2000) Percutaneous microdecompressive endoscopic cervical discectomy with laser thermodiskoplasty. Mt Sinai J Med 67:278–282

Choi G et al (2007) Modified transcorporeal anterior cervical microforaminotomy for cervical radiculopathy: a technical note and early results. Eur Spine J 16:1387–1393

Clarke MJ et al (2007) Same-segment and adjacent-segment disease following posterior cervical foraminotomy. J Neurosurg Spine 6:5–9

Cloward RB (1958) The anterior approach for removal of ruptured cervical disks. J Neurosurg 15:602–617

Connolly ES (1992) Surgery for recurrent lumbar disc herniation. Clin Neurosurg 39:211–216

Cooper RG et al (1991) The role of epidural fibrosis and defective fibrinolysis in the persistence of postlaminectomy back pain. Spine (Phila Pa 1976) 16:1044–1048

de Divitiis E, Cappabianca P (2002) Lumbar diskectomy with preservation of the ligamentum flavum. Surg Neurol 58:68. discussion 68–69

Destandau J (1999) A special device for endoscopic surgery of lumbar disc herniation. Neurol Res 21:39–42

Donceel P, Du Bois M (1998) Fitness for work after surgery for lumbar disc herniation: a retrospective study. Eur Spine J 7:29–35

Dowd GC, Wirth FP (1999) Anterior cervical discectomy: is fusion necessary? J Neurosurg 90:8–12

Ebara S et al (1992) Intraoperative measurement of lumbar spinal instability. Spine (Phila Pa 1976) 17:S44–S50

Ebeling U, Reichenberg W, Reulen HJ (1986) Results of microsurgical lumbar discectomy. Review on 485 patients. Acta Neurochir 81:45–52

Ebeling U, Kalbarcyk H, Reulen HJ (1989) Microsurgical reoperation following lumbar disc surgery. Timing, surgical findings, and outcome in 92 patients. J Neurosurg 70:397–404

Epstein NE (2002) A review of laminoforaminotomy for the management of lateral and foraminal cervical disc herniations or spurs. Surg Neurol 57:226–233. discussion 233–234

Epstein JM, Adler R (2000) Laser-assisted percutaneous endoscopic neurolysis. Pain Physician 3:43–45

Fandino J et al (1993) Reoperation after lumbar disc surgery: results in 130 cases. Acta Neurochir 122:102–104

Faulhauer K, Manicke C (1995) Fragment excision versus conventional disc removal in the microsurgical treatment of herniated lumbar disc. Acta Neurochir 133:107–111

Ferrer E et al (1988) Lumbar microdiscectomy: analysis of 100 consecutive cases. Its pitfalls and final results. Acta Neurochir Suppl (Wien) 43:39–43

Fessler RG, Khoo LT (2002) Minimally invasive cervical microendoscopic foraminotomy: an initial clinical experience. Neurosurgery 51:S37–S45

Fontanella A (1999) Endoscopic microsurgery in herniated cervical discs. Neurol Res 21:31–38

Forst R, Hausmann B (1983) Nucleoscopy – a new examination technique. Arch Orthop Trauma Surg 101:219–221

Frank EH, Hsu FP (2002) An endoscopic dural retractor for spinal stenosis surgery. Minim Invasive Neurosurg 45:136–138

Fritsch EW, Heisel J, Rupp S (1996) The failed back surgery syndrome: reasons, intraoperative findings, and long-term results: a report of 182 operative treatments. Spine (Phila Pa 1976) 21:626–633

Frykholm R (1951) Lower cervical vertebrae and intervertebral discs; surgical anatomy and pathology. Acta Chir Scand 101:345–359

Getty CJ et al (1981) Partial undercutting facetectomy for bony entrapment of the lumbar nerve root. J Bone Joint Surg (Br). 63-B:330–335 63-B:330–335

Goald HJ (1978) Microlumbar discectomy: followup of 147 patients. Spine (Phila Pa 1976) 3:183–185

Goald HJ (1980) Microlumbar discectomy: follow-up of 477 patients. J Microsurg 2:95–100

Goel VK et al (1986) Mechanical properties of lumbar spinal motion segments as affected by partial disc removal. Spine (Phila Pa 1976) 11:1008–10012

Gore DR, Sepic SB (1998) Anterior discectomy and fusion for painful cervical disc disease. A report of 50 patients with an average follow-up of 21 years. Spine (Phila Pa 1976) 23:2047–2051

Gottlob C et al (1992) Holmium:YAG laser ablation of human intervertebral disc: preliminary evaluation. Lasers Surg Med 12:86–91

Grieve JP et al (2000) Results of posterior cervical foraminotomy for treatment of cervical spondylitic radiculopathy. Br J Neurosurg 14:40–43

Guiot BH, Khoo LT, Fessler RG (2002) A minimally invasive technique for decompression of the lumbar spine. Spine (Phila Pa 1976) 27:432–438

Haher TR et al (1994) The role of the lumbar facet joints in spinal stability. Identification of alternative paths of loading. Spine (Phila Pa 1976) 19:2667–2670. discussion 2671

Hakuba A (1976) Trans-unco-discal approach. A combined anterior and lateral approach to cervical discs. J Neurosurg 45:284–291

Harrop JS et al (2003) Cervicothoracic radiculopathy treated using posterior cervical foraminotomy/discectomy. J Neurosurg 98:131–136

Hauerberg J et al (2008) Anterior cervical discectomy with or without fusion with ray titanium cage: a prospective randomized clinical study. Spine (Phila Pa 1976) 33:458–464

Henderson CM et al (1983) Posterior-lateral foraminotomy as an exclusive operative technique for cervical radiculopathy: a review of 846 consecutively operated cases. Neurosurgery 13:504–512

Hermantin FU et al (1999) A prospective, randomized study comparing the results of open discectomy with those of video-assisted arthroscopic microdiscectomy. J Bone Joint Surg Am 81:958–965

Hijikata S (1975) Precutaneous discectomy: a new treatment method for lumbar disc herniation. J Toden Hosp 5:5–13

Hilton DL Jr (2007) Minimally invasive tubular access for posterior cervical foraminotomy with three-dimensional microscopic visualization and localization with anterior/posterior imaging. Spine J 7:154–158

Hirabayashi S et al (1993) Microdiscectomy and second operation for lumbar disc herniation. Spine (Phila Pa 1976) 18:2206–2211

Hoogland T et al (2006) Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases. Spine (Phila Pa 1976) 31:E890–E897

Hopp E, Tsou PM (1988) Postdecompression lumbar instability. Clin Orthop Relat Res 227:143–151

Hult L (1951) Retroperitoneal disc fenestration in low-back pain and sciatica; a preliminary report. Acta Orthop Scand 20:342–348

Iida Y et al (1990) Postoperative lumbar spinal instability occurring or progressing secondary to laminectomy. Spine (Phila Pa 1976) 15:1186–1189

Isaacs RE, Podichetty V, Fessler RG (2003) Microendoscopic discectomy for recurrent disc herniations. Neurosurg Focus 15:E11–E14

Jho HD (1996) Microsurgical anterior cervical foraminotomy for radiculopathy: a new approach to cervical disc herniation. J Neurosurg 84:155–160

Jodicke A et al (2003) Risk factors for outcome and complications of dorsal foraminotomy in cervical disc herniation. Surg Neurol 60:124–129. discussion 129–130

Johnson JP et al (2000) Anterior cervical foraminotomy for unilateral radicular disease. Spine (Phila Pa 1976) 25:905–909

Jonsson B, Stromqvist B (1993) Repeat decompression of lumbar nerve roots. A prospective two-year evaluation. J Bone Joint Surg (Br) 75:894–897

Kaigle AM, Holm SH, Hansson TH (1995) Experimental instability in the lumbar spine. Spine (Phila Pa 1976) 20:421–430

Kambin P, Sampson S (1986) Posterolateral percutaneous suction-excision of herniated lumbar intervertebral discs. Report of interim results. Clin Orthop Relat Res 207:37–43

Kambin P et al (1996) Transforaminal arthroscopic decompression of lateral recess stenosis. J Neurosurg 84:462–467

Kambin P et al (1998) Arthroscopic microdiscectomy and selective fragmentectomy. Clin Orthop Relat Res 347:150–167

Kato Y, Panjabi MM, Nibu K (1998) Biomechanical study of lumbar spinal stability after osteoplastic laminectomy. J Spinal Disord 11:146–150

Katz JN et al (1991) The outcome of decompressive laminectomy for degenerative lumbar stenosis. J Bone Joint Surg Am 73:809–816

Kawaguchi Y, Matsui H, Tsuji H (1996) Back muscle injury after posterior lumbar spine surgery. A histologic and enzymatic analysis. Spine (Phila Pa 1976) 21:941–944

Khoo LT, Fessler RG (2002) Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis. Neurosurgery 51:S146–S154

Kim SS, Michelsen CB (1992) Revision surgery for failed back surgery syndrome. Spine (Phila Pa 1976) 17:957–960

Knight MT et al (1998) Endoscopic laser foraminoplasty on the lumbar spine – early experience. Minim Invasive Neurosurg 41:5–9

Komp M et al (2011) Bilateral operation of lumbar degenerative central spinal stenosis in full-endoscopic interlaminar technique with unilateral approach: prospective 2-year results of 74 patients. J Spinal Disord Tech 24:281–287

Komp M et al (2014) Operation of lumbar zygoapophyseal joint cysts using a full-endoscopic interlaminar and transforaminal approach: prospective 2-year results of 74 patients. Surg Innov 21:605–614

Kotilainen E (1999) Percutaneous nucleotomy in the treatment of cervical disc herniation: report of three cases and review. Minim Invasive Neurosurg 42:152–155

Kotilainen E (2001) Clinical instability of the lumbar spine after microdiscectomy. In: Gerber BE, Knight MT, Siebert WE (eds) Lasers in the musculoskeletal system. Springer, Berlin/Heidelberg/New York

Kotilainen E, Valtonen S (1993) Clinical instability of the lumbar spine after microdiscectomy. Acta Neurochir 125:120–126

Kulkarni V, Rajshekhar V, Raghuram L (2004) Accelerated spondylotic changes adjacent to the fused segment following central cervical corpectomy: magnetic resonance imaging study evidence. J Neurosurg 100:2–6

Laing RJ et al (2001) Prospective study of clinical and radiological outcome after anterior cervical discectomy. Br J Neurosurg 15:319–323

LaRocca H, Macnab I (1974) The laminectomy membrane. Studies in its evolution, characteristics, effects and prophylaxis in dogs. J Bone Joint Surg (Br) 56B:545–550

Lee SH et al (2006) Operative failure of percutaneous endoscopic lumbar discectomy: a radiologic analysis of 55 cases. Spine (Phila Pa 1976) 31:E285–E290

Lewis PJ et al (1987) Long-term prospective study of lumbosacral discectomy. J Neurosurg 67:49–53

Maroon JC (2002) Current concepts in minimally invasive discectomy. Neurosurgery 51:S137–S145

Maroon JC, Onik G, Sternau L (1989) Percutaneous automated discectomy. A new approach to lumbar surgery. Clin Orthop Relat Res 238:64–70

Martins AN (1976) Anterior cervical discectomy with and without interbody bone graft. J Neurosurg 44:290–295

Mathews HH (1996) Transforaminal endoscopic microdiscectomy. Neurosurg Clin N Am 7:59–63

Mayer HM (2005) The microsurgical interlaminar, paramedian approach. In: Mayer HM (ed) Minimally invasive spine surgery. Springer, Berlin/Heidelberg/New York

Mayer HM, Brock M (1993) Percutaneous endoscopic discectomy: surgical technique and preliminary results compared to microsurgical discectomy. J Neurosurg 78:216–225

McCulloch JA (1996) Focus issue on lumbar disc herniation: macro- and microdiscectomy. Spine (Phila Pa 1976) 21:45S–56S

Mixter WJ, Barr JS (1934) Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 211:210–215

Mummaneni PV et al (2007) Clinical and radiographic analysis of cervical disc arthroplasty compared with allograft fusion: a randomized controlled clinical trial. J Neurosurg Spine 6:198–209

Nabhan A et al (2007) Disc replacement using pro-disc C versus fusion: a prospective randomised and controlled radiographic and clinical study. Eur Spine J 16:423–430

Nakagawa H et al (2003) Microendoscopic discectomy (MED) for lumbar disc prolapse. J Clin Neurosci 10:231–235

Nandoe Tewarie RD, Bartels RH, Peul WC (2007) Long-term outcome after anterior cervical discectomy without fusion. Eur Spine J 16:1411–1416

Natarajan RN et al (1999) Study on effect of graded facetectomy on change in lumbar motion segment torsional flexibility using three-dimensional continuum contact representation for facet joints. J Biomech Eng 121:215–221

Nystrom B (1987) Experience of microsurgical compared with conventional technique in lumbar disc operations. Acta Neurol Scand 76:129–141

Oktenoglu T et al (2007) Anterior cervical microdiscectomy with or without fusion. J Spinal Disord Tech 20:361–368

Papadopoulos EC et al (2006) Three-level anterior cervical discectomy and fusion with plate fixation: radiographic and clinical results. Spine (Phila Pa 1976) 31:897–902

Parke WW (1991) The significance of venous return impairment in ischemic radiculopathy and myelopathy. Orthop Clin North Am 22:213–221

Pechlivanis I et al (2006) Anterior uncoforaminotomy in the treatment of recurrent radiculopathy after anterior cervical discectomy with fusion. Minim Invasive Neurosurg 49:323–327

Pedram M et al (2003) Pharyngolaryngeal lesions in patients undergoing cervical spine surgery through the anterior approach: contribution of methylprednisolone. Eur Spine J 12:84–90

Perez-Cruet MJ et al (2002) Microendoscopic lumbar discectomy: technical note. Neurosurgery 51: S129–S136

Pickett GE et al (2006) Complications with cervical arthroplasty. J Neurosurg Spine 4:98–105

Putti V (1927) New conceptions in the pathogenesis of sciatic pain. Lancet 2:53–60

Ramirez LF, Thisted R (1989) Complications and demographic characteristics of patients undergoing lumbar discectomy in community hospitals. Neurosurgery 25:226–230. discussion 230–231

Rantanen J et al (1993) The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. Spine (Phila Pa 1976) 18:568–574

Riew KD et al (2007) Posterior cervical spine surgery for radiculopathy. Neurosurgery 60:S57–S63

Roh SW et al (2000) Endoscopic foraminotomy using MED system in cadaveric specimens. Spine (Phila Pa 1976) 25:260–264

Rompe JD et al (1999) Intra- and postoperative risk analysis after lumbar intervertebral disk operation. Z Orthop Ihre Grenzgeb 137:201–205

Ruetten S (2005) The full-endoscopic interlaminar approach for lumbar disc herniations. In: Mayer HM (ed) Minimally invasive spine surgery. Springer, Berlin/Heidelberg/New York

Ruetten S (2011) Full-endoscopic operations of the spine in disk herniations and spinal stenosis. Surg Technol Int 21:284–298

Ruetten S, Meyer O, Godolias G (2002) Epiduroscopic diagnosis and treatment of epidural adhesions in chronic back pain syndrome of patients with previous surgical treatment: first results of 31 interventions. Z Orthop Ihre Grenzgeb 140:171–175

Ruetten S, Komp M, Godolias G (2005) An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-endoscopic uniportal transforaminal approach-technique and prospective results of 463 patients. Spine (Phila Pa 1976) 30:2570–2578

Ruetten S, Komp M, Godolias G (2006) A new full-endoscopic technique for the interlaminar operation of lumbar disc herniations using 6-mm endoscopes: prospective 2-year results of 331 patients. Minim Invasive Neurosurg 49:80–87

Ruetten S et al (2007a) Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach. J Neurosurg Spine 6:521–530

Ruetten S et al (2007b) A new full-endoscopic technique for cervical posterior foraminotomy in the treatment of lateral disc herniations using 6.9-mm endoscopes: prospective 2-year results of 87 patients. Minim Invasive Neurosurg 50:219–226

Ruetten S et al (2008a) Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes: a prospective, randomized, controlled study. Spine (Phila Pa 1976) 33:940–948

Ruetten S et al (2008b) Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. Spine (Phila Pa 1976) 33:931–939

Ruetten S et al (2009a) Surgical treatment for lumbar lateral recess stenosis with the full-endoscopic interlaminar approach versus conventional microsurgical technique: a prospective, randomized, controlled study. J Neurosurg Spine 10:476–485

Ruetten S et al (2009b) Full-endoscopic anterior decompression versus conventional anterior decompression and fusion in cervical disc herniations. Int Orthop 33:1677–1682

Ruetten S et al (2009c) Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic interlaminar and transforaminal versus microsurgical revision. J Spinal Disord Tech 22:122–129

Sanderson PL, Getty CJ (1996) Long-term results of partial undercutting facetectomy for lumbar lateral recess stenosis. Spine (Phila Pa 1976) 21:1352–1356

Saringer WF et al (2003) Endoscopic anterior cervical foraminotomy for unilateral radiculopathy: anatomical morphometric analysis and preliminary clinical experience. J Neurosurg 98:171–180

Savitz MH (1994) Same-day microsurgical arthroscopic lateral-approach laser-assisted (SMALL) fluoroscopic discectomy. J Neurosurg 80:1039–1045

Savolainen S, Rinne J, Hernesniemi J (1998) A prospective randomized study of anterior single-level cervical disc operations with long-term follow-up: surgical fusion is unnecessary. Neurosurgery 43:51–55

Schick U et al (2002) Microendoscopic lumbar discectomy versus open surgery: an intraoperative EMG study. Eur Spine J 11:20–26

Schoeggl A et al (2002) Outcome after chronic sciatica as the only reason for lumbar microdiscectomy. J Spinal Disord Tech 15:415–419

Semmes RE, Murphey F (1943) The syndrome of unilateral rupture of the sixth cervical intervertebral disc with compression of the seventh cervical nerve root – a report of four cases with symptoms simulating coronary disease. JAMA 121:1209–1214

Sharma M, Langrana NA, Rodriguez J (1995) Role of ligaments and facets in lumbar spinal stability. Spine (Phila Pa 1976) 20:887–900

Sihvonen T et al (1993) Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. Spine (Phila Pa 1976) 18:575–581

Smith L et al (1963) Enzyme dissolution of the nucleus pulposus. Nature 198:1311–1312

Sonntag VK, Klara P (1996) Controversy in spine care. Is fusion necessary after anterior cervical discectomy? Spine (Phila Pa 1976) 21:1111–1113

Stambough JL (1997) Lumbar disk herniation: an analysis of 175 surgically treated cases. J Spinal Disord 10:488–492

Stolke D, Sollmann WP, Seifert V (1989) Intra- and postoperative complications in lumbar disc surgery. Spine (Phila Pa 1976) 14:56–59

Stookey B (1928) Compression of the spinal cord due to ventral extradural cervical chondromas: diagnosis and surgical treatment. Arch Neurol Psychiatr 20:275–291

Stücker R (2005) The transforaminal endoscopic approach. In: Mayer HM (ed) Minimally invasive spine surgery. Springer, Berlin/Heidelberg/New York

Thorell W et al (1998) The long-term clinical outcome of patients undergoing anterior cervical discectomy with and without intervertebral bone graft placement. Neurosurgery 43:268–273. discussion 273–274

Tureyen K (2003) Disc height loss after anterior cervical microdiscectomy with titanium intervertebral cage fusion. Acta Neurochir 145:565–569. discussion 569–570

Valls J, Ottolenghi CE, Schajowicz F (1948) Aspiration biopsy in diagnosis of lesions of vertebral bodies. JAMA 136:376–382

van den Bent MJ et al (1996) Anterior cervical discectomy with or without fusion with acrylate. A randomized trial. Spine (Phila Pa 1976) 21:834–839. discussion 840

Villavicencio AT et al (2007) The safety of instrumented outpatient anterior cervical discectomy and fusion. Spine J 7:148–153

Waddell G et al (1988) Assessment of the outcome of low back surgery. J Bone Joint Surg (Br) 70:723–727

Wang WJ, Zhou JN, Yu JM (2001) Treatment of cervical disc herniation with percutaneous arthroscopic microdisectomy. Hunan Yi Ke Da Xue Xue Bao 26:366–368

Wang MC et al (2007) Complications and mortality associated with cervical spine surgery for degenerative disease in the United States. Spine (Phila Pa 1976) 32:342–347

Weber BR et al (1997) Posterior surgical approach to the lumbar spine and its effect on the multifidus muscle. Spine (Phila Pa 1976) 22:1765–1772

Wenger M et al (2001) Long-term outcome of 104 patients after lumbar sequestrectomy according to Williams. Neurosurgery 49:329–334. discussion 334–335

Williams RW (1986) Microlumbar discectomy. A 12-year statistical review. Spine (Phila Pa 1976) 11:851–852

Wilson DH, Kenning J (1979) Microsurgical lumbar discectomy: preliminary report of 83 consecutive cases. Neurosurgery 4:137–140

Woertgen C et al (1997) Prognostic factors of posterior cervical disc surgery: a prospective, consecutive

study of 54 patients. Neurosurgery 40:724–728. discussion 728–729
Woertgen C et al (2000) Long term outcome after cervical foraminotomy. J Clin Neurosci 7:312–315
Yeung AT, Tsou PM (2002) Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. Spine (Phila Pa 1976) 27:722–731
Yorimitsu E et al (2001) Long-term outcomes of standard discectomy for lumbar disc herniation: a follow-up study of more than 10 years. Spine (Phila Pa 1976) 26:652–657
Young S, Veerapen R, O'Laoire SA (1988) Relief of lumbar canal stenosis using multilevel subarticular fenestrations as an alternative to wide laminectomy: preliminary report. Neurosurgery 23:628–633
Zander T et al (2003) Influence of graded facetectomy and laminectomy on spinal biomechanics. Eur Spine J 12:427–434
Zhou YC, Zhou YQ, Wang CY (1994) Percutaneous cervical discectomy for treating cervical disc herniation – a report of 12 cases. J Tongji Med Univ 14:110–113
Zollner J et al (1999) The effect of various nucleotomy techniques on biomechanical properties of the intervertebral disk. Z Orthop Ihre Grenzgeb 137:206–210

Microsurgical Disc Surgery

J. Schunck

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_19

19.1 Indication

The primary goal in disc surgery is to treat nerve root irritation or compression due to displaced disc tissue. In the case of spinal stenosis, bony decompression is indicated. Both methods of treatment are possible with a microsurgical technique using a surgical microscope. The microsurgical approach has become firmly established in everyday clinical practice.

19.2 Preinterventional Diagnostics

Preinterventional diagnostics for intervertebral disc surgery include, in addition to the anamnesis, carefully collected clinical and neurological findings from which the disturbance of the nerve root emerges, and a cross-sectional image procedure (MRI or CT scan). In most cases, timely x-rays in 2 planes are available. In cases of doubt, supplementary electrophysiological examinations are necessary. If several nerve roots are affected by the herniated disc, a targeted nerve root blockade under CT control can be helpful in visualizing the nerve root with the corresponding clinical symptoms. If spondylolisthesis is suspected, functional images can provide information about a possible extension of the operation. If inflammatory and/or tumorous concomitant diseases are suspected, further differential diagnostic examinations are required.

19.3 Necessary Instruments

A surgical microscope is required which, if possible, is equipped with the additional option for intraoperative documentation of findings. A sterile cover for the surgical microscope and positioning aids for the operating table must also be available. The instruments consist of wound retractors and microsurgical instruments for the preparation and removal of intervertebral disc material or bony parts in the case of supplementary decompression (punches, rongeurs, nerve root hooks, drill bits). An X-ray image intensifier for floor localization must be available at the beginning and during the procedure.

19.3.1 Costs

The costs for an intervertebral disc operation result from the materials used as well as their acquisition. The operation time is to be estimated at an average of 60 min per disc level. The revenue of the intervertebral disc surgery is composed of individual OPS codes. These include the access route and the number of operated floors on the cervical, thoracic and lumbar spine (OPS codes: 5-030ff, 5-031ff, 5-032ff). Sequestrotomy alone is covered by OPS code 5-830.1. Removal of disc tissue gff. with inclusion of a sequestrum is covered by OPS code 5-831 "Excision of diseased disc tissue" and in more detail by the corresponding subcodes. In the case of bony decompression due to spinal stenosis, the removed bony portions, which are shown under OPS code 5-832 "Excision of diseased bony and articular tissue of the spine," must be recorded in addition to the principal diagnosis. The microsurgical technique is to be additionally coded for intervertebral disc interventions and bony decompression using OPS code 5-984, without this having a revenue-increasing effect.

19.4 Pre-Intervention Education

Preinterventional information about spinal surgery is provided in accordance with the general legal requirements using special information sheets. No special distinction is made in the information sheets with regard to the surgical technique, whether the open or microsurgical procedure is performed.

19.5 Implementation of the Intervention

Depending on the location of the spine, the procedure is performed under general anesthesia in either a semi-sitting or prone position. Preoperative localization of the disc level to be operated by X-ray image intensifier and marking. After positioning and sterile draping, skin incision of approx. 2.5 cm length, depending on the number of levels, widening

of the access path. Insertion of retractors and preparation of the surgical site. Resection of the intervertebral disc sequestrum, if necessary with evacuation of the intervertebral disc space. For bony decompression, depending on the degree of stenosis, a laminotomy is performed, whereby, in contrast to a laminectomy, the spinous process, interspinous ligaments and medial ligamentum flavum are preserved and, if no hemilaminectomy is performed, parts of the lamina are also preserved. Insertion of a wound drain according to the surgeon's instructions.

19.6 Possible Complications

Complications associated with disc surgery using open and/or microsurgical techniques should be named. These relate to injury to the nerves and spinal cord membranes, bleeding, instability and recurrence. Furthermore, worsening of preoperative neurological disorders may occur. Other rare complications include bladder and/or rectal weakness and paraplegia. General complications include the occurrence of possible local infections and the risks of thrombosis and embolism.

19.7 Results in the Literature

The introduction of microsurgical techniques using a surgical microscope is first described in 1977 by Yasargil (1977) and by Caspar (Caspar et al. 1991). Microsurgical intervention is considered a significant step in disc surgery for the surgical treatment of stenoses throughout the spine. Several studies are available regarding the results in comparison to open procedures.

In a prospective randomized study, the microsurgical technique using an operating microscope was compared with the open technique via an intralaminar approach in 80 operated patients with lumbar disc herniations (Lagarrigue and Chaynes 1994). After 12–18 months, 90% of patients in both groups showed an excellent or good result according to MacNab's criteria.

Another randomized prospective study reported on 60 patients with a single-level disc herniation demonstrated by computed tomography (Tullberg et al. 1993). Results after generally open and microscopic removal of the herniated disc were contrasted. At follow-up visits at 3 weeks, 2 months, 6 months, and 1 year by independent investigators, there were no differences in operative blood loss, complications, inpatient stay, work disability, and final outcome in either group. It was concluded that the use of a surgical microscope was the decision of the surgeon, as no divergent short-term results or after one year were found.

An analysis of databases (Gibson and Waddell 2007) provided information on the evidence for disc surgery for lumbar disc herniations. A total of 40 randomized controlled trials (RCT) and 2 quasi-randomized controlled trials (QRCT) were identified. It was shown that microsurgical disc surgery had comparable results to the general open surgical technique in carefully selected patients.

The evidence of outcomes after microscopic and open disc surgery were reviewed in April 2011 (Wilco et al. 2012). The results of the database analyses CENTRAL, MEDLINE, EMBASE, CINAHL, PEDRO, ICL as well as reference lists and submitted articles were included in the evaluation. Only randomized controlled trials that referred to sciatica associated with disc herniation after determining the level of evidence were evaluated. A total of 16 studies were evaluated, of which 4 had a low bias. The microscopic technique showed a significant, but not clinically relevant, longer operative time of 12 min (25% CI 2-22) and shorter incisions averaging 24 mm (95% CI 7-40) compared with the open technique. The clinical results did not reveal superiority of either technique in terms of postoperative clinical outcomes. Conclusions were influenced by the limited quality of the evidence, so that a comparative statement on the current techniques of open, microscopic and regular disc surgery cannot be made with certainty. The results of pain score related to leg and back pain, length of incision, and operative time were not clinically significant. The authors

called for further higher quality studies to investigate both effectiveness and cost.

With regard to surgical safety and complication rates, the use of the surgical microscope showed a lower number of postoperative clinically symptomatic CSF loss syndromes (Wong et al. 2015). In a total of 863 patients operated on the lumbar spine on 1–2 floors, CSF loss syndrome was observed in 15 cases (4.7%) after microsurgical approach and in 49 cases (9%) after general open surgery. Patients with general open surgical technique were 2 times more likely to have a CSF leak (odds ratio 2.3; 95% CI 1.2–3.7; *P* 0.01). After closure of the CSF leak, no recurrence occurred in any of the patients who underwent microsurgical technique. In the case of open treatment, a recurrence rate of 25% was observed.

When comparing the microsurgical and open technique to new minimally invasive endoscopic, tubular, and automated percutaneous lumbar (APLD) surgical procedures for lumbar nerve root irritation due to disc herniation, the potential benefits of the new minimally invasive procedures were examined (Rasouli et al. 2014). The questions answered were improvement of ischialgic pain or back pain by visual analogue score and neurological disturbances and functional outcome (ADL, duration of incapacity). Furthermore, complications, length of hospital stay, postoperative analgesia, quality of life and patient satisfaction were determined. Controlled trials and quasi-controlled trials from the Cochrane Registry of Controlled Trials CENTRAL (November 2013), MEDLINE (1946-11/2013) and EMBASE 1974-11/2013 were evaluated. 11 studies with 1172 patients were evaluated. Here, there was no difference in functional impairment based on the Oswestry score between the microsurgical technique and open technique compared with the newer minimally invasive techniques at 6 months. The newer minimally invasive techniques were associated with lower surgical risk and risk of infection, but with a higher rate of inpatient readmission due to recurrence of disc herniation. Slightly decreased quality of life (less than 5 points on a 100-point scale) was seen in patients with newer minimally invasive surgical techniques. Some studies found a lower length of hospital stay after newer minimally invasive surgical technique, but the results were not consistent. In summary, the better results in terms of reduction in leg pain, back pain, and inpatient readmission in the group using new surgical techniques were too small and not clinically relevant. Further studies were requested on the appropriate indications when using newer minimally invasive surgical procedures compared to standard microsurgical/open procedures.

After bony decompression, a first meta-analysis demonstrated a good to excellent result in 60–85% of cases (Turner et al. 1992). Depending on the study, a recurrence rate of 10–30% is reported. The recurrence rate increases with distance from the index operation; cardiopulmonary diseases and concomitant rheumatic disease have an unfavorable effect. Reasons given for reoperation include inadequate decompression, the occurrence of a new stenosis in the operated or further floor(s) or symptoms in the sense of segmental instability (Katz et al. 1997).

The recurrence rate after microsurgical decompression for lumbar spinal stenosis is reported to be 29.1% depending on the degeneration of the lower disc segments (grade IV according to Pfirrmann) (Hwang et al. 2016). The studied patients with a lower degree of degeneration showed no recurrence. Another meta-analysis showed comparable recurrence rates of 3–28% after different surgical methods, with the highest recurrence rate after implantation of an intraspinous spreader (Machado et al. 2015).

A significant difference of the other surgical techniques in case of decompression alone could not be found on the basis of the published results.

The question of outcomes after decompression alone or with additional fusion for lumbar stenosis was evaluated using a meta-analysis (Chang et al. 2017). This showed that supplemental fusion in the treatment of spinal stenosis did not improve outcomes within a 2-year follow-up period. With fusion, longer operative times, higher blood loss, and higher complication rates were observed. According

to the authors' recommendation, the options for surgical treatment of spinal stenosis should be further logged and discussed.

Very low and low quality evidence was shown in the review of studies deposited in the MEDLINE, EMBASE, AMED, CINAHL, Web of Science, LILACS and Cochrane Library databases up to 11/2014 (Machado et al. 2015) comparing the incidence of complications or recurrences after decompression with fusion and decompression alone for lumbar spinal stenosis (Machado et al. 2015). Patients after decompression with fusion had a higher rate of complications compared with decompression alone (20/64, 31% vs. 3/24, 13%; *P* 0.07) and a higher rate of reoperation (9/92, 10% vs. 1/37, 3%; *P* 0.47) than after decompression alone.

19.8 Conclusion and Clinical Relevance

In general, microsurgical techniques are dependent on the learning curve and level of training of the surgeon. Microsurgical techniques have become widely accepted for disc and decompression surgery of the spine. The advantage is less damage to soft tissue and bony structures. The advantages of a microsurgical approach to intervertebral disc surgery, which was first described in the 1970s, are a shorter skin incision and, in the case of revision, less scar tissue. The occurrence of cerebrospinal fluid loss syndromes was observed in one study. Without influence on the clinical outcome are the slightly longer operation times than with the open procedure. Microsurgical techniques are standardized for bony decompression in the treatment of spinal stenosis. However, studies do not show significant superiority of each surgical method when decompression alone is performed without fusion. The additional expense due to the use of a microscope and the operative need for additional surgical material do not lead to additional revenue in the DRG system. Based on the current literature, the open and microsurgical approaches show no differences in the evidence of clinical outcomes in disc surgery.

References

Caspar W, Campbell B, Barbier DD et al (1991) The Caspar microsurgical discectomy and comparison with a conventional standard lumbar disc procedure. Neurosurgery 28:78–87

Chang W, Yuwen P, Zhu Y, Wei N, Feng C, Zhang Y, Chen W (2017) Effectiveness of decompression alone versus decompression plus fusion for lumbar spinal stenosis: a systematic review and meta-analysis. Arch Orthop Trauma Surg 137(5):637–650

Gibson JN, Waddell G (2007) Surgical interventions for lumbar disc prolapse: updated Cochrane Review. Spine (Phila Pa 1976) 32(16):1735–1747

Hwang HJ, Park HK, Lee GS, Heo JY, Chang JC (2016) Predictors of reoperation after microdecompression in lumbar spinal stenosis. Korean J Spine 13(4):183–189

Katz JN, Lipson SJ, Lew RA et al (1997) Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis: Patient selection, costs, and aurgical outcomes. Spine 22:1123–1131

Lagarrigue J, Chaynes P (1994) Comparative study of disk surgery with or without microscopy. A prospective study of 80 cases. Neurochirurgie 40:116–120

Machado GC, Ferreira PH, Harris IA, Pinheiro MB, Koes BW, van Tulder M et al (2015) Effectiveness of surgery for lumbar spinal stenosis: a systematic review and meta-analysis. PLoS One 10(3):e0122800. https://doi.org/10.1371/journal.pone.0122800.eCollection2015

Rasouli MR, Rahimi-Movaghar V, Shokraneh F, Moradi-Lakeh M, Chou R (2014) Minimally invasive discectomy versus microdiscectomy/open discectomy forsymptomatic lumbar disc herniation. Cochrane Database Syst Rev 9:CD010328. https://doi.org/10.1002/14651858.CD010328.pub2

Tullberg T, Isacson J, Weidenhielm L (1993) Does microscopic removal of lumbar disc herniation lead to better results than the standard procedure? Results of a one-year randomized study. Spine 18:24–27

Turner JA, Ersek M, Herron L et al (1992) Surgery for lumbar spinal stenosis: Attempted meta-analysis of the literature. Spine 17:1–8

Wilco C, Jacobs H, Arts MP, van Tulder MW, Rubinstein SM, van Middelkoop M, Ostelo RW, Verhagen AP, Koes BW, Wilco CP (2012) Surgical techniques for sciatica due to herniated disc, a systematic review. Eur Spine J 21(11):2232

Wong AP, Shih P, Smith TR, Slimack NP, Dahdaleh NS, Aoun SG, El Ahmadieh TY, Smith ZA, Scheer JK, Koski TR, Liu JC, Fessler RG (2015) Comparison of symptomatic cerebral spinal fluid leak between patients undergoing minimally invasive versus open lumbar foraminotomy, discectomy, or laminectomy. Neurosurgery 81:3–4

Yasargil MG (1977) Microsurgical operation of herniated lumbar disc. Adv Neurosurg 4:81

Minimally Invasive Spondylodesis Via Percutaneous Approach with Tubular Retractors

U. Hubbe

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_20

Open spondylodesis is one of the largest spinal surgeries and is associated with significant access trauma. There is sometimes considerable blood loss and not infrequently wound healing problems. In this operation, the use of minimally invasive procedures can therefore reduce the access trauma particularly significantly.

Spondylodesis aims to provide a stable connection of vertebrae for life. This goal is typically achieved with a dorsal transpedicular screw-rod system and the attachment of bone in the disc space or at the facet joints. Only bony fusion of the involved vertebrae can ensure permanent stability, as screw-rod systems alone usually cannot permanently withstand the high load. After approx. 4–5 years, fatigue fractures of the systems or material loosening occur (Galbusera et al. 2015).

Until the late 1990s, open dorsoventral, usually two-stage surgery with insertion of a iliac crest span for ventral support was the method of choice for spondylodesis (McAfee et al. 1998). A reduction in surgical and access trauma has been achieved by introducing cages for ventral support: these are filled with local bone from the access area of the dorsal spine for fusion, eliminating the need for iliac crest removal and the additional trauma of ventral access. Nevertheless, open spondylodesis requires extensive exposure of the spine to identify the necessary anatomic landmarks, placement of the cage in the disc space after clearing out the disc material, and insertion of converging screws through the pedicles into the vertebral bodies according to the correct trajectory. As a rule, this requires exposure of at least one segment above and below the heights to be fused in order to be able to mobilize the paravertebral musculature detached from the spinous processes sufficiently far laterally so that a convergent transpedicular screw trajectory can be achieved (Fig. 20.1). A disproportionately large approach is therefore necessary, particularly for monosegmental operations. The optimal convergence of the screw competes here with a restriction of the extension of the access.

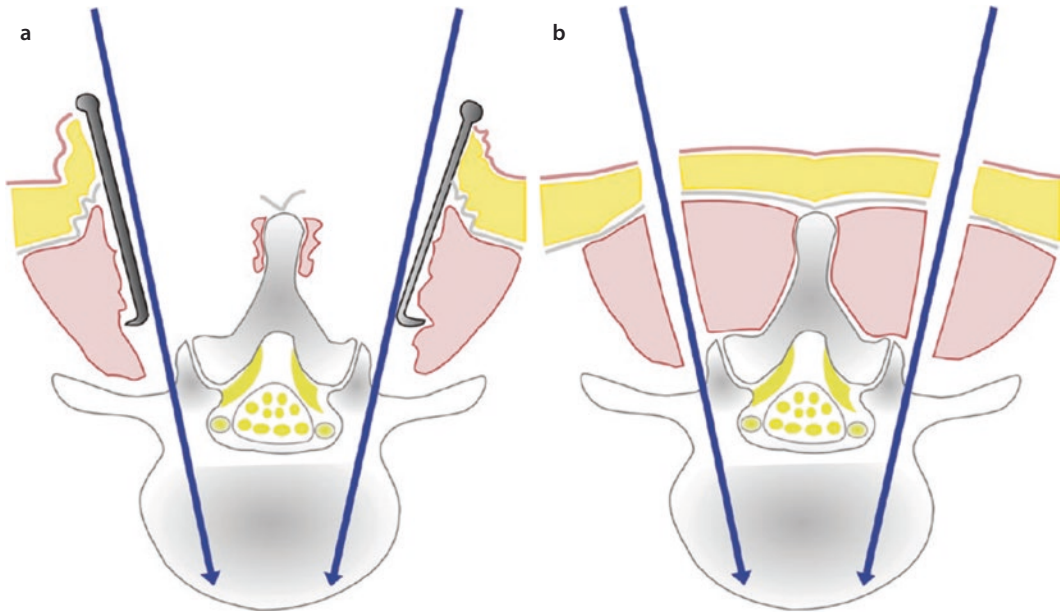


Fig. 20.1 Access routes of spondylodesis. **a** Extent of retraction of the access tissue to expose the convergent transpedicular screw trajectory (*blue arrows*) for open spondylodesis. **b** Circumscribed local tissue retraction for minimally invasive percutaneous exposure of the screw trajectory (*blue arrows*). **c** a.p. radiograph: the *pink line* marks the exposure required to create 4 screw trajectories during open spondylodesis. **d** a.p. radiograph: the *pink line* marks the exposure required to create 4 screw trajectories minimally invasively percutaneously. (With kind permission,)

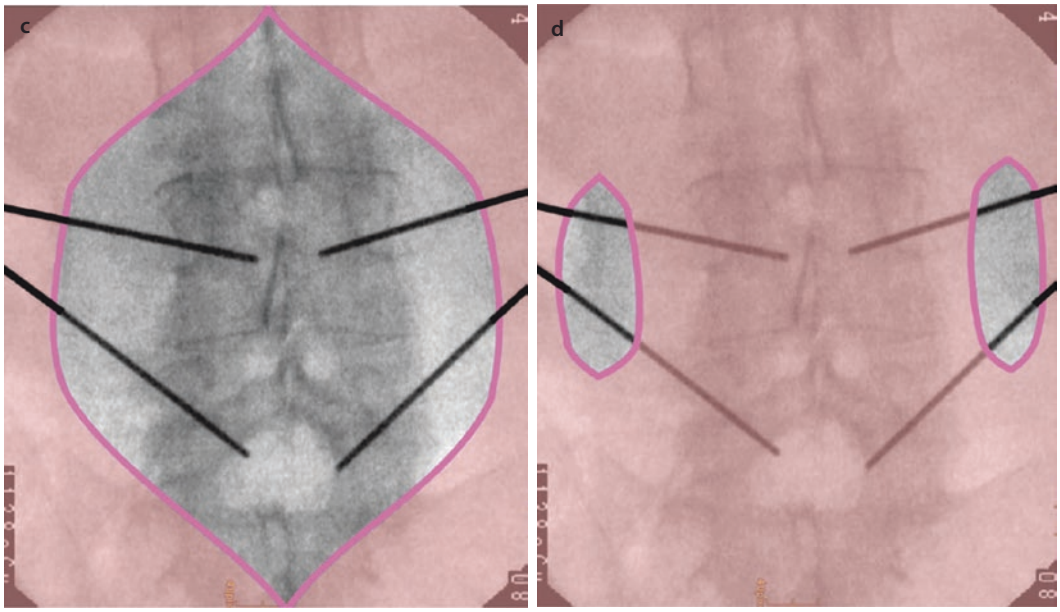


Fig. 20.1 (continued)

Cages were initially implanted on both sides from the dorsal interlaminar approach (posterior lumbar interbody fusion, **PLIF**; Fig. 20.2a). In the course of time, the transforaminal approach (transforaminal lumbar interbody fusion, **TLIF**; Fig. 20.2b) described by Harms as early as 1982 for the placement of a (larger) cage was also adopted for the minimally invasive surgical technique (Harms and Rolinger 1982; Schwender et al. 2005). In the PLIF technique, extensive removal of parts of the vertebral arch and facet joints is necessary on both sides before the cages, which are usually 1 cm wide and vary in height depending on the anatomical conditions, are inserted directly past the dura, which is strongly retracted for this purpose, into the disc space. The spatial constriction to the dura and nervous structures carries the risk of neurological deficits and is the reason for a high incidence of dura injuries.

Complications such as nerve damage or dura fistulas and pseudomeningocele can occur as a result of dura injuries during open access. The main advantage of the TLIF technique is that the access to the disc space is only on one side. The oblique transforaminal trajectory uses the significantly wider space in the nerve root socket and therefore manages with significantly less traction on the dura and the nerve root located therein.

A major step towards further reducing the invasiveness of spondylodesis operations was the development of percutaneous screw systems. These open up the possibility of inserting the screws through very small accesses (approx. 1.5 cm/screw) on a direct transmuscular trajectory, i.e. in the sense of a modified minimized Wiltse approach, with optimal convergence into the pedicles (Fig. 20.3). This was initially achieved by mounting extenders on the heads of the polyaxial pedicle screws, which allow percutaneous insertion of the longitudinal rods required for fixation of the segment. Via the extenders—more or less guided depending on the system—the threading and finally the pressing and fixation of the longitudinal rods into the screw heads takes place (Fig. 20.3c, d).

The latest development is long head screws with long extensions of the tulip heads. These allow further minimization of access to the screw entry points and require even smaller incisions of the skin and less dilatation of the underlying musculature. They also allow percutaneous reduction of olisthesis and compression and distraction of the vertebral bodies. After fixation of the rods, the overlong

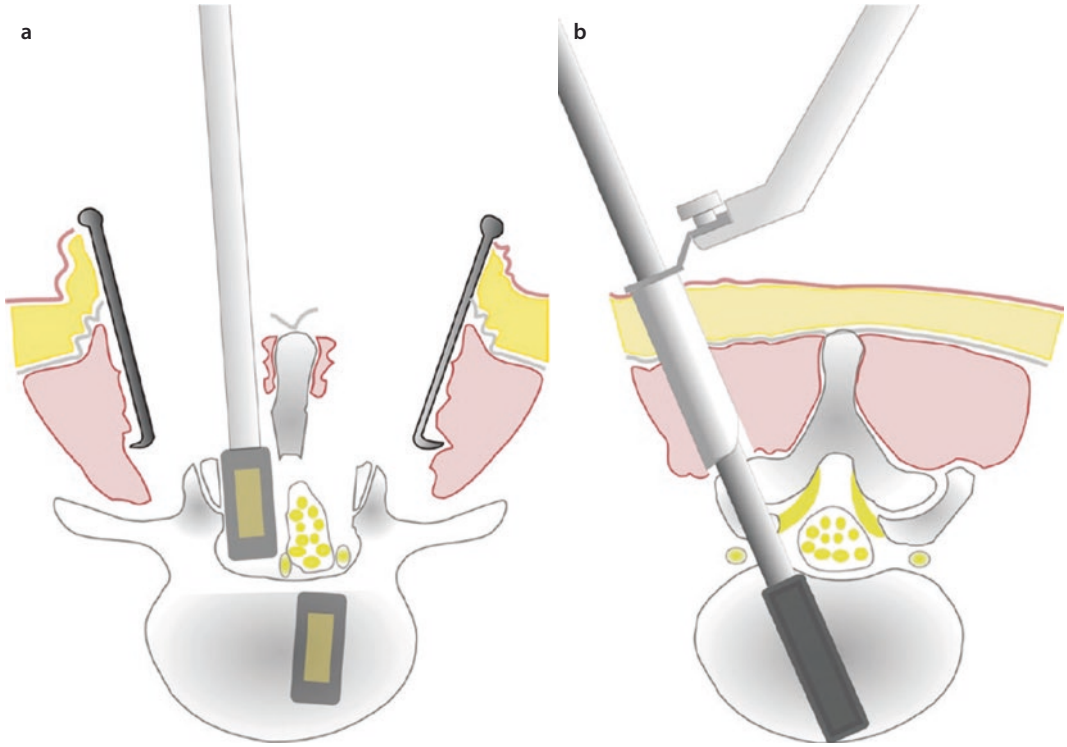


Fig. 20.2 **a** Open approach: trajectory for implantation of a PLIF cage; reciprocal cage already implanted. **b** Percutaneous minimally invasive approach: trajectory for implantation of a TLIF cage; only one cage is required. (With kind permission, © U. Hubbe. All Rights Reserved)

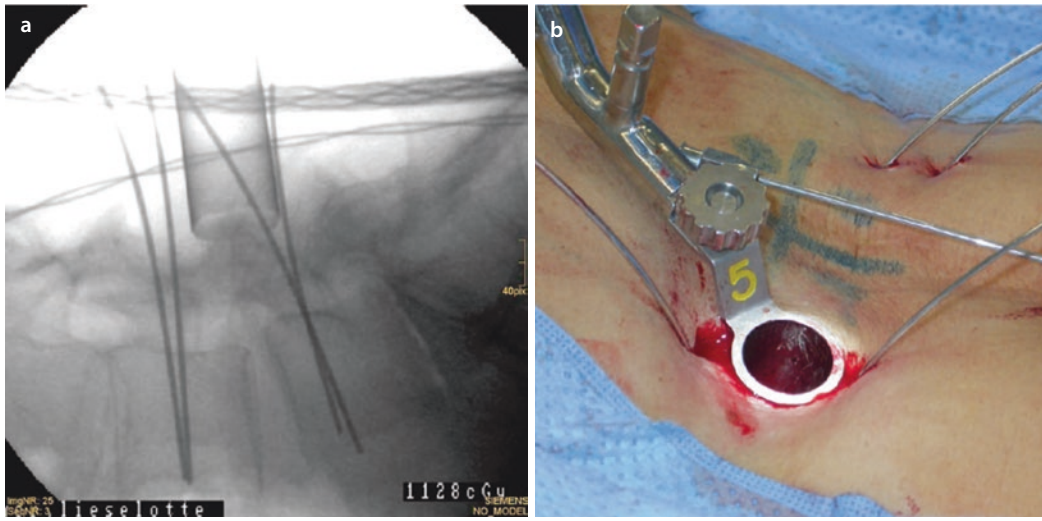


Fig. 20.3 Minimally invasive spondylodesis percutaneously. **a** Lateral intraoperative fluoroscopic image: 4 K-wires already inserted and tubular retractor (20 mm) in projection onto the disc space. **b** View of the surgical area. **c** Intraoperative a.p. fluoroscopy image: 4 pedicle screws in situ, the rods were swivelled through the screw heads via the extenders. **d** Guided swivelling of the rods via the extenders; view from the outside

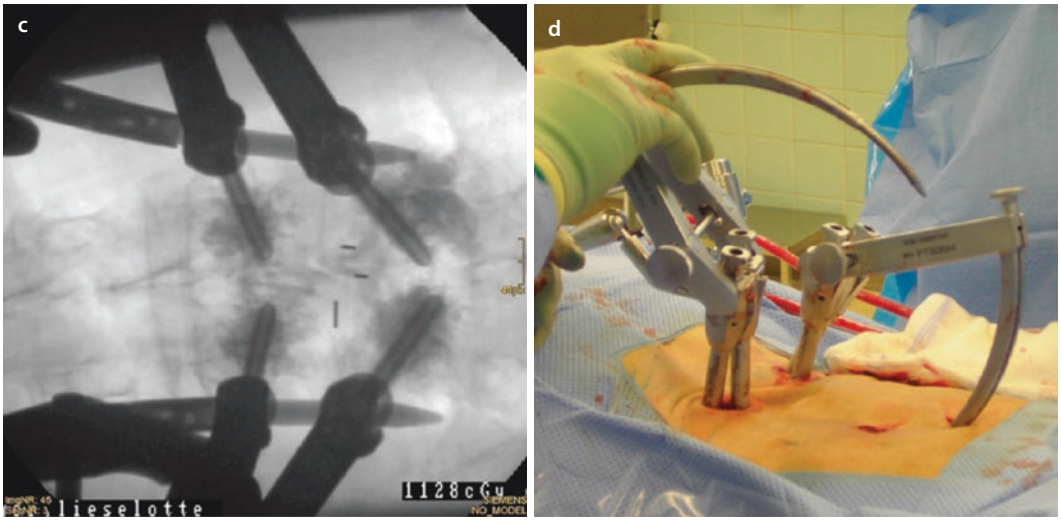


Fig. 20.3 (continued)

valves of the screw heads are broken off and disposed of. By inserting the screws and rods via minimized paraspinal trajectories, the midline skin incision for PLIF cage insertion could be significantly reduced (Wiesner et al. 1999; Foley and Gupta 2002).

The next major step in minimizing the invasiveness of spondylodesis was the adoption of the tubular approach for interbody fusion in terms of the TLIF technique. Now, for the first time, the complete stabilization operation could be performed using a minimally invasive modified Wiltse approach (Foley et al. 2003) (Fig. 20.3).

If spondylodesis is indicated, the minimally invasive technique via a percutaneous approach with tubular retractors can usually be used. Exceptions to this are reoperations in which an extension of a spondylodesis must be performed or revisions with, for example, a loosened fixator. In these cases, at least a mini-open approach must be used to expose the existing instrumentation. Minimally invasive techniques are also not advantageous in the treatment of juvenile scoliosis. For the treatment of spondylodiscitis, however, the minimally invasive techniques are excellent (Deininger et al. 2009).

20.1 Indication

Spondylodesis is typically indicated for spinal disorders when

- symptomatic macroinstability is present,
- there is evidence of symptomatic micro instability or
- a degenerative deformity leads to foraminal root compression, which cannot be treated meaningfully by decompression of the foramen alone.

In addition, spondylodesis is also indicated for symptomatic isthmic spondylolistheses.

20.2 Preinterventional Diagnostics

MRI scans are usually used to determine the indication for spondylodesis of the lumbar and thoracic spine. These provide information about the width of the spinal canal in terms of concomitant spinal canal stenoses or foraminal stenoses, olistheses present in the supine position or indirect signs of instability according to Modic.

In order to assess the bony conditions, a CT should also be performed, which also provides indications of any reduced bone quality that may be present.

Radiographic function studies may demonstrate macroinstability. In addition, the acquisition of spinal images to assess sagittal and coronary balance should now be standard practice prior to stabilization surgery.

With this diagnostic procedure, detailed planning of the spondylodesis is possible, including determination of the length of the screws required and the cage system to be used in accordance with the angle required for relordosis of the spinal column. The distance of the two parasagittal skin incisions to the midline can already be determined here. For possible useful additional anatomical information, the relevant images should be available intraoperatively. In each case, 4 axial pedicle-parallel CT slices of the pedicles to be fitted with screws as well as the level of the TLIF access on the PACS system ("picture archiving and communication system") and at least one lateral X-ray negative image, in the case of scoliosis also the a.p. X-ray image, have proven to be useful.

20.3 Necessary Instruments

A percutaneous screw system is required for screw-rod osteosynthesis. A large number of systems are available on the market, all of which allow the percutaneous insertion of screws and rods. Particular attention should be paid to the instruments provided for distraction and compression, as this is essential for endplate-sparing insertion of the cage and optimal correction of sagittal balance and compensation of scoliosis (► Sect. 20.5).

For ventral support and fusion, a cage system is required with implantation instruments that allow the cage to be inserted over the 20 mm tube. Typically, straight cages in the oblique technique are used for this purpose. The use of classic TLIF cages, which are inserted transversely along the anterior edge of the spine, is also possible with a suitable implantation instrument.

The tubular retractor system is also required. This consists of a holding arm, which is sterilely fixed to the standard fixing bars of the operating table, and a set of dilators of ascending diameter for atraumatic dilatation of the subcutaneous tissue, muscle fascia and musculature. The dilators have a scale to indicate the length of the surgical tube appropriate for the surgery. In addition, a number of surgical tubes of different lengths with the diameter of 20 mm are required. Tubular retractors are available in lengths ranging from 3 to 9 cm in increments of 1 cm. Some tubular access instrument sets include a pointed K-wire for initial perforation of the access tissues. In our practice, this has proven to be unnecessary, even dangerous, for access (possible unintentional duraperforation) and has therefore been removed from our sets.

Sufficiently long instruments should be available for decompression. In obese patients, the use of 9 cm long tubes may be necessary. The instruments should then have at least 11–12 cm working length.

Costs

The costs for the percutaneous fixator vary greatly, but are usually somewhat higher than those of an open fixator (as a rough guide, approx. €1000). Depending on the manufacturer, suitable cages are available for approx. 500–1600€. The tubular access system with a holding arm and a set of dilators is about 4300€, each surgical tube costs about 700€. There are also rental instrument sets with plastic disposable tubes.

Order Addresses

- Percutaneous fixator: Almost all manufacturers of screw-rod systems also have a percutaneous internal fixator in their product range.
- Cages: Suitable cage systems are offered, for example, by the companies Aesculap (TSPACE, PEEK or titanium-coated), Maxxspine (Sharx, highly porous 3D-printed titanium), Medtronic (Capstone, PEEK or solid titanium), Stryker (UniLIF, PEEK), Ulrich-Medical (PEZO-T, Pezo-P, PEEK or solid titanium).
- Tubular retractor: Medtronic, System Metrx.

20.4 Pre-Intervention Education

Minimally invasive spondylodesis using the percutaneous approach with tubular retractors can lead to the same complications as open spondylodesis. Thus, the altered approach does not create any new surgical risks that require education. Rather, the risk of infection and wound healing problems is lower because of the small access, and blood loss is significantly lower. At the beginning of the learning curve, however, the possibility of switching to a mini-open or open Wiltse access should be explained as a precaution.

20.5 Implementation of the Intervention

Positioning is already essential for achieving good restitution of sagittal balance. The thorax, pelvis and legs should be supported over a wide area to prevent damage to the positioning. The abdomen should hang freely from the costal arch to the spina iliaca anterior superior to allow good lordosis of the area to be stabilized. Prior to sterile draping, it is helpful to perform fluoroscopy in a.p. and lateral beams. This allows the area to be exposed to be precisely located and ensures radiolucency in both planes. If navigation is to be used, the storage media as well as the operating table must be radiolucent in the area to be radiolucenced so that a 3D scan can be performed as free of artifacts as possible.

For a minimally invasive spondylodesis via percutaneous access with tubular retractors, two parasagittal skin incisions of approx. 2.5–3 cm are sufficient. For monosegmental spondylodeses, the skin incision is usually made longitudinally; for multisegmental operations, multiple cross-sections of approx. 2 cm have also proved successful (Figs. 20.1b and 20.3b).

After the skin incision, the screw channels are prepared transpedicularly with a Yamshidi needle and the K-wires are inserted. We recommend placing the K-wires prior to decompression and cage insertion, as all anatomical landmarks such as the facet joint and transverse process are still available for orientation at this time; X-ray fluoroscopy or the use of spinal navigation is also performed. In order to be able to compensate for movements of the patient on the operating table, a patient tracker should be attached when using navigation. In most cases, a holder is attached to the spinous process of the vertebrae to be operated on. Alternatively, there is a system for large-area adhesion to the skin to avoid an additional incision for the navigation tracker (Stryker). After the intraoperative 3D data set has been created, the data set is automatically registered to the patient tracker so that the navigation can be used directly. Following the placement of the K-wires, the position is checked using X-ray fluoroscopy a.p. and laterally.

In the next step, the tubular transforaminal approach is prepared with the dilator/sleeve system via the existing skin incision: Using the first dilator (approximately 5 mm thickness), the tip of the facet joint of the level to be stabilized is located by palpation and fluoroscopic control in the lateral ray path. Subsequently, the subcutaneous adipose tissue, the fascia lumbodorsalis and the paravertebral musculature are gradually dilated with dilators of increasing size up to 20 mm. The required length of the tube is read off the markings on the dilators. The tube of the selected length is inserted via the last dilator. From the sterile area, the holding arm is attached to the operating table, the tube is attached to it and temporarily fixed. Final fixation is performed after optimal alignment with the intervertebral foramen between the pedicles by renewed fluoroscopic control.

The facet joint lying dorsally over the foramen is now resected with the chisel, if possible, in order to preserve the bone as a fusion mass. The descending joint facet, which extends far caudally, is also removed, thereby exposing the lateral recess. In addition, the spinal canal must usually be decompressed to the opposite side, which is possible after swivelling the surgical tube to the opposite side.

The disc space is then opened and cleared out as far as possible. Care must be taken to resect the cartilaginous end plates as well, so

that a solid bony fusion can take place between the vertebral bodies in the further course. For free access to the disc space and gentle implantation of the cage, it is helpful to already insert the screws on the opposite side. For this purpose, the cannulated screws are inserted over the lying K-wires and can in principle be screwed in without further X-ray control. The correct depth is reached when the screw head or its extension to the surface can no longer be turned without force. By applying a distractor to the extended screw heads, the distraction, which is now applied to the vertebral bodies on the side of the TLIF access, e.g. with blunt paddle shavers, can be maintained. When the endplates are completely free, the asserved bone is most easily introduced into the disc space using a funnel and displaced to either side with the paddle shaver to clear the space for the cage (usually 10 mm wide). Depending on the model, bone is inserted into the cage. The straight cage can then be implanted diagonally into the disc space and positioned well forward, preferably in the anterior longitudinal ligament (◘ Fig. 20.2b). In this way, good distraction is achieved in the ventral region of the spine. Subsequent compression at screw head level, i.e. in the dorsal region of the spine, can finally restore lordosis. With the diagonally placed straight cage described here, a lordosis approximately corresponding to the lordosis of the cage used is achieved. We usually use cages with a 12 ° lordosis. If significantly more lordosis is to be achieved, TLIF cages (also called banana cages) placed directly at the leading edge of the vertebra are very useful to significantly increase the amount of compression at the level of the trailing edge of the vertebra. Thus, more than 20 ° of segmental lordosis can be achieved. When using TLIF cages, the fusion mass must be inserted dorsally of the cage. Care must be taken to ensure sufficient distance between the fusion material and the posterior edge of the vertebral body so that it is not displaced into the spinal canal in the course of dorsal compression and leads to nerve compression there.

Hemostasis and slow retraction of the tube now take place. Microbleeds from the dilated muscle fibers are coagulated selectively. The muscle fibres reattach without any tendency to prolapse from the dilated section of fascia, so that no fascial suture is required. The uniformly narrow dilatation channel up to the surface makes suturing in the area of the subcutaneous fat unnecessary.

The next step is to release the contralateral temporary distraction and insert the screws on the side of the tubular access over the horizontal K-wires. If necessary, cement augmentation of the screw bearing can now be performed if the bone quality is poor. This is followed by percutaneous insertion of the rods into the screw heads and fixation under compression to increase lordosis.

A final X-ray check should now be performed in 2 planes. Corrections to the rod or the depth of screw insertion can now be made easily if necessary. Once the extensions of the screw heads have been removed, such manipulations of the fixator become tedious and very time-consuming. If the control radiographs are satisfactory (◘ Fig. 20.3c), the screw head extensions as well as the instruments for rod insertion can be removed and the closure of the small skin incisions can be performed.

20.6 Possible Complications

The use of the tubular retractor does not lead to any further complications compared to the conventional open approach, since only the access from the skin to the vertebra is changed or minimized. Care should be taken not to remove the tube in one go at the end of the operation, but to retract it step by step, coagulating the smallest bleedings from the muscles that have been forced apart by the dilatation. In our practice, this procedure means that the insertion of wound drains can be completely dispensed with, even in the case of spondylodesis.

The modification of the approach does not change the general and specific risks of a spondylodesis; there are no additional risks.

20.7 Results in the Literature

In the first published studies, the minimally invasive technique was compared with the open surgical technique with regard to operating time, blood loss, infections and wound healing disorders, but also with regard to complications and possibilities of complication management. The obvious advantages with regard to blood loss, infections and wound healing disturbances could thus be proven shortly after the introduction of the minimally invasive technique (Schwender et al. 2005; Holly et al. 2006; Park and Foley 2008; Karikari and Isaacs 2010).

However, especially in the case of stabilizing procedures, it has long been doubted by many that it is possible to control intraoperative complications with minimally invasive methods and to achieve a result comparable to that of open surgical techniques in the long term. Therefore, most current studies focus on partial aspects of the comparability of minimally invasive procedures with regard to decompression, screw position, bone apposition, correction of spinal geometry, and especially the manageability of intraoperative complications. However, the comparison of long-term clinical outcomes is not yet possible due to the high patient numbers required and the long observation period (Karikari and Isaacs 2010; Kim et al. 2011; Desai et al. 2013; Tian et al. 2013; Li et al. 2014; Tian and Mao 2014; Khan et al. 2015; Pereira et al. 2015).

20.8 Conclusion and Clinical Relevance

By using the tubular retractors and a percutaneous screw system for minimally invasive spondylodesis, a maximum reduction of the access trauma is achieved. The main advantage lies in the reduction of trauma to the cutis, subcutis and paravertebral musculature as well as the preparation steps for access and wound closure. This results in the considerable advantages described in the literature with regard to blood loss, wound healing, immediate postoperative pain symptoms, reduced length of stay in hospital and time to return to work (Cole and Jackson 2007; Franke et al. 2009; Kim et al. 2011). As with all new procedures to be learned, a learning curve must first be completed. Thereafter, however, the operative time is reduced compared with the open technique. The common complications can be managed comparably well. Postoperative cerebrospinal fluid fistulas after incisional durotomies occur less frequently compared to the open approach (Klingler et al. 2015).

References

Cole JS IV, Jackson TR (2007) Minimally invasive lumbar discectomy in obese patients. Neurosurgery 61(3):539–544. discussion 544

Deininger MH, Unfried MI, Vougioukas VI, Hubbe U (2009) Minimally invasive dorsal percutaneous spondylodesis for the treatment of adult pyogenic spondylodiscitis. Acta Neurochir 151(11):1451–1457

Desai A, Bekelis K, Ball PA, Lurie J, Mirza SK, Tosteson TD et al (2013) Variation in outcomes across centers after surgery for lumbar stenosis and degenerative spondylolisthesis in the spine patient outcomes research trial. Spine (Phila Pa 1976) 38(8):678–691

Foley KT, Gupta SK (2002) Percutaneous pedicle screw fixation of the lumbar spine: preliminary clinical results. J Neurosurg 97(1 Suppl):7–12

Foley KT, Holly LT, Schwender JD (2003) Minimally invasive lumbar fusion. Spine (Phila Pa 1976) 28(15 Suppl):S26–S35

Franke J, Greiner-Perth R, Boehm H, Mahlfeld K, Grasshoff H, Allam Y et al (2009) Comparison of a minimally invasive procedure versus standard microscopic discotomy: a prospective randomised controlled clinical trial. Eur Spine J 18(7):992–1000

Galbusera F, Volkheimer D, Reitmaier S, Berger-Roscher N, Kienle A, Wilke H-J (2015) Pedicle screw loosening: a clinically relevant complication? Eur Spine J 24(5):1005–1016

Harms J, Rolinger H (1982) A one-stager procedure in operative treatment of spondylolistheses: dorsal traction-reposition and anterior fusion (author's transl). Z Orthop Ihre Grenzgeb 120(3):343–347

Holly LT, Schwender JD, Rouben DP, Foley KT (2006) Minimally invasive transforaminal lumbar interbody fusion: indications, technique, and complications. Neurosurg Focus 20(3):E6

Karikari IO, Isaacs RE (2010) Minimally invasive transforaminal lumbar interbody fusion a review of techniques and outcomes. Spine (Phila Pa 1976) 35(26S):294–301

Khan NR, Clark AJ, Lee SL, Venable GT, Rossi NB, Foley KT (2015) Surgical outcomes for minimally

invasive vs open transforaminal lumbar interbody fusion: an updated systematic review and meta-analysis. Neurosurgery 77(6):847–874

Kim CW, Siemionow K, Anderson DG, Phillips FM (2011) The current state of minimally invasive spine surgery. J Bone Joint Surg Am 93(6):582–596

Klingler JH, Volz F, Krüger MT, Kogias E, Rölz R, Scholz C, Sircar R, Hubbe U (2015) Accidental durotomy in minimally invasive transforaminal lumbar interbody fusion: frequency, risk factors, and management. ScientificWorldJournal 2015:532628

Li F, Huo H, Yang X, Xiao Y, Xing W, Xia H (2014) Comment on Tian et al.: minimally invasive versus open transforaminal lumbar interbody fusion: a meta-analysis based on the current evidence. Eur Spine J 23(4):927–928

McAfee PC, Regan JJ, Geis WP, Fedder IL (1998) Minimally invasive anterior retroperitoneal approach to the lumbar spine. Emphasis on the lateral BAK. Spine (Phila Pa 1976) 23(13):1476–1484

Park P, Foley KT (2008) Minimally invasive transforaminal lumbar interbody fusion with reduction of spondylolisthesis: technique and outcomes after a minimum of 2 years' follow-up. Neurosurg Focus 25(2):E16

Pereira P, Buzek D, Franke J, Senker W, Kosmala A, Hubbe U et al (2015) Surgical data and early post-operative outcomes after minimally invasive lumbar interbody fusion: results of a prospective, multicenter, observational data-monitored study. PLoS One 10(3):e0122312

Schwender JD, Holly LT, Rouben DP, Foley KT (2005) Minimally invasive transforaminal lumbar interbody fusion (TLIF): technical feasibility and initial results. J Spinal Disord Tech 18(Suppl):S1–S6

Tian N-F, Mao F-M (2014) Answer to the letter to the editor of Feng Li et al. entitled "minimally invasive versus open transforaminal lumbar interbody fusion: a meta-analysis based on the current evidence" by Tian N-F et al. Eur Spine J 23(4):929–930

Tian N-F, Wu Y-S, Zhang X-L, Xu H-Z, Chi Y-L, Mao F-M (2013) Minimally invasive versus open transforaminal lumbar interbody fusion: a meta-analysis based on the current evidence. Eur Spine J 22(8):1741–1749

Wiesner L, Kothe R, Ruther W (1999) Anatomic evaluation of two different techniques for the percutaneous insertion of pedicle screws in the lumbar spine. Spine (Phila Pa 1976) 24(15):1599–1603

Minimally Invasive Microsurgical Lumbar Disc Surgery with Tubular Retractors

U. Hubbe

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_21

For many years, laminectomy was the standard approach for the surgery of lumbar disc herniations. Since structures important for the statics of the spine, such as the vertebral arch, spinous process, and interspinous ligaments, and thus the posterior traction ligament of the spine, were removed, iatrogenic instabilities occurred in 2–10% of cases (Shenkin and Hash 1979; Lee 1983). The introduction of partial hemilaminectomy in place of laminectomy resulted in a significant reduction in access trauma (Yasargil and Pait 1996; Benifla et al. 2008). With this access technique and the systematic preservation of the essential portions of the facet joints, iatrogenic instabilities were no longer observed after lumbar discectomies (Hassler et al. 1996). The introduction of microsurgery into spinal surgery was accompanied by a reduction in the size of the paraspinous surgical approach and, in addition to smaller skin incisions, led to a reduction in paravertebral muscle trauma and thus access trauma (Bell and Lavyne 1984).

In recent years, minimally invasive approaches to spine surgery have been increasingly adopted, leading to further reductions in access trauma (Foley et al. 1999, 2003; Foley and Gupta 2002; Perez-Cruet et al. 2002; Holly et al. 2006; Park and Foley 2008; Karikari and Isaacs 2010; Kim et al. 2011).

In today's most common standard approach of a microdiscectomy with partial hemilaminectomy, the subcutaneous fat layer is first dissected after the skin incision, then the lumbodorsal fascia is exposed and incised. Subsequently, the paravertebral muscles are sharply separated from the spinous processes and vertebral arches adjacent above and below down to the articular facets and completely pushed off laterally. After the necessary haemostasis, self-retaining retractors are used to keep the musculature out of the surgical field (Fig. 21.1a). After the vertebral arches of the height to be operated on have been reached, the further surgical steps can be performed in the target region.

Minimally invasive tubular microdiscectomy uses tubular retractors, typically 14–18 mm in diameter and available in lengths between 3 and 9 cm in increments of 1 cm. First, anatomical and fluoroscopic planning of the surgical access is performed, followed by

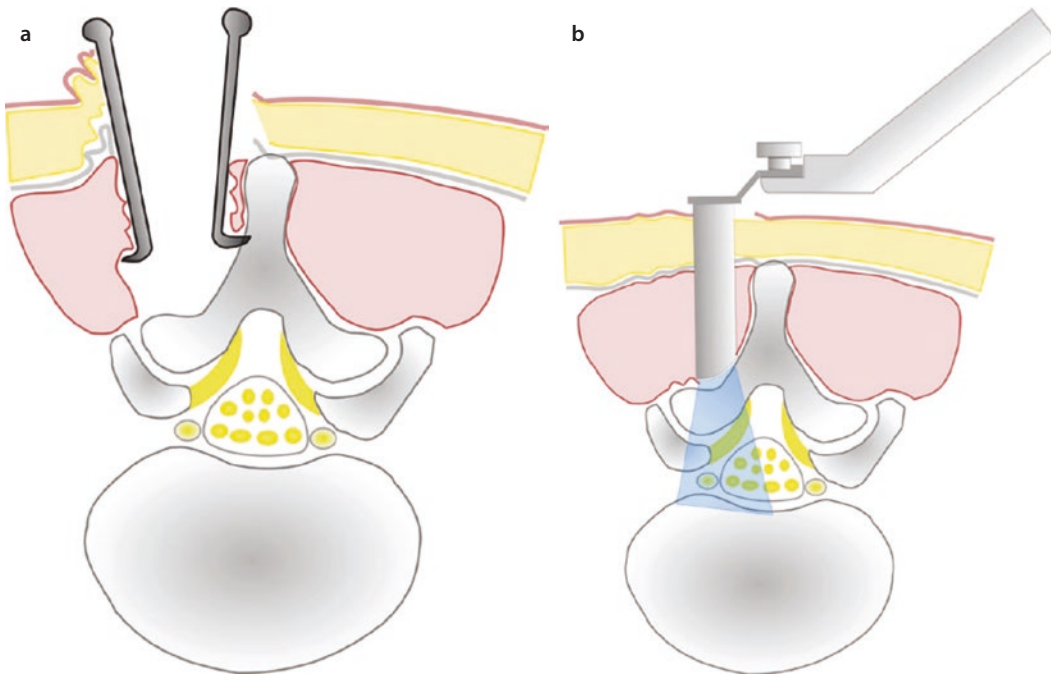


Fig. 21.1 **a** Open approach for microdiscectomy. **b** Minimally invasive tubular approach for microdiscectomy. The *blue area* marks the field of view. (Courtesy of © U. Hubbe. All Rights Reserved)

the skin incision, which needs to be only a few millimeters longer than the tube selected for surgery. The special feature of the minimally invasive tubular approach is the preparation technique: the preparation of the subcutaneous fatty tissue, the fascia lumbodorsalis and the paravertebral musculature is carried out solely by gradually dilating the tissue with dilators of increasing size, as has been common practice in gynaecology for decades with the Hegar pins for opening the cervix. The selected tube is inserted over the last dilator and secured with a holding arm attached to the operating table and, after optimal alignment with the target region, firmly fixed by renewed fluoroscopic control (◘ Fig. 21.1b). This largely prevents the preparation of the wrong height. The dilators are then removed. The further surgical steps are performed under microscopic view. After reaching the vertebral arches of the height to be operated on, the further surgical steps in the target region can be carried out as in standard microdiscectomy.

21.1 Indication

The indication for surgery of a herniated disc exists if there is an emergency indication (breech symptoms with bladder dysfunction or/and high-grade paresis) or if the 4- to 6-week conservative therapy was not successful. Accordingly, it is stated in the guideline of the Scientific Medical Societies on lumbar radiculopathy (Glocker et al. 2018).

The minimally invasive microsurgical technique with tubular retractors can in principle always be used when there is an indication for surgery on a proven herniated disc. The technique can be used for the interlaminar approach, the translaminar approach and especially for the extraspinal approach to foraminal herniated discs.

21.2 Pre-Interventional Diagnostics

For the detection of a lumbar disc herniation, the collection of the exact anamnesis and especially the course of the disease is of great importance. Typical here is the sudden onset of symptoms, although more or less pronounced back pain may precede. In addition to lumbar back pain, there is usually leg pain of varying severity, which is usually radicular in origin. In addition, hypaesthesias of the corresponding dermatome are common. Paresis of the musculature dependent on the corresponding root often indicates a higher degree of root compression. Already at a degree of strength of 3 out of 5 an operation can be performed, from a degree of strength of 2 out of 5 an operative treatment is undoubtedly indicated. Imaging diagnostics of the relevant segments of the lumbar spine should be performed at the latest when the conditions for an indication for surgery are present. For this purpose, MRI is recommended in the first place because it offers the best soft-tissue resolution and is performed without X-rays. In the event of contraindications to MRI or lack of availability in urgent cases, computed tomography is also possible, which can also be used to make the diagnosis in most cases. The decisive factor in the interpretation of imaging is that the findings must be able to explain the patient's complaints. In imaging, disc herniations are detectable in asymptomatic patients with a frequency of up to 30%. Thus, in addition to symptomatic disc herniations, asymptomatic pathologies such as disc herniations, stenoses or olistheses may be present at the same time in symptomatic patients. Based on the imaging, the height and side to be operated on as well as the required access (interlaminar, translaminar or extraspinal) must be determined preoperatively.

21.3 Necessary Instruments

The minimally invasive microsurgical operation of the herniated disc with tubular retractors is performed with the instruments and the operating microscope commonly used for microsurgical operations. In addition to these routine instruments, the tubular access instrumentation is required. This consists of a holding arm, which is sterilely fixed to the standard mounting bars of the operating table, a set of dilators of ascending diameter for atraumatic dilatation of the subcutaneous tissue, muscle fascia and musculature. The dilators have a scale to indicate the length of the surgical tubes suitable for the operation. A number of surgical tubes of different lengths and diameters are required to be able to use the most suitable one in each case (▶ Sect. 21.5). Tubular retractors typically have diameters of 14–20 mm and are available in lengths between 3 cm and 9 cm in increments of 1 cm. Some tubular access instrument sets include a pointed K-wire for initial perforation of the access tissues. In our practice, this has proven to be unnecessary, even dangerous, for access (possible unintentional duraperforation) and has therefore been removed from our sets.

Costs

The cost of the holding arm and the set of dilators is about 4300€, each surgical tube costs about 700€. There are also rental instrument sets with single-use plastic tubes.

Order address: Medtronic GmbH, Earl-Bakken-Platz 1, D-40639 Meerbusch.

21.4 Pre-Intervention Education

The standard information about an operation on the intervertebral disc via an interlaminar, translaminar or extraspinal approach is required. Information about the planned minimally invasive approach is useful, but it does not pose any particular risks. In the learning phase, information should be provided about a possible switch to open access. This also does not entail any additional risks.

21.5 Implementation of the Intervention

Tubular retractors are used for minimally invasive tubular microdiscectomy and are typically available in diameters of 14 mm, 16 mm, 18 mm or 20 mm and lengths between 3 cm and 9 cm in increments of 1 cm. The selection of the diameter of the tube depends on the experience and preference of the surgeon, the required length is read off the markings of the dilators as needed after dilatation.

The operation is performed under general anesthesia. Patients are placed in the prone position on the operating table with relief of the abdomen. Then the fluoroscopic determination of the surgical access in the lateral beam path takes place and subsequently the skin incision in the midline, which must be only a few millimeters longer than the diameter of the tube selected for surgery. The subcutaneous fatty tissue, the fascia lumbodorsalis and the paravertebral musculature are prepared by gradually dilating the tissue with the dilators of increasing size (◘ Fig. 21.2a). Already with the first dilator, the vertebral arch, the facet joint and the interlaminar window can be palpated, so that the dilators are positioned close to the midline over the transition from the cranial vertebral arch to the interlaminar window. The required length of the tube is read from the markings on the dilators. The tube is inserted at the selected length via the last dilator. From the sterile area, the holding arm is attached to the operating table, the tube is attached to it and temporarily fixed. The final fixation of the tube is carried out after optimal alignment to the target region by renewed fluoroscopic control (◘ Fig. 21.2a–d).

The holding arm ensures the exact maintenance of the fluoroscopically controlled access direction to the desired segment. Preparation of the wrong height due to displacement of the access retractor is thus largely prevented. Subsequently, the dilators are removed. The further surgical steps are performed under microscopic view. Now the interlaminar window and the vertebral arches

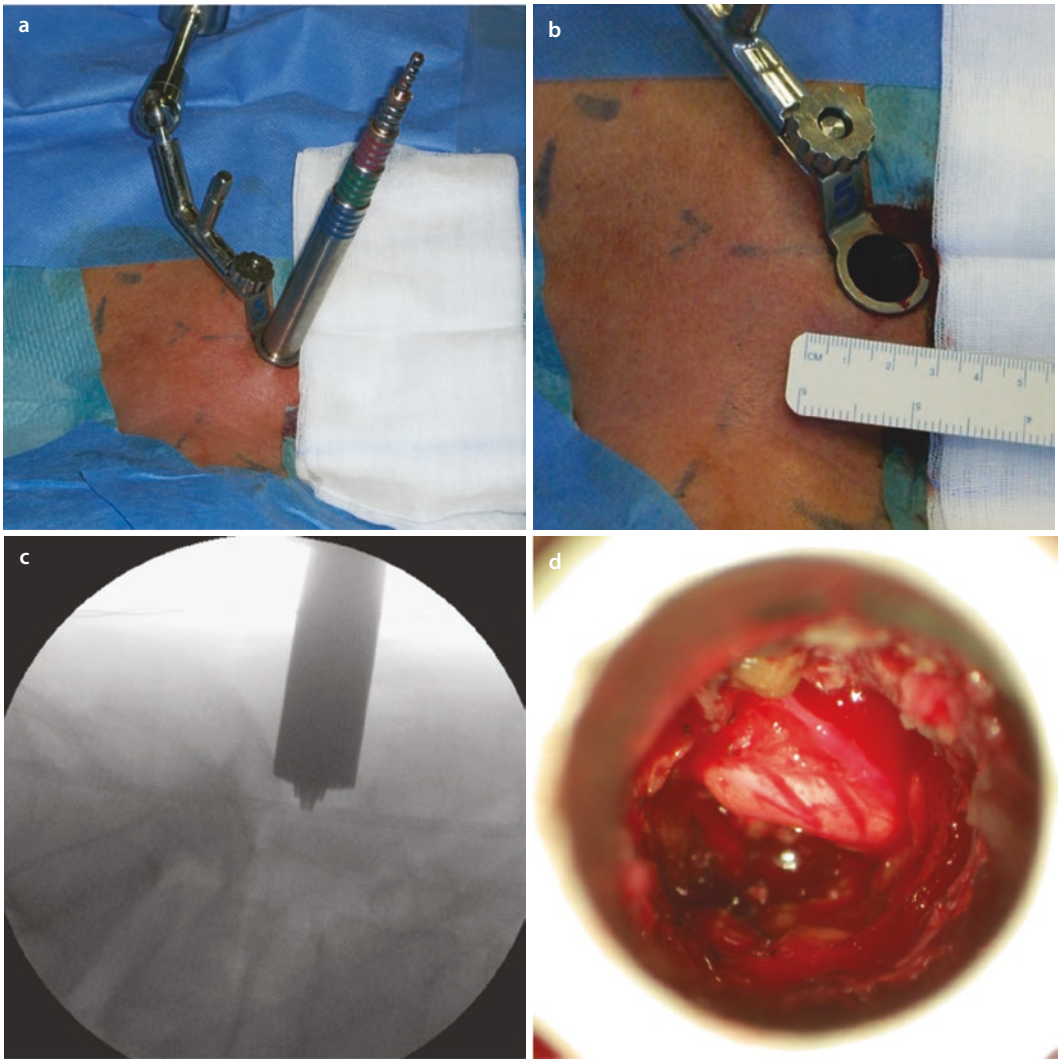


Fig. 21.2 Minimally invasive tubular microdiscectomy. **a** Dilators and tubular retractor in situ. **b** Tubular retractor after removal of dilators. **c** Tubular retractor and dilators in the fluoroscopic area. **d** Microscopic view through the tubular retractor onto the nerve root

of the height to be operated on can be exposed. The further surgical steps in the target region can be performed as in standard microdiscectomy. A slight difference to the open standard microdiscectomy is that in the tubular approach for a change of the viewing angle of the operating microscope especially when using small tube diameters (14 mm or 16 mm) also the angle of the tube (after releasing the locking of the holding arm) has to be changed to visualize a different part of the target region.

At the end of the operation, in standard microdiscectomy the retractors are removed, a layered wound closure with sutures of the fascia lumbodorsalis, depending on the thickness also of the subcutaneous fat, and finally skin closure are performed. In minimally invasive tubular microdiscectomy, the tube is slowly retracted, microbleeds from the dilated muscle fibers are selectively coagulated. The muscle fibers reattach, with no tendency to prolapse from the dilated section of fascia, so no fascial suture is required. Since the dilata-

tion channel is uniformly narrow all the way to the surface, no suture is required in the subcutaneous fat area either. Only the small skin incision is closed.

21.6 Possible Complications

The use of the tubular retractor does not lead to any further complications compared to conventional microdiscectomy, since only the access from the skin to the vertebral arch is changed or minimized. Care should be taken not to remove the tube in one go at the end of the operation, but to retract it step by step, coagulating the smallest bleedings from the muscles that have been forced apart by the dilatation. In our practice, this procedure also makes it possible to completely dispense with the insertion of wound drains.

The general and specific risks of a microdiscectomy are not changed by the modification of the access, there are no additional risks.

21.7 Results in the Literature

Minimally invasive tubular microdiscectomy is now an accepted procedure for the treatment of disc herniation (Cole and Jackson 2007; Franke et al. 2009; Kim et al. 2011). For surgeons experienced in microdiscectomy, the combination of the tubular minimally invasive approach with the use of the surgical microscope represents a minor modification of the usual surgical technique. Therefore, the learning curve is steep. This is a significant advantage compared to other minimally invasive procedures for disc surgery such as endoscopically assisted (microendoscopic discectomy, MED) or fully endoscopic (endoscopic transforaminal discectomy, ETD) minimally invasive approaches. Here, the learning curve is flat as these techniques differ significantly from standard microdiscectomy. In addition to the unfamiliar handling, visualization via a monitor and the usually two-dimensional image pose a hurdle for these procedures (Foley et al. 1999; Perez-Cruet et al. 2002; Ruetten et al. 2006; Nellensteijn et al. 2010). The technique of minimally invasive tubular microdiscectomy is also easy to learn and successful to use for surgery of recurrent disc herniations (Hubbe et al. 2016). This is also reflected in the mean operating time of 90 ± 35 min, which is comparable to the other minimally invasive procedures (MED, ETD) (98–102 min) (Isaacs et al. 2003; Le et al. 2003).

Minimally invasive tubular microdiscectomy can also be used to treat bony recess stenosis that exists concurrently with the recurrent herniation, which has been shown to be a prognostically unfavorable factor in ETD (Ahn et al. 2004).

The rate of incisional durotomy in the minimally invasive tubular microdiscectomy we studied was 16.7% (Kogias et al. 2017), which is in the middle range of what is reported for open revision microdiscectomy (13–27%) (Tafazal and Sell 2005; Khan et al. 2006; El Shazly et al. 2013; Kogias et al. 2017). This is slightly higher than the rate of (7–12.5%) reported for MED (Isaacs et al. 2003; Le et al. 2003; Smith et al. 2010) and significantly higher than the rate of "zero" published for ETD (Ahn et al. 2004; Hoogland et al. 2008; Ruetten et al. 2009). However, especially the often small dura injuries might be underdiagnosed in ETD performed under continuous irrigation with saline, as CSF leakage into the irrigation fluid is hardly detectable.

Closure of incisional durotomies with minimally invasive tubular microdiscectomy was free of complications in all cases by application of an absorbable fibrin glue patch, and in a few cases also with suture and fibrin glue. Further measures, especially reoperations, did not occur (Kogias et al. 2017). This was despite the fact that postoperative management called for early mobilization, if possible, on postoperative day 1. The success rate of the dural repair strategy used here is remarkable, as the reoperation rate after incisional durotomy is reported in the literature to be 2–9% (Wang et al. 1998; Cammisa et al. 2000; Tafazal and Sell 2005). In the open surgery comparison group, it was 6.25% (Kogias

et al. 2017). Ruban & O'Toole also mobilized their patients after incisional durotomies in minimally invasive lumbar spine surgery within the first 24 h without complications, while Than et al. had the same experience with mobilization within 48 h and Senker et al. with 2.5–5 days of bed rest (Than et al. 2008; Ruban and O'Toole 2011; Senker et al. 2013). In contrast, for incisional durotomies during open spine surgery, bed rest for up to 7 days is recommended (Wang et al. 1998; Than et al. 2008; Ruban and O'Toole 2011). Like Ruban and O'Toole and Than et al., we believe the reason for the low complication rate after incisional durotomies, despite early mobilization during minimally invasive approaches, is the small skin incisions and the minimal dead space in the access area due to the dilatation of the access tissues, resulting in adequate back pressure in the area of the durotomy. This prevents CSF fistulas and pseudomeningocele. Early mobilization reduces postoperative cardiovascular complications (Agnelli 2004).

21.8 Conclusion and Clinical Relevance

The minimally invasive microsurgical operation of the herniated disc with tubular retractors allows a significant reduction of the access trauma, can be learned quickly and, in addition to the classic interlaminar access, can be transferred to many other accesses without bringing relevant new risks. The main advantage of the minimally invasive tubular approach is the reduction of trauma to the cutis, subcutis and paravertebral musculature as well as the preparation steps for access and wound closure. This results in the advantages described in the literature with regard to blood loss, operating time, immediate postoperative pain symptoms, length of stay in hospital and time to return to work (Cole and Jackson 2007; Franke et al. 2009; Kim et al. 2011). The common complications can be managed comparably well. Postoperative CSF fistulas after incisional durotomies do not occur, in contrast to open microdiscectomy.

References

Agnelli G (2004) Prevention of venous thromboembolism in surgical patients. Circulation 110(24):4–13

Ahn Y, Lee S-H, Park W-M, Lee H-Y, Shin S-W, Kang H-Y (2004) Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: surgical technique, outcome, and prognostic factors of 43 consecutive cases. Spine (Phila Pa 1976) 29(16):E326–E332

Bell WO, Lavyne MH (1984) Retractor for lumbar microdiscectomy: technical note. Neurosurgery 14(1):69–70

Benifla M, Elamed IM, Arrelly RB (2008) Unilateral partial hemilaminectomy for disc removal in a 1-year-old child. J Neurosurg Pediatr 2(1):133–135

Cammisa FPJ, Girardi FP, Sangani PK, Parvataneni HK, Cadag S, Sandhu HS (2000) Incidental durotomy in spine surgery. Spine (Phila Pa 1976) 25(20):2663–1667

Cole JS 4th, Jackson TR (2007) Minimally invasive lumbar discectomy in obese patients. Neurosurgery 61(3):539–544. discussion 544

El Shazly AA, El Wardany MA, Morsi AM (2013) Recurrent lumbar disc herniation: a prospective comparative study of three surgical management procedures. Asian J Neurosurg 8(3):139–146

Foley KT, Gupta SK (2002) Percutaneous pedicle screw fixation of the lumbar spine: preliminary clinical results. J Neurosurg 97(1 Suppl):7–12

Foley KT, Smith MM, Rampersaud YR (1999) Microendoscopic approach to far-lateral lumbar disc herniation. Neurosurg Focus 7(5):e5

Foley KT, Holly LT, Schwender JD (2003) Minimally invasive lumbar fusion. Spine (Phila Pa 1976) 28(15):S26–S35

Franke J, Greiner-Perth R, Boehm H, Mahlfeld K, Grasshoff H, Allam Y et al (2009) Comparison of a minimally invasive procedure versus standard microscopic discotomy: a prospective randomised controlled clinical trial. Eur Spine J 18(7):992–1000

Glocker F et al (2018) Lumbale Radikulopathie. S2k-Leitlinie, AWMF online, Registernummer 030/058, S 1–38. https://www.awmf.org/uploads/tx_szleitlinien/030-058l_S2k_Lumbale_Radikulopathie_2018-04.pdf. Accessed on 07.08.2018

Hassler W, Kalkweg K, Brandner S, Slansky I (1996) Microsurgical management of lateral lumbar disc herniations: combined lateral and interlaminar approach. Acta Neurochir 138(8):901–907

Holly LT, Schwender JD, Rouben DP, Foley KT (2006) Minimally invasive transforaminal lumbar interbody fusion: indications, technique, and complications. Neurosurg Focus 20(3):E6–E5

Hoogland T, van den Brekel-Dijkstra K, Schubert M, Miklitz B (2008) Endoscopic transforaminal discectomy for recurrent lumbar disc herniation: a prospective, cohort evaluation of 262 consecutive cases. Spine (Phila Pa 1976) 33(9):973–978

Hubbe U, Franco-Jimenez P, Klingler J-H, Vasilikos I, Scholz C, Kogias E (2016) Minimally invasive tubu-

lar microdiscectomy for recurrent lumbar disc herniation. J Neurosurg Spine 24(1):48–53
Isaacs RE, Podichetty V, Fessler RG (2003) Microendoscopic discectomy for recurrent disc herniations. Neurosurg Focus 15(3):E11–E14
Karikari IO, Isaacs RE (2010) Minimally invasive transforaminal lumbar interbody fusion: a review of techniques and outcomes. Spine (Phila Pa 1976) 35(26S):294–301
Khan MH, Rihn J, Steele G, Davis R, Donaldson WF 3rd, Kang JD et al (2006) Postoperative management protocol for incidental dural tears during degenerative lumbar spine surgery: a review of 3,183 consecutive degenerative lumbar cases. Spine (Phila Pa 1976) 31(22):2609–2613
Kim CW, Siemionow K, Anderson DG, Phillips FM (2011) The current state of minimally invasive spine surgery. J Bone Joint Surg Am 93(6):582–596
Kogias E, Klingler J-H, Franco Jimenez P, Vasilikos I, Sircar R, Scholz C et al (2017) Incidental durotomy in open versus tubular revision microdiscectomy: a retrospective controlled study on incidence, management, and outcome. Clin Spine Surg 30(10):E1333–E1337
Le H, Sandhu FA, Fessler RG (2003) Clinical outcomes after minimal-access surgery for recurrent lumbar disc herniation. Neurosurg Focus 15(3):E12–E14
Lee CK (1983) Lumbar spinal instability (olisthesis) after extensive posterior spinal decompression. Spine (Phila Pa 1976) 8(4):429–433
Nellensteijn J, Ostelo R, Bartels R, Peul W, van Royen B, van Tulder M (2010) Transforaminal endoscopic surgery for symptomatic lumbar disc herniations: a systematic review of the literature. Eur Spine J 19(2):181–204
Park P, Foley KT (2008) Minimally invasive transforaminal lumbar interbody fusion with reduction of spondylolisthesis: technique and outcomes after a minimum of 2 years' follow-up. Neurosurg Focus 25(2):E16
Perez-Cruet MJ, Foley KT, Isaacs RE, Rice-Wyllie L, Wellington R, Smith MM et al (2002) Microendoscopic lumbar discectomy: technical note. Neurosurgery 51(5 Suppl):S129–S236
Ruban D, O'Toole JE (2011) Management of incidental durotomy in minimally invasive spine surgery. Neurosurg Focus 31(4):E15
Ruetten S, Komp M, Godolias G (2006) A new full-endoscopic technique for the interlaminar operation of lumbar disc herniations using 6-mm endoscopes: prospective 2-year results of 331 patients. Minim Invasive Neurosurg 49(2):80–87
Ruetten S, Komp M, Merk H, Godolias G (2009) Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic interlaminar and transforaminal versus microsurgical revision. J Spinal Disord Tech 22(2):122–129
Senker W, Meznik C, Avian A, Berghold A (2013) The frequency of accidental dural tears in minimally invasive spinal fusion techniques. J Neurol Surg A Cent Eur Neurosurg 74(6):373–377
Shenkin HA, Hash CJ (1979) Spondylolisthesis after multiple bilateral laminectomies and facetectomies for lumbar spondylosis. Follow-up review. J Neurosurg 50(1):45–47
Smith JS, Ogden AT, Shafizadeh S, Fessler RG (2010) Clinical outcomes after microendoscopic discectomy for recurrent lumbar disc herniation. J Spinal Disord Tech 23(1):30–34
Tafazal SI, Sell PJ (2005) Incidental durotomy in lumbar spine surgery: incidence and management. Eur Spine J 14(3):287–290
Than KD, Wang AC, Etame AB, La Marca F, Park P (2008) Postoperative management of incidental durotomy in minimally invasive lumbar spinal surgery. Minim Invasive Neurosurg 51(5):263–266
Wang JC, Bohlman HH, Riew KD (1998) Dural tears secondary to operations on the lumbar spine. Management and results after a two-year-minimum follow-up of eighty-eight patients. J Bone Joint Surg Am 80(12):1728–1732
Yasargil MG, Pait TG (1996) Exposure versus instability. J Neurosurg 84:891–892

OLIF Technique (Oblique Lumbar Interbody Fusion)

K. -M. Scheufler

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_22

Current oblique lumbar interbody fusion (OLIF) techniques represent different variations or interpretations of the mini-ALIF (Anterior Lumbar Interbody Fusion; Mayer 1997) technique pioneered by Mayer in the 1990s. The common feature is the mini-open (i.e., nondoscopic) anterolateral retroperitoneal approach to the discs between L1 and S1 (Kim et al. 2016; Li et al. 2017; Mobbs et al. 2015; Molloy et al. 2016; Scheufler 2007; Woods et al. 2017) using dedicated retractor systems. To this extent, the common narrative in the Anglo-American literature that current OLIF techniques have evolved as a variant of lateral lumbar interbody fusion (LLIF/XLIF/DLIF, Lateral Lumbar Interbody Fusion/Extreme Lateral Interbody Fusion/Direct Lateral Interbody Fusion) with the aim of reducing intervention-typical complications is inaccurate. Rather, the increasing spread of the OLIF technique is based on a return to surgical procedures that have already been practiced for decades (in Germany and France).

Analogous to the alternative anterior interbody fusion techniques, the advantages of the OLIF technique are based on the accessibility of the entire intervertebral space of individual and—if required—multiple lumbar segments. The variable and easily expandable access allows not only intersomatic fusion but also the performance of more complex procedures, such as lumbar vertebral body replacement, endoprosthetic disc replacement and revision surgery (both from the left and right). The wide anterior access to the disc space allows (analogous to the ALIF technique) an effective decompression of the spinal canal (e.g. in case of median disc herniations or vertebral fractures) and, due to the possibility of a comprehensive ventral release, including resection of the anterior longitudinal ligament, the use of a wide range of implant systems with a large contact surface, high primary stability and variable geometry for the correction of deformities. In this context, the use of so-called hyperlordotic cages (intersomatic implants with lordosis angles between 15 and 25°) simplifies the restoration of the physiological sagittal profile of the lumbar spine, especially when used in the caudal lumbar segments between L4 and S1. In contrast to the classic ALIF (via anterior or anterolateral pararectal access), the OLIF technique facilitates and accelerates retroperitoneal access by means of gravity retraction of the peritoneal sac on the one hand, and on the other hand shortens the path to the spine and simplifies the preparation of the prevertebral vessels due to the viewing and working angle. The access angle can be varied between 0 and 90° as required during hardware implantation using so-called orthogonal maneuvers.

22.1 Indication

The range of indications for the OLIF technique is broad and includes:

- degenerative disc disease:
  - Osteochondrosis/foraminal stenosis,
  - median disc herniation,
- Deformities:
  - Spondylolisthesis,
  - Scoliosis,
  - Kyphosis,
- traumatic lesions:
  - Vertebral fracture,
  - disco-ligamentous instability,
- inflammatory diseases:
  - Spondylodiscitis,
  - Spondylitis,
- neoplastic diseases:
  - Metastases,
  - primary vertebral tumors,
- Revision Surgery:
  - Pseudarthrosis,
  - Cagedislocation/sintering.

In addition to pronounced truncal obesity, previous ipsilateral retroperitoneal (especially vascular) surgery in the access area and previous local radiotherapy are considered relative contraindications. For retroperitoneal revision procedures, preoperative ureteral splinting on the access side using a double-J catheter is recommended. A vascular surgery stand-by is recommended as needed for support during access or potential vascular complications, especially during revision procedures (Mobbs et al. 2015).

22.2 Preinterventional Diagnostics

In addition to the indication-specific imaging analysis of local and regional pathomorphological changes, e.g. of the treatment-dependent section of the lumbar spine by means of MRI, CT and native X-rays (if necessary in the functional position), the preinterventional diagnostics includes the preparation of standing images of the entire spine (for the preoperative analysis of the spinal balance) and the qualified imaging of the prevertebral vessels. While in younger patients the visualization of the angioanatomy in the context of preoperative MR section imaging is usually sufficient, in older patients as well as after ventral preinterventions, the performance of a CT angiography is recommended due to the more frequently encountered, intervention-relevant changes in the position (dolichoectasia) and wall structure (calcification) of the prevertebral vessels. In addition to the detailed representation of the local vascular anatomy, the latter also allows the assessment of the position (deviations) of visceral organs in the access area (kidneys, etc.). In the case of revision surgery, especially after previous (also endovascular) vascular surgery, extended imaging diagnostics may be necessary – within the framework of interdisciplinary intervention planning involving vascular surgery.

22.3 Necessary Instruments

In addition to basic surgical instruments, the instrument sets required for OLIF access include specific access instruments (in particular a suitable retractor system) as well as rasparatories, curettes, grasping forceps, etc. with an extended shaft. Various manufacturers offer corresponding ALIF/LLIF/OLIF instrument sets. Both frame-bound retractor systems (preferred by the author) and free, Langenbeck-like retractors with the possibility of fixation to the spinal column can be used to keep the spatially limited surgical corridor free. It should be noted that retractors with a fixed 90° angle between the valve and the shaft (as with classic Langenbeck retractors) are **not** suitable for use in the oblique access corridor of the OLIF technique. Furthermore, a variable, lockable articulation between retractor valve and shaft is advantageous. Due to the limited access dimensions, the role of the surgical assistant in OLIF is very limited, so the ergonomics of the working field (especially the handling of the retraction system) has a decisive effect on safety and time-efficient performance of the procedure. For access preparation, long straight and curved clamps (stem swabs) and fine long (Metzenbaum) scissors are required. Adequate illumination of the surgical field requires a freely movable and focusable ceiling light with high luminosity. Alternatively, the surgical area can be illuminated with an endoscopic light guide. Vascular clamps, vascular clips, vascular sutures and haemostyptics (Gelfoam, Flowseal, etc.) must be kept ready to hand in the operating theatre. The author recommends keeping 2 separate stick swabs on hand throughout the procedure for compression in case of vascular injury.

Various implant systems are available for the OLIF technique. These include cages, vertebral body replacement systems and locking plates that can be implanted from the lateral, oblique anterolateral or anterior side.

22.4 Pre-Intervention Education

In addition to the typical risks of anterior retroperitoneal access (injury to the peritoneum and viscera, the ureter and the prevertebral vessels with potentially high blood loss), the procedure-specific information includes the possibility of a lesion of the ilioinguinal nerve and the superior hypogastric plexus with the typical sequelae, especially in male patients. The risk of compartment syndrome should also be discussed. Further obligatory educational content includes the risks of injury to the cauda sac and exiting nerve roots, the possibility of misplacement of implants, the development of pseudarthrosis, local infection and retroperitoneal haematoma, furthermore abdominal wall hernia.

22.5 Implementation of the Intervention

The intervention is performed under general anesthesia and—in the hands of the author—does not require any specific preparatory measures (bowel evacuation, etc.). As with all spinal surgery, consistent thrombosis prophylaxis with medication is recommended.

As a rule, the approach is from the left side. However, extensive clinical studies have shown that access from the right side is also possible and safe, particularly with regard to potential vascular complications. The patient is placed in a stable 90° lateral position, with the arms extended on padded splints (Fig. 22.1). For time-efficient and most stable positioning of the patient, it is also recommended to use a lateral positioning pad for the trunk, a tunnel pad for the legs (to relieve pressure on the lower leg) and table-fixed (mutually mounted) positioning pads to support the pelvis and thorax (Fig. 22.1). The trunk can be additionally secured with Fixomull if necessary. Belt fixation in the area of the pelvis should be avoided, as this may interfere with access to the L5/S1 segment. In contrast to the lateral access variants (XLIF/LLIF/DLIF), unfolding the table is not necessary, but may facilitate precise alignment of the lumbar spine in slender patients. As part of the radiographic confirmation of accurate 90° lateral positioning, the location and orientation of the target disc spaces are marked on the skin under lateral fluoroscopy. Based on the ventral extension of this mark(s), the position and required length of the skin incision is determined. For simplified orientation, the course of the iliac crest or lower costal arch is marked. The lower lumbar segments (L3-S1) can be accessed via a single skin incision 5–6 cm ventral to the iliac crest (Fig. 22.2). The upper lumbar segments are accessed via a skin incision below the costal arch (Fig. 22.2). The length of the skin incision for monosegmental instrumentation is typically 4–5 cm (depending on physiognomy), and approximately 6–7 cm for bi- and trisegmental instrumentation. The location and orientation of the potential skin incisions is in a semicircle ventral to the costal arch or anterior iliac crest.

The surgical field is then sterilely covered, including the iliac crest and lower costal arch (Fig. 22.3). Ensuring an ergonomic working position during access preparation requires a significantly elevated table position. First, the strong fascia of the obliqus abdominis externus muscle is opened in the orientation of the skin incision. Subsequently, the oblique abdominal muscles are bluntly split in layers in the direction of the fibers until the

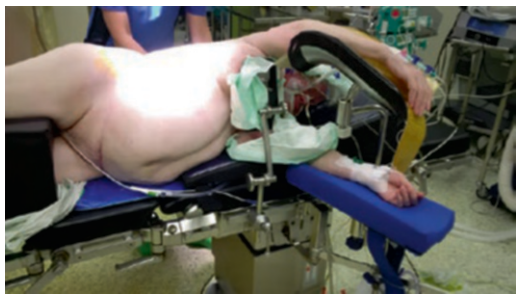


Fig. 22.1 Typical positioning of the patient for an OLIF approach in the 90° lateral half position. In contrast to the lateral access procedures (XLIF/LLIF), the table does not have to be unfolded laterally. Access can be performed from either the left or right side, taking into account the specific vascular anatomy. The thorax is supported on a special pad that relieves the dependent shoulder. The arms are supported on outriggers, the upper leg on a tunnel cushion. The trunk is secured with positioning pads. The corridor to the target segment must not be restricted by positioning pads (e.g. in the symphysis area)

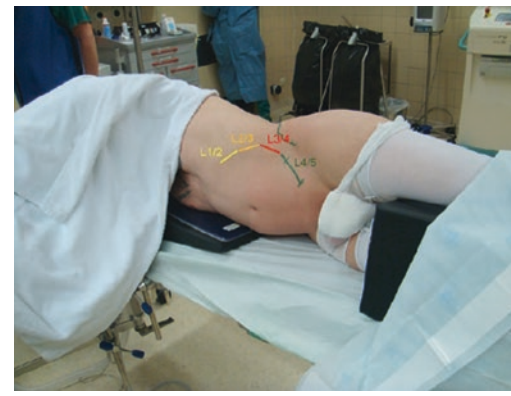


Fig. 22.2 Typical 90° lateral positioning and locations of skin incisions for access to each segment of the lumbar spine. Those of the caudal segments (L3/4-L5/1) can usually be accessed via a single incision

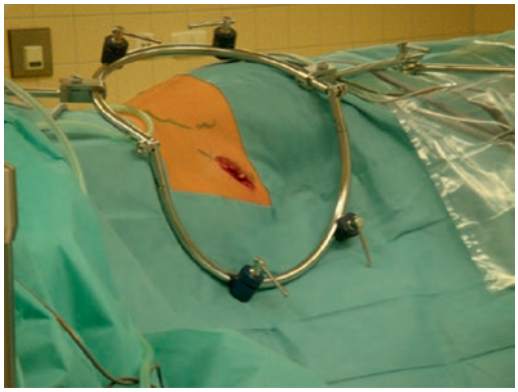


Fig. 22.3 Positioning a frame retractor system over the surgical field. The use of an articulated joint is recommended so that the low-profile frame can be positioned around the patient's torso. This not only simplifies access, but also allows undisturbed intraoperative fluoroscopic control in 2 planes

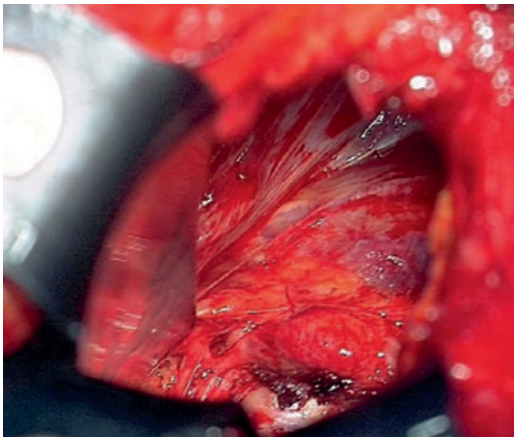


Fig. 22.4 Operative situs in the subphrenic left OLIF approach to the upper lumbar spine or thoracolumbar junction. After detaching the peritoneal sac from the lower surface of the diaphragm, the quadratus lumborum muscle and the psoas muscle are clearly visible. The intervertebral disc space L1/2 is visible at the lower edge of the picture

relatively thin (often not reliably delineated) transversus fascia is reached. After opening this fascia, one encounters the preperitoneal fatty tissue (caution: with the subcostal approach to the proximal segments of the lumbar spine, one encounters the peritoneum directly!) The peritoneal sac is now bluntly detached from the lateral abdominal wall and spontaneously descends caudally by gravity retraction. After reaching the retroperitoneal space, the psoas muscle is reached directly between L3 and S1, and the quadratus lumborum muscle, which is located further dorsally, is reached rostrally from L3 (the peritoneal sac must subsequently be mobilized retrogradely here – i.e., in a ventral direction – over the psoas muscle; Fig. 22.4). The genitofemoral nerve running on the psoas muscle can be easily identified and spared (Fig. 22.5). The surgical access is gradually widened by repositioning the valves of the retractor system with visualization of the common iliac sinus running directly medial to the psoas muscle (when approaching from the left) and the ureter running medial to the artery in the paraperitoneal fatty tissue (and usually adherent to the peritoneal sac) (Fig. 22.5). When approaching from the right, the common iliac vein is first encountered medial to the psoas muscle, and only medial to it is the common iliac artery encountered. The peritoneal sac and ureter are retracted together further mediocaudally, and the iliac vessels are followed rostrally to the bifurcation. To protect the superior hypogastric plexus, which runs in the prevertebral adipose tissue (usually clearly visible), the dissection is performed bluntly with a swab. The intervertebral disc compartments L4/5

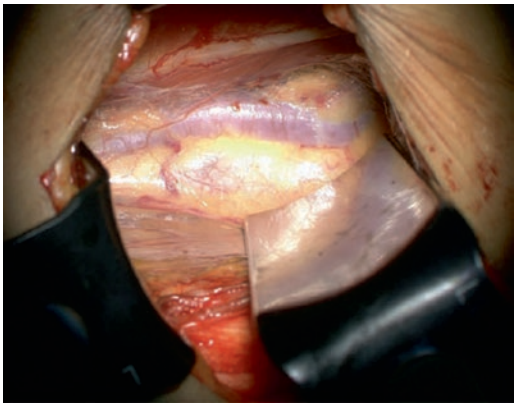


Fig. 22.5 Operative site of the left OLIF approach to the lower lumbar spine. In the upper part of the picture the M. psoas is visible, directly medial (caudal) of it the A. iliaca communis sinistra in the retroperitoneal fat tissue. Below the caudal retractor blade the ureter adherent to the peritoneal sac is visible as a bright, horizontally oriented structure

and L5/S1 as well as the promontory can now be palpated with a swab so that a height orientation is quickly possible. The reliable identification of intervertebral spaces located further rostrally requires a lateral X-ray check at this point.

The **access to the disc space L5/S1 is** made between the iliac vessels below the bifurcation. The iliac vessels are each retracted laterally (the bifurcation cranially if necessary), and the median sacral vessels (A. and V. sacralis mediana) are coagulated and transected. By adjusting the retractor veins, complete visualization of the anterior annulus is now possible (Fig. 22.6). Alternatively, free retractors can be fixed to the L5 and S1 vertebrae using fixation screws (caution: protect the adjacent vessels using Tabotamp/Gelfoam before screwing the fixation screws in or out!). When accessing the L5/S1 segment in isolation, a right-sided approach is generally preferable, as the risk of damage to the superior hypogtricus plexus is lower when mobilizing the plexus from the right (Edgard-Rosa et al. 2012).

Access to the L4/5 disc space is lateral to the iliac vessels (between the psoas muscle and the vascular fork or iliac vessels), which are retracted caudally (medially). If exposure of the entire ventral annulus (analogous to L5/S1) is desired, venous release (ligation/coagulation and transection of the iliolumbar vein) must be performed prior to mobilization of the iliac vein. The corresponding anatomical variants of the iliolumbal vein must be taken into account. Adequate release of the iliac vein leads to free retractability of the vein medially (without resistance). Resistance during retraction indicates an inadequate venous release (e.g. caused by adherence of the iliac vein to the L4/5 annulus fibrosus or the ventral surface of the L5 vertebra). Further gradual blunt mobilization with a stick swab is then required before medial retraction. Otherwise, the vein can be completely displaced contralaterally with a retractor vein (Fig. 22.7). Safe mobilization of the common iliac vein requires adequate training and experience.

Access to the lumbar intervertebral discs proximal to L4/5 is between the aorta and the psoas muscle, alternatively from the right

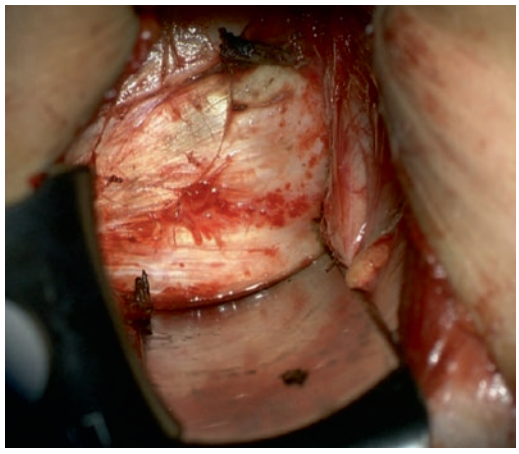


Fig. 22.6 Intraoperative situs after exposure of the disc space L4/5 (left-sided approach). After retraction of the vascular forks (visible under the caudal retractor blade), the ventral annulus can be completely exposed (analogous to the situation with the anterior approach to the cervical spine)

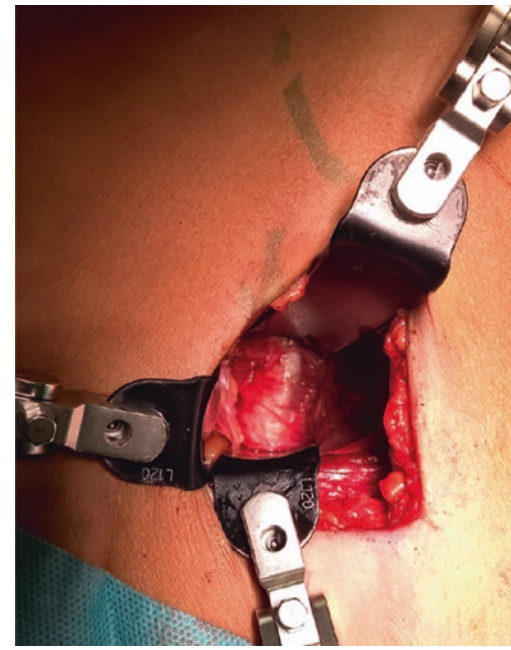


Fig. 22.7 Intraoperative situs after exposure of the disc space L4/5 (left approach). The marking of the iliac crest can be seen in the upper section of the picture. The skin incision lies approx. 4–5 cm medial to the iliac crest. To keep the operative corridor free, 3 retractor veins are usually sufficient. The disc space is oriented vertically. Precise 90° positioning facilitates orientation during interbody instrumentation

between the vena cava and the psoas muscle. For complete mobilization and displacement of the large prevertebral vessels (aorta, v. cava) with subsequent exposure of the entire ventral circumference of the intervertebral disc compartments, ligation/coagulation and transection of the segmental vessels above and below the target disc is required in each case. In the case of interventions in the area of the thoracolumbar transition via a subphrenic approach, the attachments of the diaphragm at BWK12 or LWK1 and LWK2 can be detached if necessary as part of the visualization of the intervertebral discs (Fig. 22.8).

Furthermore, the procedure is virtually identical to the procedure for anterior cervical discectomy and fusion. Discectomy and evacuation of the intervertebral space (if necessary, removal of a (para)median disc herniation with the aid of the surgical microscope or magnifying glasses) are performed with long anterior instruments (Cobb rasparators, grasping forceps, etc.). Also analogous to the procedure on the cervical spine, a corpectomy is performed with the aid of chisels, grasping forceps, punches, etc. Resection of the ventral (and, if necessary, the dorsal) annulus fibrosus and longitudinal ligament enables thorough correction of both advanced spondylolistheses and rotational olistheses (in the context of adult scolioses) and kyphoscoliotic deformities through complete segment mobilization. Depending on the indication, reconstruction and stabilization is performed purely ventrally (with cage and plate; Fig. 22.9a, b) or ventrodorsally in the sense of a 360-degree procedure (Fig. 22.10). The accessibility of the iliac crest via the skin incision (to the lower lumbar segments) allows the use of autologous cancellous bone in the context of interbody fusion.

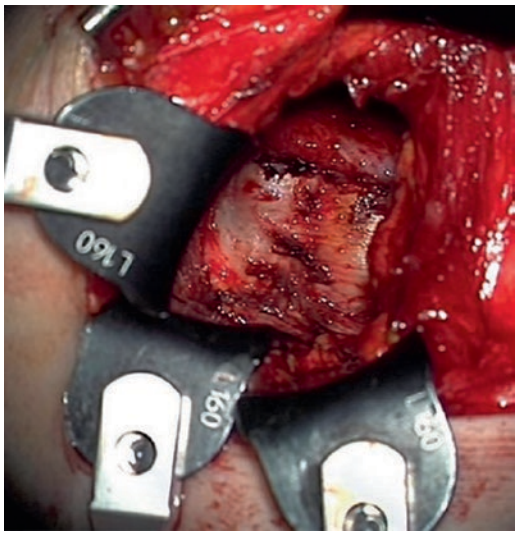


Fig. 22.8 Intraoperative situs after exposure of the disc compartments Th12/L1 and L1/2 (left approach). After alignment of the retractor veins, the approach is oriented perpendicular (0°) to the spine

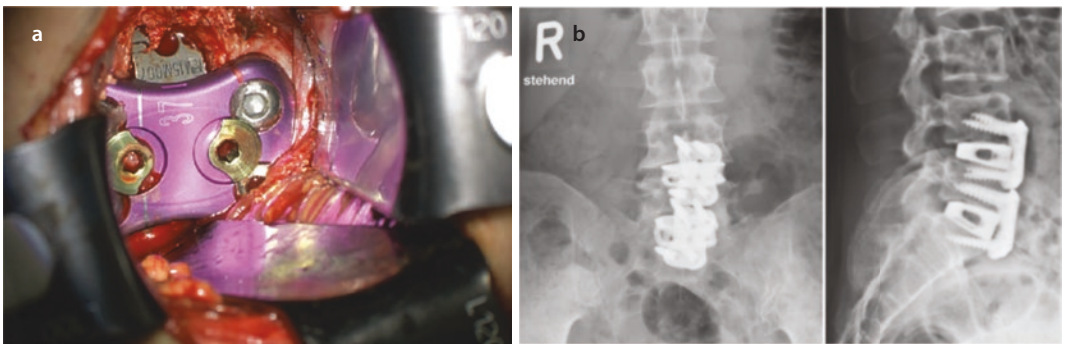


Fig. 22.9 **a** Intraoperative situs after cage implantation and ventral plate osteosynthesis in segment L4/5 (left approach). **b** Postoperative radiographs of the lumbar spine after bisegmental OLIF L4/5 and L5/S1. Instrumentation with titanium cages and ventral plate osteosynthesis

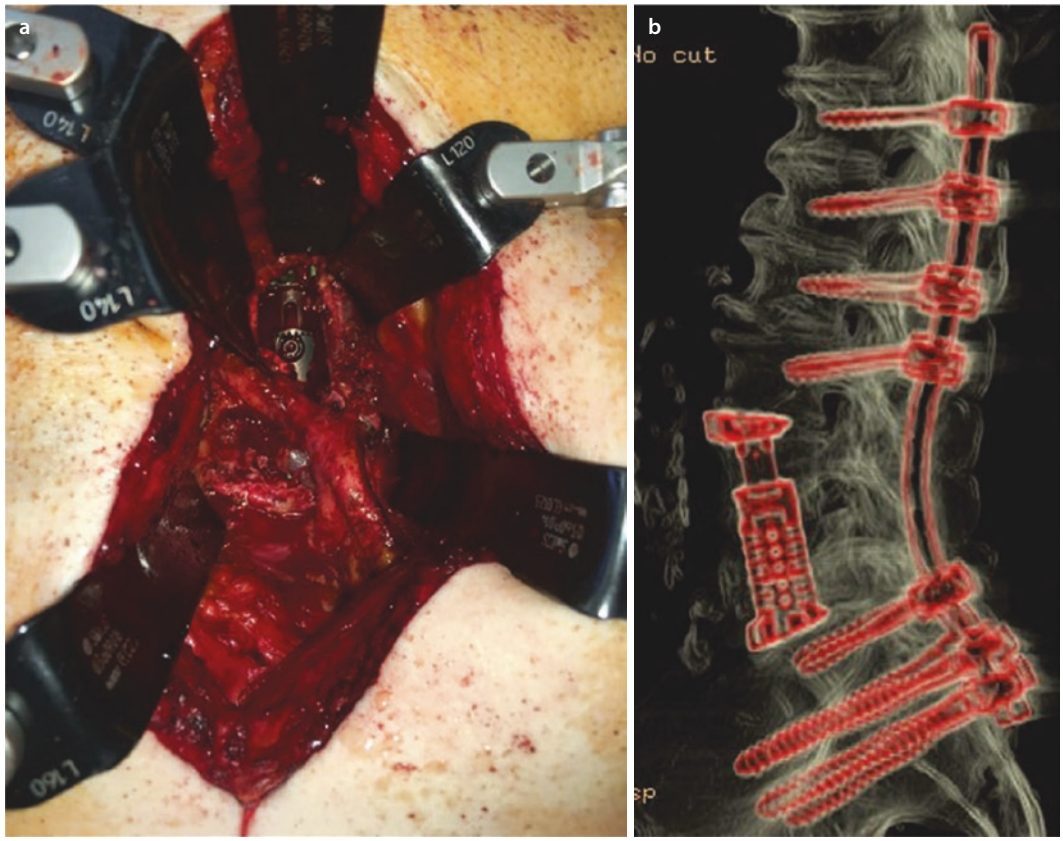


Fig. 22.10 Extended OLIF approach for L4 and L5 vertebral body replacement. **a** Intraoperative site after exposure and mobilization of the arterial and venous vascular forks and implantation of a distraction cage between L3 and Os sacrum. **b** Reconstruction of the associated postoperative CT showing the location of the distraction cage and posterior fixator

22.6 Possible Complications

Complications typical of surgery include (ranked by frequency):

- Sympathicolysis (<10%),
- Vascular Injuries (<10%),
- Damage to the superior hypogastric plexus (<5%),
- Femoralgia, hip flexor weakness (<1%),
- Plexus/root injuries (<1%),
- Injury to the ureter and visceral organs (<1%).

(Bateman et al. 2015; Li et al. 2017; Mehren et al. 2016; Mayer and Wiechert 2002; Mobbs et al. 2016; Rothenfluh et al. 2014; Scheufler 2007; Silvestre et al. 2012; Quraishi et al. 2013).

22.7 Results in the Literature

Reports on clinical outcomes and complications of the OLIF technique include application experience over more than two decades (Mayer 1997; Mayer and Wiechert 2002; Mehren et al. 2016) and demonstrate the safety of the procedure compared with various alternative procedures (Mehren et al. 2016; Mobbs et al. 2015; Than et al. 2011). The OLIF approach has been successfully used in fusion procedures, for arthroplasty lumbar disc replacement, in deformity surgery, revision and other complex procedures. Compared with lateral lumbar access options (XLIF/LLIF/DLIF), there is a more favorable complication profile with no need for neuromonitoring (Abe et al. 2017; Jin et al. 2018; Kim et al. 2016). Compared with posterior fusion

procedures, the lack of requirement to open the spinal canal and the possibilities of extensive segmental repositioning are offset by the need for additional direct spinal decompression for concentric stenoses and additive posterior pedicle fixation for higher-grade (especially sagittal) instabilities (Mobbs et al. 2015; Zairi et al. 2017).

22.8 Reimbursement of Costs

Payment is made according to the number of segments supplied, analogous to the ALIF or XLIF/LLIF/DLIF. Costs for intraoperative monitoring do not apply.

22.9 Conclusion and Clinical Relevance

The advantages of the OLIF technique lie not only in the range of indications but also in the possibilities for extensive correction or reduction as well as in high fusion and low complication rates. In addition to the necessary infrastructural requirements and instrumentation, the prerequisites for safe use include adequate knowledge of the anterior access anatomy and specific training in vessel preparation.

References

Abe K, Orita S, Mannoji C et al (2017) Perioperative complications in 155 patients who underwent oblique lateral interbody fusion surgery: perspectives and indications from a retrospective, multicenter survey. Spine 42:55–62

Bateman DK, Millhouse PW, Shahi N, Kadam AB, Maltenfort MG, Koerner JD, Vaccaro AR (2015) Anterior lumbar spine surgery: a systematic review and meta-analysis of associated complications. Spine J 15:1118–1132

Jin J, Ryu KS, Hur JW, Seong JH, Kim JS, Cho HJ (2018) Comparative study of the difference of perioperative complication and radiologic results: MIS-DLIF (minimally invasive direct lateral lumbar interbody fusion) versus MIS-OLIF (minimally invasive oblique lateral lumbar interbody fusion). Clin Spine Surg 31(1):31–36

Kim JS, Choi WS, Sung JH (2016) Minimally invasive oblique lateral interbody fusion for L4-5: clinical outcomes and perioperative complications. Neurosurgery 63:190–191

Li JX, Phan K, Mobbs R (2017) Oblique lumbar interbody fusion: technical aspects, operative outcomes, and complications. World Neurosurg 98:113–123

Mayer HM (1997) A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine 22:691–699

Mayer HM, Wiechert K (2002) Microsurgical anterior approaches to the lumbar spine for interbody fusion and total disc replacement. Neurosurgery 51:159–165

Mehren C, Mayer HM, Zandanell C, Siepe CJ, Korge A (2016) The oblique anterolateral approach to the lumbar spine provides access to the lumbar spine with few early complications. Clin Orthop Relat Res 474:2020–2027

Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ (2015) Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 1:2–18

Mobbs RJ, Phan K, Daly D, Rao PJ, Lennox A (2016) Approach-related complications of anterior lumbar interbody fusion: results of a combined spine and vascular surgical team. Global Spine J 6:147–154

Molloy S, Butler JS, Benton A, Malhotra K, Selvadurai S, Agu O (2016) A new extensile anterolateral retroperitoneal approach for lumbar interbody fusion from L1 to S1: a prospective series with clinical outcomes. Spine J 16:786–791

Quraishi NA, Konig M, Booker SJ, Shafafy M, Boszczyk BM, Grevitt MP, Mehdian H, Webb JK (2013) Access related complications in anterior lumbar surgery performed by spinal surgeons. Eur Spine J 22:16–20

Rothenfluh DA, Koenig M, Stokes OM, Behrbalk E, Boszczyk BM (2014) Access-related complications in anterior lumbar surgery in patients over 60 years of age. Eur Spine J 23:86–92

Scheufler KM (2007) Technique and clinical results of minimally invasive reconstruction and stabilization of the thoracic and thoracolumbar spine with expandable cages and ventrolateral plate fixation. Neurosurgery 61:798–808

Silvestre C, Mac-Thiong JM, Hilmi R, Roussouly P (2012) Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 6:89–97

Than KD, Wang AC, Rahman SU, Wilson TJ, Valdivia JM, Park P, La Marca F (2011) Complication avoidance and management in anterior lumbar interbody fusion. Neurosurg Focus 31:E6

Woods KR, Billys JB, Hynes RA (2017) Technical description of oblique lateral interbody fusion at L1-L5 (OLIF25) and at L5-S1 (OLIF51) and evaluation of complication and fusion rates. Spine J 17:545–553

Zairi F, Sunna TP, Westwick HJ, Weil AG, Wang Z, Boubez G, Shedid D (2017) Mini-open oblique lumbar interbody fusion (OLIF) approach for multi-level discectomy and fusion involving L5-S1: preliminary experience. Orthop Traumatol Surg Res 103:295–299

Lumbar Epiduroscopy

B. C. Schultheis, G. Schütze, and P. A. Weidle

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_23

23.1 Introduction

Modern pain therapy for chronic spinal pain syndromes can only be effective if the cause of the pain is clearly and unequivocally identified. However, the diagnosis and therapy of chronic spinal pain syndromes is complex and a lasting therapeutic success is difficult to achieve.

For a large number of patients with pain syndromes close to the spinal cord, endoscopic examination (epiduroscopy) is considered a diagnostic hope in pain medicine; it also represents a promising therapeutic perspective. Interventional pain therapy is becoming increasingly important in diagnosis and therapy. The spinal interventional diagnostic and therapeutic procedures presented in this chapter represent a valuable opportunity for improved treatment of patients with chronic pain syndromes if patient selection and indications are accurate.

In this chapter, the percutaneous, flexible endoscopic examination technique (spinal endoscopy, epiduroscopy, EDS) is presented exclusively in the area of the lumbar spine of the pain patient. Spinal endoscopy (epiduroscopy, spinaloscopy) is not a last resort for selected pain patients, but an important component of the diagnosis and therapy of chronic spinal pain syndromes. We see EDS as an integral part of an interdisciplinary, multimodal, pain therapy treatment concept.

23.1.1 Definition

Epiduroscopy (EDS) is a percutaneous minimally invasive endoscopic examination of the epidural space that allows spatial and color images of anatomical structures close to the spinal cord, such as the dura mater spinalis, blood vessels, connective tissue, nerves, and fatty tissue. Pathological structures and changes such as adhesions, sequestra, inflammatory processes, fibrosis and stenosing processes can also be described endoscopically (Schütze 2008, 2011; Kim et al. 2017).

According to an international expert recommendation in Iserlohn (Germany) on September 17, 1998, the expert conference in Bad Dürkheim (Germany) on October 3, 1998, a consensus conference in Innsbruck (Austria) in 2001 and in Graz (Austria) in March 2006, the following definition of epiduroscopy was adopted in 2002:

» Epiduroscopy is a percutaneous minimally invasive endoscopic examination of the epidural space that can also be used to perform therapeutic interventions.

The consensus committee (D. Beltrutti [Italy], G. J. Groen [Netherlands], L. Sabersky [USA], A. Sander-Kiesling [Austria], G. Schütze [Germany], G. Weber [Austria]) of the consensus conference held in Graz, Austria, on March 3–4, 2006, organized by the World Initiative on Spinal Endoscopy (WISE), agreed on the following definitions:

» Epiduroscopy (EDS) or spinal (canal) endoscopy is defined as a percutaneous, minimally invasive, endoscopic examination of the epidural space using a flexible endoscope inserted through the sacral hiatus.

This allows for the following:

- Visualization of normal anatomical structures, e.g. dura mater, blood vessels, connective tissue, nerves and fatty tissue.
- Visualization of pathological structures, e.g. adhesions, sequestra, inflammatory processes, fibrosis, stenotic changes.
- Targeted treatment with e.g. epidural steroids, epidural catheter placement, electrode implantation for spinal cord stimulation (SCS), cytokine therapy.
- In addition to epiduroscopy, other analyses are possible, e.g. biopsy, aspiration, light refractive index.

Epiduroscopy (EDS) is an important component of invasive-interventional pain therapy. When the indication is precise and the risks and side effects are taken into account, EDS is an important diagnostic procedure and a supportive diagnostic and therapeutic option in a multimodal, interdisciplinary pain therapy concept.

23.2 Indications

Everyday algesiological work also includes dealing with unexplained pain symptoms. The classification and treatment of chronic pain syndromes close to the spinal cord can be extremely complicated if conventional diagnostics do not offer a sufficient explanation for the cause of the pain. Epiduroscopy is available for the diagnosis and treatment of spinal cord-related pain syndromes. It is useful to divide the indications for epiduroscopy into diagnostic and therapeutic.

23.2.1 Diagnostic Indications

The diagnosis of pain syndromes close to the spinal cord is the main indication for epiduroscopy. The spectrum of diagnostic indications is supplemented by the differentiation of pathological-anatomical conditions, e.g. epidural fibrosis after invasive procedures and radiculopathies, tissue sampling (biopsy), preparation of swabs, sampling of irrigation fluids, and the epidural pain provocation test (EPPT) (Kim et al. 2017).

In the case of unclear, contradictory clinical and/or radiological findings, the question of whether epiduroscopy should be considered does not arise. In patients with pain syndromes close to the spinal cord, a comprehensive epidurographic and endoscopic diagnosis should be carried out in order to prevent chronic pain.

23.2.2 Therapeutic Indications

Therapeutic indications for epiduroscopy include procedures such as targeted topical pharmacotherapy, resolution of scar fields, placement of catheters and implantation of stimulating electrodes (radiofrequency therapy, spinal cord stimulation) under direct vision, in cases of epidural problematic passage or when placement is not possible or too risky for the patient in radiological procedures.

In 2006, the consensus committee of the World Initiative on Spinal Endoscopy (WISE) made the following recommendations on diagnostic and treatment strategies:

23.2.3 Indications According to WISE

1. Improving diagnostics:
   - Diagnosis of clinically relevant epidural pathology when pain is attributed to the epidural space (spinal canal): based on history, clinical examination and supporting laboratory tests.
   - Biopsy for histopathological and/or histochemical examination.
   - Provocation test (physical or chemical e.g. laser, electrical, mechanical).
2. Treatment Strategies:
   - Rinse.
   - Direct application of pharmacotherapeutic agents.
   - Direct lysis of adhesions/scars by physical or chemical means (e.g. mechanical, pharmacological, laser, radiofrequency).
3. As a supporting tool:
   - Placement of catheter systems (epidural, spinal).
   - Implantation of stimulation electrodes (Spinal Cord Stimulation, SCS).
   - Supplement for minimally invasive operations.
   - Foreign body removal.
   - Potentially suitable for postoperative evaluation.

Epiduroscopy has become an essential part of the diagnosis and treatment of pain syndromes close to the spinal cord and we are convinced that it should be used primarily in the sense of "first line" (Fig. 23.1).

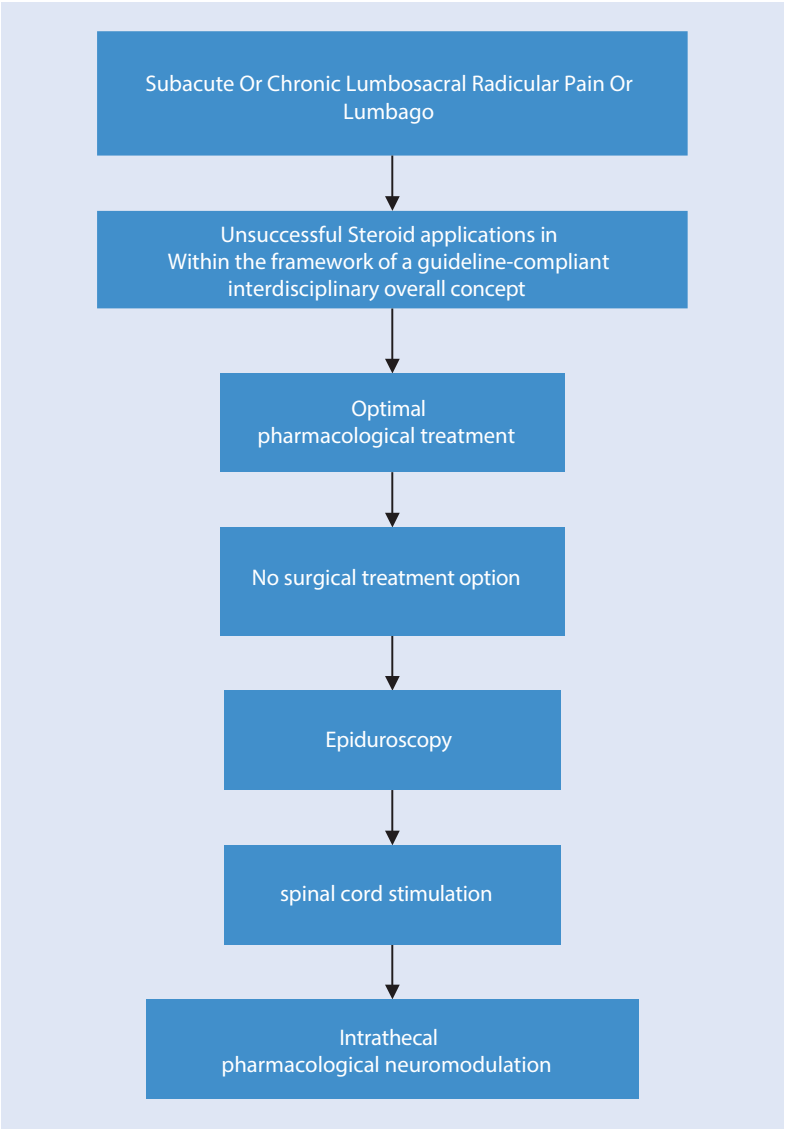


Fig. 23.1 Treatment tree for the use of epiduroscopy in our department

23.2.4 Contraindications

For epiduroscopy, the contraindications are the same as for regional anaesthesia procedures close to the spinal cord, of course, taking into account the patient's anatomical conditions.

Contraindications for Epiduroscopy
- Hemorrhagic diathesis
- Anticoagulant therapy
- Infections in the area of the puncture site
- Special neurological diseases
- Patients at high cardiovascular risk
- Rejection of the EDS by the patient

In addition, the recommendations of the German Society for Anaesthesiology and Intensive Care Medicine on "Spinal anaesthesia and thromboembolism prophylaxis/anticoagulation" and "On the required time interval between anticoagulant administration and peridural/spinal puncture or removal of a peridural catheter" should be referred to.

The consensus committee of the World Initiative on Spinal Endoscopy (WISE) recommended the following contraindications already in 2006.

- Absolute contraindications:

  Psychiatric disorders that may potentially interfere with the patient's medically necessary consent and/or affect the perception of pain, retinal disorders, increased risk for or presence of elevated intracranial pressure, pregnancy, manifest bowel and bladder dysfunction and sensory disturbances in the S2–S4 range, congenital or acquired anomalies that do not allow safe endoscopy, cerebrovascular disease, renal or hepatic insufficiency, inflammatory or dystrophic skin lesions in the region of the sacral canal (anal fistula, fistula sacral osteomyelitis, etc.), meningeal cyst, meningocele, meningomyelocele, severe respiratory insufficiencies (COPD), known allergies to drugs required for the procedure, unstable angina pectoris, malignant tumor.
- Relative contraindications:

  Coagulopathies, psychiatric illnesses that may interfere with the patient's ability to give necessary consent and/or affect the perception of pain, inability to lie prone for more than 60 min, severe respiratory insufficiencies (COPD), medication abuse or alcohol abuse, etc.

23.3 History of Epiduroscopy

By B. I. Hirschowitz developed the first flexible endoscope in 1958 (Hirschowitz et al. 1958). These were great moments in medicine, which pioneered diagnostics and therapy, and which resulted from intuition and careful observation by dedicated researchers, but also from coincidences, from fulminant errors as well as from misjudgements and misinformation. Endoscopic examination of the epidural space is still a relatively young technique in terms of its clinical application.

However, experiments to visualize the spinal canal have been performed for over 60 years. Burman (1931) pioneered the use of arthroscopic instruments to inspect dissected cadaveric spines. The first myeloscope for patient use was developed by Stern (1936). Pool reported the first clinical application of myeloscopy in 1938 (Pool 1938). The author examined 400 patients by 1942 and was able to make diagnoses such as neuritis, nucleus prolapse, neoplasms, adhesions, and venous congestion in numerous cases. Despite these encouraging results, the largely unrivaled position of this diagnostic method in the pre-CT era, and its relative technical simplicity, myeloscopy was not further described until the late 1960s. Sabersky attributes this to the introduction and widespread use of myelography and the lack of photographic documentation of findings (Sabersky and Brull 1995).

Since 1967, it was mainly the Japanese Ooi who took up myeloscopy again. Between 1967 and 1977, he examined a total of 208 patients with a set of instruments that combined a flexible light source with rigid optics (Ooi 1981). In the following years, Blomberg (1985); Holström et al. (1995) and Möllmann et al. (1992) examined the spatium epidurale of human cadavers and patients.

A prerequisite for the application of spinal endoscopy in the clinic was the development of small-caliber flexible optics and light sources. In 1991, Heavner et al. reported on endoscopic examinations of the epidural and spinal space of rabbits, dogs and human cadavers using a flexible endoscope (Heavner et al. 1991).

The technique of epiduroscopy with flexible optics has also been used clinically in patients since the early 1990s. Schütze and Kurtze published results of video-optical examinations of the epidural space for the first time in pain patients with a "flexible catheter-secured epiduroscopic unit" (Schütze and Kurtze 1985).

Leu reports in 1993 on peridural and intraductal endoscopies in patients with sacral access (Leu 1993). In 1996, the Food and Drug Administation (FDA) approves epiduroscopy for the diagnosis of the epidural space.

In 1997, Schütze was able to report for the first time on epiduroscopically assisted SCS electrode implantations for neuromodulation. Clinical applications with epiduroscopically

assisted laser therapy for postnucleotomy syndromes are described by Rütten's working group.

In 1997, the authors Michel and Metzger state: Advantages of epiduroscopy are that EDS can be used to assess epidural pathology (Schütze 2008). In a 1999 paper, Winston C. V. Parris concludes that epiduroscopy is a technique that may prevail in the new millennium (Parris 1999). The role of epiduroscopy in chronic back pain is defined, wrote Ovassapian 2000.

In 2000, Schütze reported on the methodology and a retrospective study of 165 epiduroscopies and in 2001 one epiduroscopic-sonographic examinations (Schütze 2000). Igarashi et al. describe epiduroscopic examinations in 52 pregnant women (Igarashi et al. 2000). Graziotti performed close to 300 epiduroscopic interventions (Graziotti 2007).

The introduction of a flexible epiduroscope with FLEX-X2 technology in 2005 makes it possible for the first time to be diagnostically and therapeutically effective in the entire spatium epidurale from sacral to cervical.

In 2005, Rafaeli and Rhigetti described the use of a special radiofrequency probe in conjunction with disposable epiduroscopes to cut through scarring and adhesions in the lumbar epidural space (Raffaelli and Righetti 2005).

As early as 2006, Pabst Verlag published the first book on epiduroscopy *Epiduroskopie—Ein praxisorientierter Leitfaden zur epiduroskopischen Diagnostik und Therapie rückenmarksnaher Schmerzsyndromes* together with a DVD (Schütze 2006).

23.4 Anatomical Notes

In endoscopy of spaces close to the spinal cord, the spatium epidurale is of primary interest and forms the focus of endoscopic examination in pain patients (Fig. 23.2).

The spatium epidurale extends from the foramen magnum of the skull base to segments S2-S3 in the hiatus sacralis. The sacral hiatus is the primary access route for spinal endoscopy and is located at approximately the level of neuroforamen S5, although it may extend to the level of S4. The sacral hiatus is closed by the sacrococcygeal ligament.

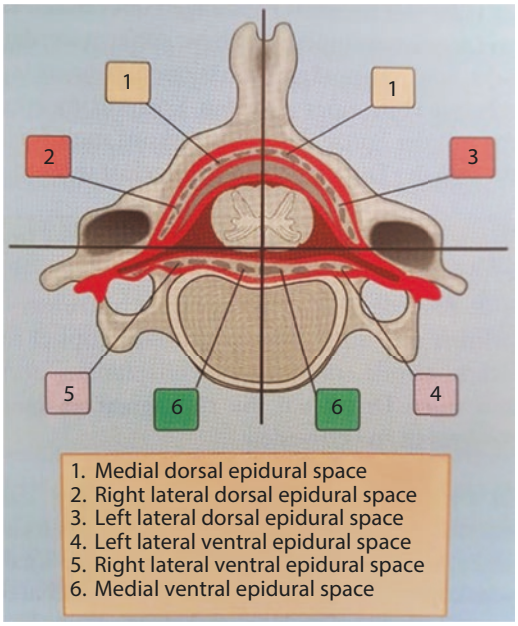


Fig. 23.2 Schematic representation of the topography of the spatium epidurale. (From Schütze 2011; with kind permission)

The spinal canal has a characteristic shape depending on the flexibility of the spinal column. In areas of high mobility, the spinal canal is triangular. Ventrally, the spinal canal is bounded by the vertebral bodies, intervertebral discs and the ligamentum longitudinale posterior. The dorsal boundary is formed by the ligamentum flavum and the vertebral arches, and laterally by the pedicles and laminae.

The spinal canal, canalis spinalis, contains the medulla spinalis, which is surrounded by the cerebrospinal fluid in the dura mater spinalis. Normal epiduroscopic findings of the epidural space are shown in Fig. 23.3.

Three spaces are distinguished in the spinal canal:

- Spatium epidurale,
- Subarachnoid space and
- Subdural space.

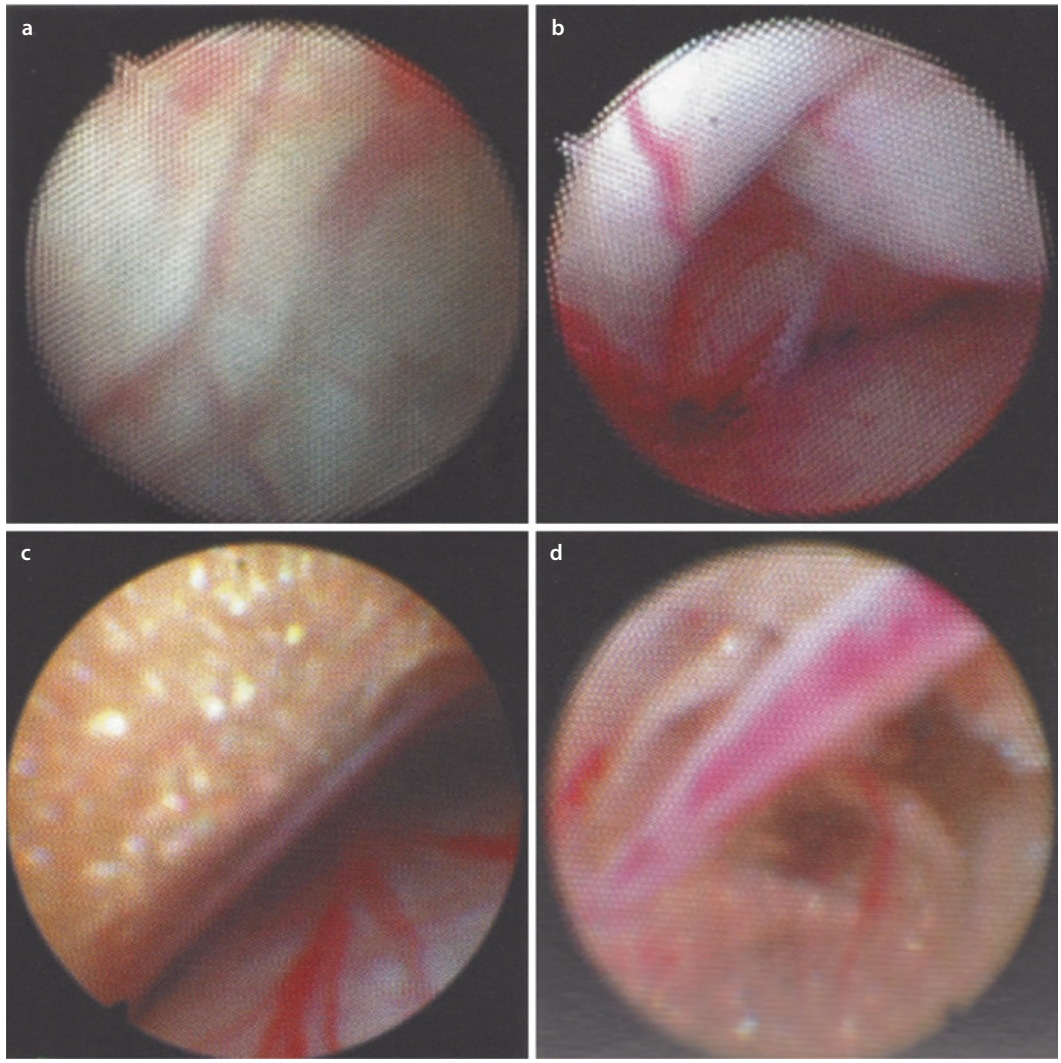


Fig. 23.3 **a-d** Epiduroscopic normal findings of the epidural space. **a** Dura mater spinalis; **b** radix dorsalis; **c** epidural fat; **d** epidural blood vessels. (From Schütze 2011; with kind permission)

23.4.1 Spinal Cord Spaces

1. Spatium epidurale: The spatium epidurale can be divided into four compartments (ventral and dorsal compartments and two lateral compartments). The lateral compartment contains the nerve roots.
2. Subarachnoid space: The arachnoid lies adjacent to the dura mater on the inside and is separated from it by a generally closed, partly capillary area, the subarachnoid space, which is only widened by fluid or air accumulation and becomes recognizable as the subdural space. The subarachnoid space contains the spinal cord and the outgoing nerve roots, which are covered by the pia mater, and the cerebrospinal fluid.
3. Subdural space: The subdural space is formed by the spinal dura mater and arachnoid, which lies directly inside the dura. It is not a space in the true sense of the word, but is only formed by the action of external force with a rupture of the neuroendothelium that connects the two meninges (Shah and Heavner 2003).

23.5 Pathophysiology, Pathological Findings and Algesiological Relevance

23.5.1 Pathophysiological Observations

Spinal pain syndromes are a very heterogeneous group of diseases that can be assigned to systemic, rheumatic and neuroinflammatory causes, which may influence epidural structures and functions in the spatium epidurale. Thus, they cannot always be assigned to a single pathological category, as has been shown by this work, among others.

Following surgical procedures or chronic inflammatory irritation near the spinal canal, there is increased release of tumor necrosis factor α (TNF-α) and specifically interleukin-1 and -6 (IL-1 and IL-6). These lead to an increase in plasminogen activator inhibitors. These enzymes ultimately lead to inhibition of fibrin degradation, resulting in increased deposition of fibrin in connective tissue, allowing adhesions and fibrosis to develop (Smith 2003; diZerga 1997; Thompson et al. 1995).

At this time, most adhesions and epidural fibrosis are composed of macrophages, fibroblasts, mast cells, and phagocytes. Over time, the proportion of fibrocytes decreases and the adhesions are converted from collagen fibers to vascular cords (Leonhardt 1971; Liakakos et al. 2001). Activation of the immunological system occurs through the release of interleukin 8, TNF-α, IL-6, tumor growth factor β (TGF-β) and platelet-derived growth factor (PDGF). Further, there is activation of the extrinsic coagulation system, triggering the formation of fibrin. When two damaged epidural surfaces that are wetted with fibrin come into contact, they can stick together and form adhesions.

> A mismatch between fibrin generation and degradation ultimately leads to fibrosis of the epidural space and hardening of the fibrin (Kim et al. 2017).

The possibility of achieving pain reduction by fluid administration into the epidural space suggests more of a neurochemical cause, which can be triggered by mechanical stress on various structures (Sabersky and Kitahata 1995; Olmarker and Myers 1998; Kayama et al. 1996; Cornefjord et al. 1996).

Radicular pain is not always the result of nerve compression (Olmarker et al. 1993; Olmarker and Myers 1998; Rydevik et al. 1984; Devor 1991). Nerve compression results in nerve dysfunction with motor and sensory dysfunction, whereas pain is only triggered by an accompanying inflammatory response. This has been shown in particular by the work of Howe (Howe et al. 1977). Compression of a peripheral nerve resulted only in a short-term formation of action potentials. Whereas compression of an inflamed nerve resulted in a permanent increase in action potentials. However, prolonged nerve compression itself can cause inflammation with immigration of macrophages and inflammatory cytokines (Kobayashi et al. 2005). This compression or fixation of the nerve root in the neuroforamen leads to stretching, decreased intraneural microcirculation, and ischemia (Rydevik et al. 1984). Disruption of axonal blood flow negatively affects neurotransmitter metabolism and triggers impaired nerve function (Kobayashi et al. 2005).

Injuries to the endoneural blood vessels lead to a breakdown of the blood-nerve barrier and the development of intraneural edema, which triggers or further increases pain. The prolonged intraneural edema leads to a vicious circle with infiltration of fibroblasts, increased scarring, which further compromises the perfusion of the nerve.

Local demyelination leads to ectopic excitation, causing dysesthesias and pain attacks (Devor 1991). The nucleus pulposus of the intervertebral disc contains proinflammatory interleukins (Olmarker et al. 1995; Olmarker and Myers 1998; Rydevik et al. 1984, 1990).

Tearing of the annulus fibrosus can lead to the release of large amounts of phospholipase A2 into the epidural space. This may trigger an inflammatory response with release of TNF-α from mononuclear inflammatory cells. This further enhances the inflammatory response (Olmarker et al. 1995, 1996).

There is no single mechanism underlying the development of pain. Different inflammatory and immunological processes can lead to an activation of nociceptors.

23.5.2 Pathological Findings

Adhesions and Fibrosis

Adhesions can be detected endoscopically in a large number of patients with spinal cord pain syndromes. Adhesive structures near the spinal cord are usually whitish in color and are easily visible endoscopically (Figs. 23.4, 23.5, 23.6 and 23.7).

The decisive factor is whether these pathological-anatomical changes close to the spinal cord are relevant to the patient's pain. The leakage of proteoglycans from the annulus fibrosus into the spatium epidurale may induce the development of adhesions and fibrosis.

Persistent pain after spinal surgery is common (Hayek et al. 2009; Schofferman et al. 2003; Slipman et al. 2002). Epidural fibrosis has a variety of causes, the most common being spinal surgical procedures (Yang et al. 2011; Robertson 1996; Gill et al. 1985; Bartynski and Petropoulou 2007; Farrokhi et al. 2011; Pospiech et al. 1995). The probability of scarring after laminectomies

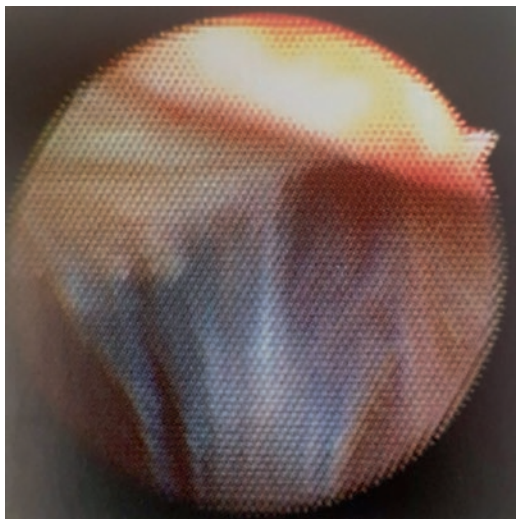


Fig. 23.4 Adhesions. (From Schütze 2011; with kind permission)

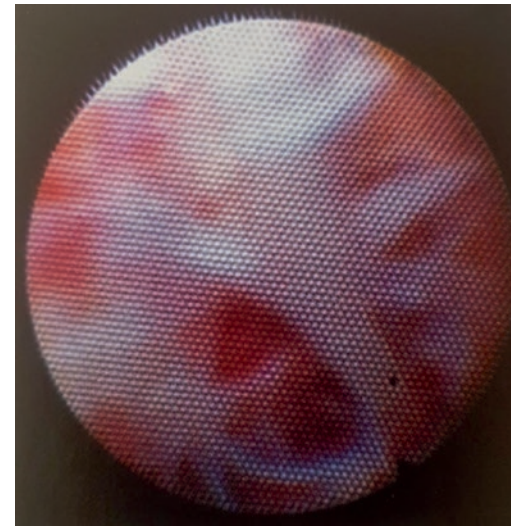


Fig. 23.5 Fibrosis. (From Schütze 2011; with kind permission)

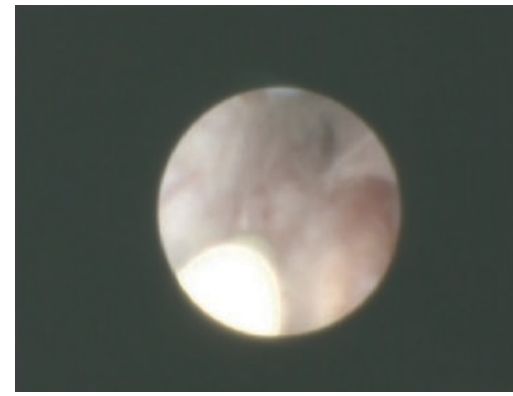


Fig. 23.6 Pronounced scarring at the level of a spondylodesis

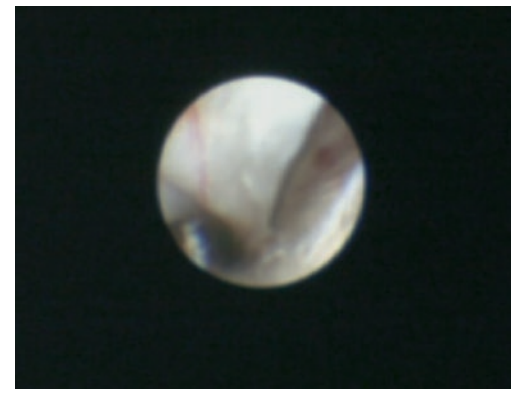


Fig. 23.7 Algesiologically relevant adhesion of the dura. In the lower left of the picture, the Resaflex probe before loosening of the adhesions

without spondylodesis ranges from 5% to 30% (Otani et al. 1997). Bosscher and Heavner (2012a, b) demonstrated high-grade epidural scarring in 83% of all patients with persistent postoperative pain using epiduroscopy. The more extensive the surgery, the more pronounced the scarring was. Only in 16% of the patients examined could scarring be detected in an MRI examination.

Fibrosis probably results from a local inflammatory reaction and concomitant edema in the nervous structures.

Congested Vessels

Epidural examination of patients with failed back surgery syndrome (FBSS) revealed congested and pseudovaricularly altered blood vessels. In an examination of 120 patients, Schütze (2011) detected these changes in the ventral compartment in only 12% of patients (Fig. 23.8).

Radiculitis

Chronic inflammatory processes such as epiduritis and radiculitis appear in the endoscopic image as edematous distended tissue structures. The epidural structures appear – due to hyperemia – strongly reddened. Pain, hyperalgesia and allodynia are only triggered by the neural inflammation (Kizelshteyn et al. 1991).

Arachnoiditis

This is a complex neuropathic pain process (Day 2001). Burton (1978) divides the course of arachnoiditis into 3 stages.

1. Stage: Inflammatory signs of the pia mater with hyperemia and swelling of the cauda fibers and nerve roots.
2. Stage: Fibroblast proliferation with collagen deposition in the tissue.
3. Stage: Pronounced proliferation of the pia mater with dense collagen structure, leading to constrictive overgrowth of the atrophic and ischemic nerve root. The dura mater spinalis appears thickened and the tissue has an increased blood supply (Schütze 2011) (Fig. 23.9).

Epiduroscopy is a complementary diagnostic and therapeutic pain medicine procedure.

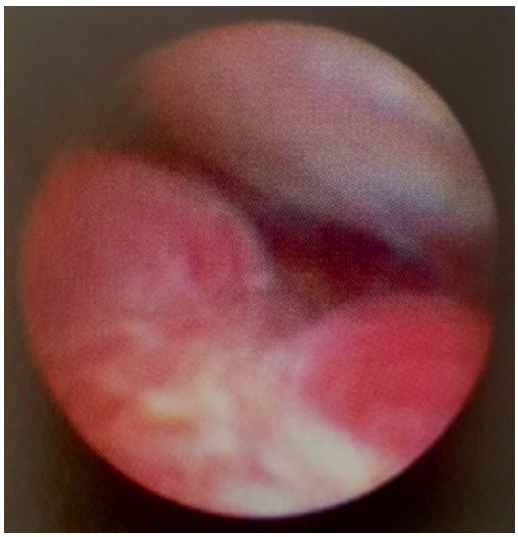


Fig. 23.8 Congested blood vessels. (From Schütze 2011; with kind permission)

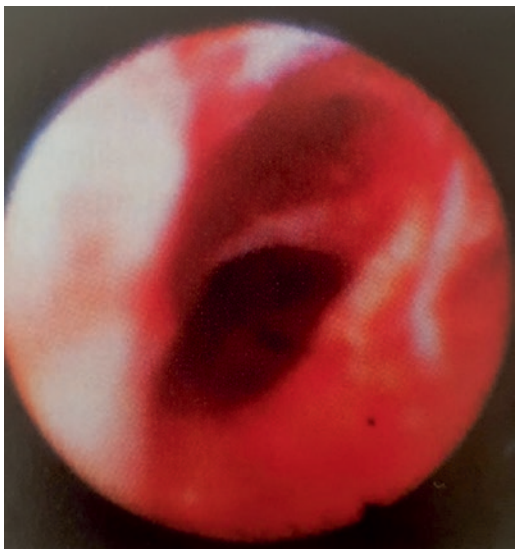


Fig. 23.9 Arachnoiditis. (From Schütze 2011; with kind permission)

23.6 Preinterventional Diagnostics

A thorough history and physical examination are required prior to the decision to perform epiduroscopy. These are supplemented by a radiological and neurological assessment. The imaging diagnostics include a computed tomography or MRI examination of the affected spinal segment in addition to native X-ray images.

23.7 Necessary Instruments

Various instruments for performing spinal endoscopy are available on the medical device market.

The instruments necessary to perform epiduroscopy include the following elements:

- Sterile instruments:
  - Epiduroscope (optics from Baholzer GmbH, Fig. 23.10),
  - Sluice Set,
  - Resascope (Baholzer GmbH), approved for "single use" (Fig. 23.11),
  - MRI reablator: molecular resonance generator (Fig. 23.12),
  - 1 × 3F Fogarty catheter (Fig. 23.13),
  - Resalon,

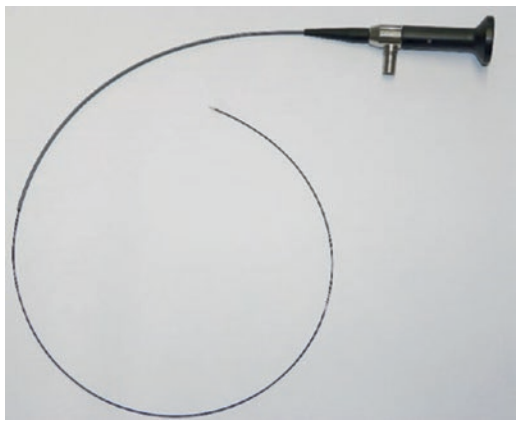


Fig. 23.10 Baholzer optics for use with the resascope. (Courtesy of Baholzer Endoskopie Systeme GmbH & Co. KG)

Fig. 23.11 Resascope with two ports for a working channel and a separate channel for the recyclable fiber optics. (Courtesy of Baholzer Endoskopie Systeme GmbH & Co. KG)

Fig. 23.12 MRI reablator. (Courtesy of the company Baholzer Endoskopie Systeme GmbH & Co. KG)

Fig. 23.13 Resaloon Fogarty catheter. (Courtesy of the company Baholzer Endoskopie Systeme GmbH & Co. KG)

  - Camera and video monitoring system (e.g. Wolf, Storz),
  - Pressure infusion system for rinsing solution NaCl 0.9%,
  - Resaflex probe (Fig. 23.14),
  - Epiduroscopes 7.5 Charr with working and irrigation channel 3.6 Charr and corresponding light guides and sterilization tray (Fig. 23.15),
- Laser Equipment System,
- epidural catheter Vygon,
- X-ray C-arm and radiation protection equipment.

Fig. 23.14 Resaflex dissection probe for use with the MRI reablator. (Courtesy of the company Baholzer Endoskopie Systeme GmbH & Co. KG)

Costs and Order Addresses

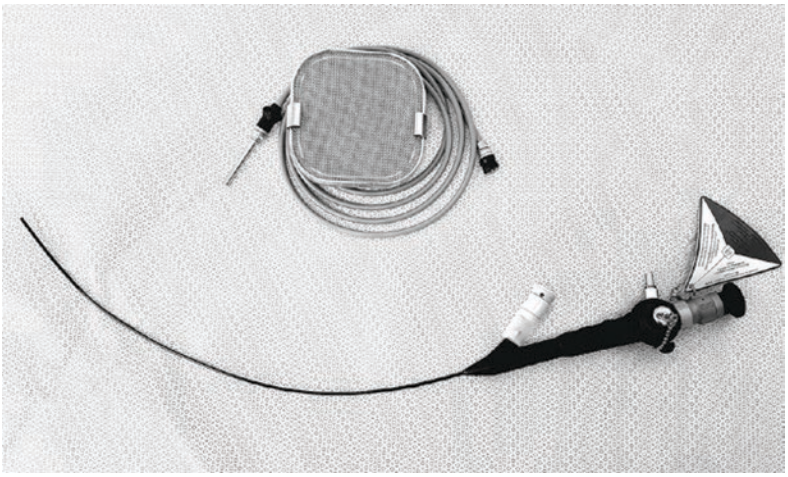
Epiduroscopes, probes and optics: Baholzer Endoskopie GmbH & Co KG, Neckartal 100, D-78628 Rottweil (► www.baholzer.de).

- Complete set Resascope plus balloon 900€,
- Resaflex probe €500,
- Radio frequency generator €10,000,
- Baholzer 1.5 mm fiber optics 3500€.

Epiduroscope incl. Introducer/lock from the company Almikro GmbH & Co. KG, Löwenweg 1e, D-79189 Bad Krozingen/Hausen (e-mail: info@almikro.de).

- Cost per endoscope about 7000€,
- Video tower as for endoscopic procedures.

Fig. 23.15 Flexible fibroscope



23.8 Preintervention Education

As with all surgical or interventional procedures, information is provided about the general and specific risks of the intervention. In addition to the general risks such as infections, nerve and vascular injuries, information should also be provided about the side effects of pharmacological therapy, in particular allergic reactions, respiratory and circulatory disorders.

Specific risks include the risk of dura injury with postpuncture headache, repeat surgery, and spinal reoperation if epidural hemorrhage occurs.

23.9 Implementation of the Intervention

23.9.1 General Preparations

Epiduroscopy should be performed in an operating room under sterile conditions. Adequate intravenous antibiotics and the necessary baseline monitoring of vital signs occur prior to the skin incision for placement of the sacral introducer.

Analgesia is induced via an intravenous line. Care must be taken to ensure that the patient is still able to respond adequately to questions posed.

23.9.2 Positioning of the Patient and Puncture of the Sacral Hiatus

When positioning the patient on the operating table, care must be taken to ensure that the lumbar spine is de-lordosed using adequate positioning pillows. Before surgical disinfection, a compress is placed in the anal fold to avoid irritation of the mucosa by the disinfectant.

After surgical skin disinfection and sterile draping, the hiatus sacralis is first visualized radiologically in the a.p. and then in the lateral X-ray path.

After local anesthesia and puncture of the sacral hiatus in loss-of-resistance technique, a Seldinger wire is inserted into the sacral canal. The puncture should be performed under radiological control and without significant resistance. After successful insertion of the Seldinger wire, a dilator is placed over the guide wire into the canalis sacralis.

23.9.3 Epidurography

When the introducer reaches the S1-S2 level, an epidurography with contrast medium should be performed. The distribution of the contrast medium provides information about the sacral anatomical-pathological situation. Throughout the procedure, the position of the epiduroscope is controlled by X-ray checks in the lateral and a.p. radiographic path.

Park and Lee (2017) demonstrated that there seems to be no correlation between the extent of adhesiolysis achieved and the degree of pain reduction in lumbar spinal stenosis. However, this raises the question of whether these adhesions were then also relevant to pain.

23.9.4 Flushing

Epidural irrigation with physiological NaCl solution serves to improve optical vision. In addition to bolus irrigation, there is also the possibility of volume- and pressure-controlled epidural irrigation via an infusion system with pressure bag. Special attention should be paid to the volume and infusion pressure, which should not exceed 60 mmHg. The amount of irrigation solution administered must be documented.

One of the first clinical signs of "overinfusion" is the onset of headache in the patient. At the first sign of epidural overinfusion, immediately pause the examination. The maximum infusion volume is 350 mL, the mean volume 220 mL.

23.9.5 Epiduroscopy

The insertion of the endoscope into the sacral canal via hiatus sacralis should be done without resistance and force. Advancement of the endoscope in the epidural target direction now begins. To improve the optical view, the application of intermittent NaCl boluses may be helpful.

The epiduroscope should only be advanced in the region close to the spinal cord under visual control. Extreme caution must be exercised if the anatomical structures cannot be clearly identified. This applies in particular to patients who have undergone previous surgery in the area to be examined. X-ray controls in the a.p. and lateral beam path are recommended for exact localization of the epiduroscope.

In addition to epidural irrigation, a Fogarty catheter can be carefully advanced to improve the view close to the spinal cord. The expandable Fogarty catheter can facilitate the endoscopic view when using resascopes in the cavum epidurale.

The balloon catheter has the advantage that it can dilate the epidural space. When used in sacral-lumbar pathological epidural situations, the balloon catheter can improve visualization of the structures near the spinal cord (◘ Fig. 23.16). As an alternative to targeted epidural laser adhesiolysis, a balloon catheter can help to resolve epidural fibroization and adhesions in special situations.

As a matter of principle, blind advancement of the optics of the endoscope or of instruments (laser fiber, grasping forceps, catheter electrodes, etc.) in the working channel must be strictly avoided during epiduroscopy.

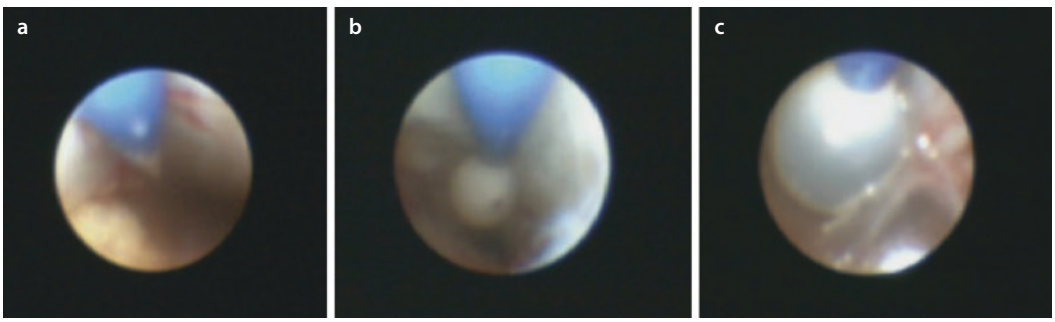
A microbiological sample should be taken to detect pathological changes in the spinal canal. It is also recommended that a biopsy be taken during microsurgical loosening of adhesions and scar tissue (with the aid of biopsy forceps and subsequent histological findings).

During the endoscopic examination, pain provocation tests should be performed according to the patient's clinical condition in order to determine which of the pathological-anatomical structures can trigger the patient's pain. The algesiological evaluation is to be documented in the operation report.

If adhesions or fibrosis of pain-relevant scar strands cannot be resolved by the balloon catheter or epiduroscope alone, controlled detachment, transection, or removal of algesiologically relevant pathological changes can be performed with the aid of surgical instruments, radiofrequency probes, or laser fibers (Raffaeli and Righetti 2005; Schütze 2008; Kim et al. 2017).

One advantage of the Resaflex probe (◘ Fig. 23.17) and the bioresonance generator is the possibility of sensory and motor testing in the area to be transected. In therapeutic use, thanks to the quantitative molecular resonance technique, selective precise lesioning is effected at low temperatures.

Targeted endoscopic use of diode lasers with light guides of 320 µm bare fiber for epidural adhesiolysis, scar resection, or hemostasis is also an important component of invasive interventional pain management (Schütze 2011; Ruetten et al. 2002; Kim et al. 2017).



◘ **Fig. 23.16** **a–c** Resaloon catheter

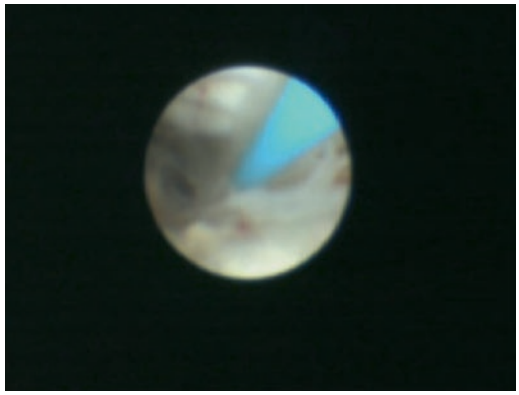


Fig. 23.17 Resaflex probe for cutting scar strands after sensory and motor testing

23.9.6 Conclusion of Investigation

During and after completion of the spinal endoscopic examination, attention should be paid to any bleeding in the target area of the epidural space. Pharmacological analgesic and antiphlogistic therapy, placement of an epidural catheter, or SCS electrode under visualization may be performed prior to removal of the epiduroscope.

23.10 Possible Complications

As with all invasive spinal procedures, complications can occur in rare cases with epidural endoscopy. The experience of the surgeon, the clinic setting, strict asepsis and careful patient selection are criteria for the outcome of the epiduroscopically assisted technique.

Occasional cardiac arrhythmias, cerebral seizures, visual disturbances or blindness in retinal hemorrhages, dural perforations with postpuncture headache, epidural hematomas or infections of the meninges have been described in the literature (Wagner et al. 2006). Sphincter or bladder dysfunction and neurological dysfunction such as confusional states may occur (Kim et al. 2017).

Strict attention must be paid to documenting and limiting the epidural infusion volume. According to the literature, administered amounts of 200 mL NaCl 0.9% in total are considered safe (Kim et al. 2017).

23.11 Results in the Literature

The positive effects of epiduroscopy have been demonstrated in several studies. This applies both to quantitative outcome parameters, e.g. pain scores and functional improvements, and to qualitative parameters such as the recording of sensory nerve function or contrast medium distribution.

In a clinical study of patients with chronic lumbar and radicular pain, epiduroscopy was superior to magnetic resonance imaging alone in determining the spinal segment causing the pain. According to the authors, the reason for this is that thanks to the pain provocation tests, a functional examination of the pathological changes found is possible. However, imaging is purely observational (Bosscher and Heavner 2012b).

In 2004, Schütze reported on 500 epiduroscopies in patients with pain. In this work, in addition to endoscopically assisted epidural analgesic therapy, the treatment of pain-relevant epidural fibrosis and adhesions using laser technology was also presented (Schütze 2004).

In a similar study, Geurts et al. prospectively investigated whether pathological changes detected in MRI examinations could be confirmed by epiduroscopy and whether targeted injections after adhesiolyses led to a reduction in radicular pain. During epiduroscopy, adhesions were detected in 19 of 20 patients. In 8 of these patients, 6 of whom had never had previous lumbar spine surgery, adhesions were present that were not detectable on MRI scans. Six of the patients showed signs of nerve root inflammation and 11 of 20 patients showed significant improvement (Geurts et al. 2002).

Thanks to epiduroscopy, treatable pathological findings can be detected. Thus, epiduroscopy has significant diagnostic and prognostic value (Kim et al. 2017).

Bosscher and Heavner examined 114 patients by epiduroscopy in 2014. In this way, the outcome could be correctly predicted in 78% of the patients – with a sensitivity of 75% for a good or very good outcome and a specificity for no or moderate improvement of

82%. This study also demonstrated a specificity for epidural pathological changes of 91% (Bosscher and Heavner 2014).

In a prospective, randomized, double-blind study, Manchikanti et al. examined 83 patients who had radicular pain for 6 months that did not improve after conservative therapy with radiographically guided epidural injections and percutaneous adhesiolysis using a Racz catheter. Group 1 of the study acted as a control group in which the epiduroscope was advanced to the level of the sacral canal and a mixture of a local anesthetic and steroid was administered. No attempts at adhesiolysis were made. Group 2 was epiduroscopied and adhesiolysis was performed at the target level. The same mixture of local anesthetics and steroid was then injected. The outcome parameters were pain, functional parameters and psychological state of the subject. Pain scores improved significantly at 1, 3, and 6 months in 23 patients in group 2 (57%). All other outcome parameters including psychometric tests also improved significantly at 1, 3 and 6 months. In the control group, the improvement occurred only in the first month and not later. The authors conclude that epiduroscopy is an effective treatment measure especially in patients who have not benefited permanently from epidural infiltrations or percutaneous adhesiolysis (Manchikanti et al. 2005).

In a prospective study with a follow-up of 12 months, 38 patients with chronic radicular pain were examined. They showed a significant improvement in symptoms after adhesions were released from the dura (Richardson et al. 2001).

Manchikante et al. came to comparable results in the examination of 85 patients in whom a total of 112 epiduroscopies were performed. The patients showed chronic persistent radicular pain that did not improve after conventional therapy including epidural corticosteroid injections. During epiduroscopy, adhesiolysis was performed and a mixture of local anesthetics and cortisone was administered. Long-term results improved significantly and the cost-effectiveness of the procedure was demonstrated (Manchikanti et al. 1999, Manchikanti 2000).

Two studies followed a different adhesiolysis technique in 14 patients using the resablator with an output power of 4 MHz to dissolve adhesions. One month after adhesiolysis, 75% of patients described a 90% improvement in pain (Rafaelli and Rhigetti 2005).

In 2011, Kim et al. published a study in which 98 patients with chronic lumbar and radicular pain underwent treatment with either epidurocopically guided laser adhesiolysis and steroid injection or epidurocopically assisted steroid application only. This showed that patients treated with laser adhesiolysis had better pain reduction after 4 weeks and 6 months and that this reduction lasted longer (Kim et al. 2011).

However, the extent of epidurographic changes following adhesiolysis in patients with lumbar spinal stenosis does not appear to correlate with the extent of subsequent pain reduction (Park and Lee 2017). Igarashi et al. (2004) studied the effects of epiduroscopy in degenerative lumbar canal stenosis. Based on the number of affected nerve roots, patients (n = 58, mean age 71 years) were divided into two groups. A monosegmental group (n = 34) and a multisegmental group (n = 24). In all patients, the epidural space was irrigated with physiological saline during the examination, adhesions were loosened, and a local anesthetic combined with a corticosteroid was administered at the end. Improvement in back pain was demonstrated in all patients 12 months post interventionem. With regard to radicular symtomatology, there was a reduction in pain in the monosegmental radicular group for the duration of 12 months. In contrast, patients with multilevel radiculopathy had relief for only 3 months. Regardless of the normalization of biochemical effects due to adhesiolysis for radicular pain, it should be emphasized that the nerve root regained sufficient range of motion (Igarashi et al. 2004).

23.12 Reimbursement of Costs

The codes for the procedures based on the Operation and Procedure Code (OPS) version 2018 can be found in ◘ Table 23.1.

Within the framework of the German Medical Fee Schedule (GOÄ), neurolysis can be billed as an independent service with the number 2582 and the number 471 (initiation and monitoring of epidural anesthesia for up to 3 days).

◘ **Table 23.1** OPS codes

DRG/ICD	Description
5-032.00	Dorsal access lumbar spine 1 segment
5-986ff	The use of minimally invasive technique is to be coded additionally, if not indicated as a separate code 5-986ff
5-059 b	The use of an endoscopy system must be coded separately 5–059.b if the code for the procedure does not contain this information
5.036.6	Adhesiolysis (secondary procedure)
1-698.1	Diagnostic endoscopy by puncture, incision and intraoperatively on the central nervous system-intraspinal diagnostic endoscopy
G96.1	Disease of the meninges, not elsewhere classified; including meningeal adhesion (cerebral) (spinal)
G55.3	Compression of nerve roots and nerve plexus, in other diseases of the spine and back (M45-M46+), (M53-M54+)
M48.09	Spinal canal stenosis, spinal claudication in spinal canal stenosis
1-404	Percutaneous (needle) biopsy of intraspinal tissue
5-038.21	Implantation or exchange of a catheter for intrathecal and epidural infusion, permanent catheter for continuous infusion
5-032.8	Access to the Os sacrum and Os coccygis, dorsal
5-934	Microsurgical technique
5-033.0	Decompression
5-059.f	Pulsed radiofrequency on ganglia
5-059.f1	Through multifunction electrode
5-056	Neurolysis and decompression of a nerve
5-056.41	Endoscopic
5-056.8	Nerves leg

German Institute of Medical Documentation and Information (DIMDI): ► https://www.dimdi.de/static/de/klassi/ops/kodesuche/onlinefassungen/opshtml2017/#code5; ► http://www.icd-code.de

23.13 Conclusion and Clinical Relevance

In recent years, significant progress has been made in the development of adequate instrumentation for the safe performance of epiduroscopy. In addition to extended diagnostics, these instruments also permit an expansion of therapeutic options.

Epiduroscopy (EDS) is an efficient and future-oriented minimally invasive endoscopic procedure for the diagnosis and treatment of pain syndromes close to the spinal cord.

The epiduroscopic and histological identification of dorsal and ventral pathological-anatomical structures, respectively, as well as the realization of an epidural pain provocation test for pain assessment are of therapeutic relevance – which allows a targeted therapy of affected pain-relevant regions.

In addition to endoscopic support for invasive interventional procedures, e.g. laser- or radiofrequency-assisted solution of pain-relevant scar fields or endoscopic placement of catheters and SCS electrodes, significantly expand the available therapeutic options for pain patients.

For a part of the patients with chronic back pain, who could not find an adequate explanation for their complained pain or therapeutic effects with the existing diagnostic procedures, spinal endoscopy represents an effective and safe diagnostic, but also therapeutic procedure.

References

Bartynski WS, Petropoulou KA (2007) The MR imaging features and clinical correlates in low back pain-related syndroms. Magn Reson Imaging Clin N Am 25:137–154

Blomberg RG (1985) A method for spinal canal endoscopy and spinaloscopy: presentation of preliminary results. Acta Anaesthesiol Scand 21:113–116

Bosscher HA, Heavner J (2012a) Incidence and serverity of epidural fibrosis after back surgery: an endoscopic study. Pain Pract 10:18–24

Bosscher HA, Heavner JE (2012b) Diagnosis of the vertebral level from which low back or leg pain originates. A comparison of clinical evaluation, MRI and epiduroscopy. Pain Pract 12(7):506–512

Bosscher HA, Heavner JE (2014) Lumbosacral epiduroscopy findings predict treatment outcome. Pain Pract 14(6):506–514

Burman MS (1931) Myeloscopy or the direct visualisation of the spinal canal and ist contents. J Bone Joint Surg 13:695–696

Burton CV (1978) Lumbosacral arachnoiditis. Spine 3(1):24–30

Cornefjord M et al (1996) Mechanical and biochemical injury of spinal nerve roots: a morphological and neurophysiological study. Eur Spine J 5:187–192

Day PL (2001) The adhesive arachnoiditis syndrome. http://www.cofwa.org/aasyndrome-10-03.pdf. Accessed on 14.08.2018

Devor M (1991) Neuropathic pain and and injured nerve: peripheral mechanisms. Br Med Bull 47:619–630

diZerga GS (1997) Biochemical events in in peritoneal tissue repair. Eur J Surg Suppl 577:10–16

Farrokhi MR et al (2011) The effect of methylene blue on peridural fibrosis formation after laminectomy in rats: an experimental novel study. Spine J 11:147–152

Geurts JW et al (2002) Targeted methylprednisolone acetate/hyaluronidase/clonidine injection after diagnostic epiduroscopy for chronic sciatica: a prospective, 1-year follow-up study. Reg Anesth Pain Med 27:343–352

Gill GG et al (1985) Pedicle fat grafts for the prevention of scar in low-back surgery: a preliminary report on the first 92 cases. Spine (Phila Pa 1976) 10:662–667

Graziotti P (2007) DVD epiduroscopy. Spine-aligna pty Ltd, 91 Circle. West Australia, Dalkeith. http://www.ipmnt.net

Hayek SM et al (2009) Effectiveness of spinal endoscopic adhesiolysis in post lumbar surgery syndrome. A systemic review. Pain Physician 12:419–435

Heavner JE et al (1991) Percutaneous evaluation of the epidural and subarachnoid space with a flexible fiberscope. Reg Anaesth 15:85

Hirschowitz BI et al (1958) Demonstration of a new gastroscope, the fiberscope. Gastroenterology 35(1):50. discussion 51–53

Holström B et al (1995) Risk of catheter migration during combined spinal epidural block: percutaneous epiduroscopy in autopsy cases. Anesth Analg 80:747–753

Howe JF et al (1977) Mechanosensitivity of dorsal root ganglia and chronically injured axons: a physiological basis for the radicular pain and nerve root compression. Pain 3:24–41

Igarashi T et al (2000) The fiberoscopic findings of the epidural space in pregnant women. Clin Invest Anesthesiol 92:1631–1636

Igarashi T et al (2004) Lysis of adhesions end epidural injection of steroid/local anaesthetic during epiduroscopy potentially alleviate low back and leg pain in elderly patients with lumbar spinal stenosis. Br J Anaesth 93(2):181–187

Kayama S et al (1996) Incision of the anulus fibrosus induces nerve root morphologic, vascular, and functional changes. An experimental study. Spine 21:2539–2543

Kim JD et al (2011) Epiduroscopic laser disc and neural decompression. J Neurosurg Rev 1(S1):14–19

Kim DH et al (2017) Epiduroscopy: atlas of procedures, 1. Aufl. Thieme, Janeiro/New York/Stuttgart/Dehli/Rio de Janeiro

Kizelshteyn G et al (1991) Epidural baloon catheter system lysing epidural adhesions. Reg Anesth 15(1):87
Kobayashi Y et al (2005) Effect of mechanical compression on the lumbar nerve root: localization and changes intraradicular inflammatory cytokines, nitric oxide and cyclooxygenase. Spine (Phila Pa 1976) 30:1699–1705
Leonhardt H (1971) Histologie und Zytologie des Menschen. Georg Thieme Verlag, Stuttgart
Leu H (1993) Percutaneous techniques: decompression and intradiscal laser in discoscopy, external pedicular fixation, percutaneous interbody fusion, peridural endoscopy with discoscopy. In: 12th course of percutaneous endoscopic spinal surgery, Zürich
Liakakos T et al (2001) Peritoneal adhesions: etiology, pathophysiology, and clinical significance. Recent advances and management Dig Surg 18(4):260–273
Manchikanti L (2000) The value and safety of epidural endoscopic adhesiolysis. Am J Anesthisol 2:275–278
Manchikanti L et al (1999) Non-endoscopic and endoscopic adhesiolysis in post lumbar mainectomy syndrome: a one year outcome study and cost effectiveness analysis. Pain Physician 2:52–58
Manchikanti L et al (2005) [ISRCTN 16558617] a randomized, controlled trial of spinal endoscopic adhesiolysis in chronic refractory low back and lower extrimity pain. BMC Anesthesiol 5:10
Möllmann M et al (1992) Spinaloskopie zur Darstellung von Problemen bei der Anwendung der kontinuierlichen Spinalanästhesie. Anästhesist 41:544–547
Olmarker K, Myers RR (1998) Pathogenesis of sciatic pain: role of herniated nucleus pulposus and deformation of spinal nerve root and dorsal root ganglion. Pain 78:99–105
Olmarker K et al (1993) Autologous nucleus pulposus induces neurophysiologic and histologic changes in porcine cauda equina nerve roots. Spine 18:1425–1432
Olmarker K et al (1995) Inflammatogenic properties of nucleus pulposus. Spine 20:665–669
Olmarker K et al (1996) Ultrastructural changes in spinal nerve roots included by autologous nucleus pulposus. Spine 21:411–414
Ooi Y (1981) Myeloscopy. Orthop Trauma Surg 24:659–669
Otani K et al (1997) Experimental disc herniation: evaluation of the natural course. Spine 22:2894–2899
Park CH, Lee SH (2017) Epidurographic findindings following percutaneous epidural adhesiolysis failed to correlate with level of pain reduction in patientes with lumbar spinal stenosis. Pain Med 18:842–845
Parris WCV (1999) What is new and on the horizon in pain management. Am Soc Anesthesiol 63:10
Pool JL (1938) Direct visualization of dorsal nerve roots cauda equina by means of a myeloscope. Arch Neurol Psychiatr 39:1308–1312
Pospiech J et al (1995) Epidural scar tissue formation after spinal surgery: an experimental study. Eur Spine J 4:213–219
Raffaelli W, Righetti D (2005) Surgical radio-frequency epiduroscopy technique (R-res-ablator) and FBSS treatment: preliminary evaluations. Acta Neurochir Suppl 92:121–125
Richardson J et al (2001) Spinal endoscopy in chronic low back pain with radiculopathy. A prospective case series. Anaesthesia 56:454–460
Robertson JT (1996) Role of epidural fibrosis in the failed back: a review. Eur Spine J 5:52–56
Ruetten S et al (2002) Application of Holium YAG laser in epiduroscopy: extended practicabillites in the treatment of chronic back pain syndrome. J Clin Laser Med Surg 20(4):203–206
Rydevik B et al (1984) Pathoanatomy and pathophysiology of nerve root compression. Spine 9:7–15
Rydevik B et al (1990) Diffusion from the cerebral spinal fluidas a nutritional pathway für spinal nerve roots. Acta Physiol Scand 138:247–248
Sabersky LR, Brull SJ (1995) Spinal and epidural endoscopy: a historical review. Yale J Med 68:7
Sabersky LR, Kitahata LM (1995) Direct visualization of the lumbosacral epidural space through the sacral hiatus. Anesth Analg 80:839–840
Schofferman J et al (2003) Failed back surgery: etiology and diagnostic evaluation. Spine J 3:400–403
Schütze G (2000) Techniken und Technologien zur Therapie chronischer Schmerzen. Wissenschaftliche Verlagsabteilung, Aachen, Grünenthal GmbH
Schütze G (2004) Epiduroskopie eröffnet neue Wege gegen Rückenschmerzen. Schmerz 4:12–13
Schütze G (2006) Epiduroskopie. Ein praxisorientierter Leitfaden zur epiduroskopischen Diagnostik und Therapie rückenmarksnaher Schmerzsyndrome. Pabst Science Publishers, Lengrich
Schütze G (2008) Spinal endoscopy – epiduroscopy. Springer, Heidelberg
Schütze G (2011) Interventionelles Schmerzmanagement-Bildgestützte Verfahren zur Diagnostik und Therapie rückenmarksnaher Schmerzsyndrome – Spinale Endoskopie, pharmakologische und elektrische Neuromodulation. Uni-Med Verlag, Bremen
Schütze G, Kurtze H (1985) Direct observation of the epidural space with a flexible catheter-secured epiduroscopic unit. Reg Anesth 19:85–89
Shah RV, Heavner JE (2003) Recognition of the subarachnoid and subdural compartements during epiduroscopy: two cases. Pain Pract 3(4):321–325
Slipman CW et al (2002) Etiologies of failed back surgery syndrome. Pain Med 3:200–214
Smith S (2003) The adhesive arachnoiditis syndrome. Circle of friends with Arachnoidits (COFWA). http://cofwa.og/AASYNDROME-10-03.pdf. Accessed on 14.08.2018
Stern EL (1936) The spinascope: a new instrument for visualizing the spinal canal and its contents. Med Rec (NY) 143:31–32
Thompson JN et al (1995) Pathogenesis and prevention of adhesión formation. Br J Surg 82(1):3–5
Wagner K et al (2006) Risks and complications of epdural neurolysis – a review with case reprort. Anesthesiol Intensmed Notfallmed Schmerzther 41:213–222
Yang J et al (2011) Application of liposome-encapsulated hydroxycamptothecin in the prevention of epidural scar formation in New Zealand white rabbits. Spine J 11:218–223

Dorsal Root Ganglion Stimulation

B. C. Schultheis, S. Schu, and P. A. Weidle

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_24

24

24.1 Introduction

The treatment of chronic pain poses great challenges to modern medicine. Especially the management of patients with neuropathic pain is only possible to a limited extent with classical therapy methods.

Generally, the treatment algorithm begins with a detailed history and careful physical examination. Therapeutic options include adapted pharmacotherapy, diagnostic and therapeutic infiltrations, and psychological/psychiatric presentation. If therapeutic success is inadequate, more complex techniques are employed. The question is whether the pain is local, regional or multilocular.

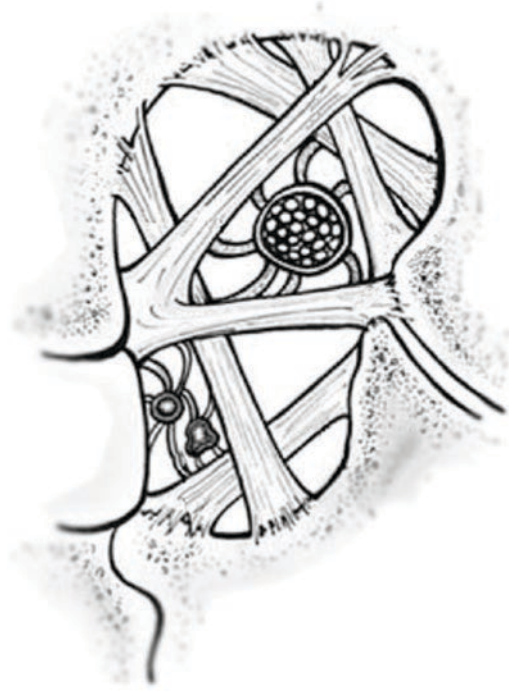
At the end of these treatment options are often neuromodulative therapy methods, e.g. neurostimulation of the spinal ganglion (dorsal root ganglion, DRG), spinal cord stimulation (SCS) or pharmacological neuromodulation using intrathecal pumps. In this way, otherwise untreated pain syndromes, e.g. FBSS (Failed Back Surgery Syndrome), peripheral arterial occlusive disease, chronic angina pectoris and also patients with CRPS (Complex Regional Pain Syndrome) can be successfully treated.

However, there are pain syndromes that are often very difficult to treat using conventional SCS. For example, the stimulation of certain body regions such as the thoracic wall, groin area and other complexly innervated body parts is difficult. In the search for new therapeutic approaches, the spinal ganglion (dorsal root ganglion) presented itself because it is a highly organized anatomical structure that plays a critical role in the development and maintenance of chronic pain.

In humans, there are 31 paired (right and left) mixed spinal nerves, which are responsible for the transmission of autonomic, sensory and motor information from the periphery and from the spinal cord. Thus, 8 paired spinal nerves are found cervically, 12 thoracically, 5 pairs each lumbally and sacrally, and one coccygeal pair. These spinal nerves form from sensory dorsal afferent axons and ventral motor efferent axons, and each emerges from the neuroforamen of two adjacent vertebrae (Hasegawa et al. 1993, 1996; Sheng et al. 2010).

As the sensory dorsal nerve root emerges from the neurofarm, the dorsal ganglion forms. It is a collection of bipolar cell bodies surrounded by glial cells and the axons of the sensory cells of the dorsal ganglion that form the primary afferent sensory nerves. The dorsal ganglion sensory neurons are called pseudounipolar neurons. They have two axon arms that functionally act as one axon and the nucleus located in the dorsal ganglion, which are connected to them via a tight junction.

From a clinical-practical point of view, the anatomical conditions in the neuroforamen are therefore particularly noteworthy (◘ Figs. 24.1 and 24.2). It also appears important that the dorsal ganglia contain the largest proportion of sensory neurons in the body and are primarily responsible for transduction of sensory information from the periphery and transmission to the central nervous system. The cell bodies take a crucial role in modulating pain signals and sensory impulses by synthesizing and releasing their own neurotransmitters (Devor 1999). The dorsal ganglion does not



◘ **Fig. 24.1** Within the neuroforamen, the spinal ganglion is fixed by numerous ligaments. Parallel to the spinal nerve run an artery and a vein. (Mod. n. Juoj8derivative work)

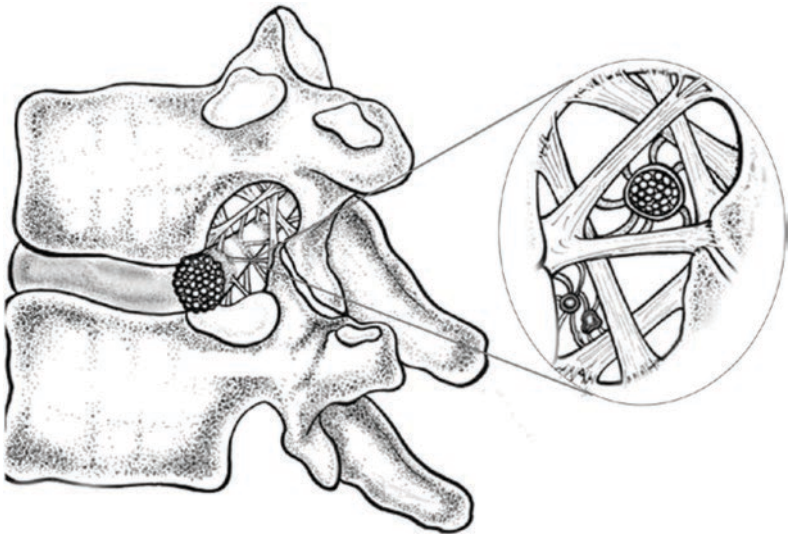


Fig. 24.2 Anatomical relationships in the neuroforamen. (Mod. n. Juoj8derivative work)

play a passive role in the development of chronic pain; rather, it is actively involved. The DRG neurons do not act among themselves: they are isolated from each other by satellite glial cells. They do, however, respond to peripheral and central stimuli such as nociception, peripheral afferent nerve injury, and inflammation. Throughout the central and peripheral nervous system, nerves are isolated and protected by the blood-brain and blood-nerve barriers (Ballabh et al. 2004; Shimizu et al. 2011). In the spinal ganglia, the situation is different: there is no blood-nerve barrier and both large and small molecules and macrophages can cross the satellite glial cells (Hu and McLachlan 2002). When a DRG neuron is triggered, a delayed, long-lasting response occurs through an information pathway between glial cells called the sandwich synapse (SS). The discovery of transmission from glial cells to DRG neurons supports the theory of a molecular DRG/SS relay system (Segond von Blanchet et al. 2009).

The satellite glial cells express receptors for various neuroactive messengers, e.g. chemokines, cytokines, adenosine-5′-triphosphate (ATP) and bradykinin. On the one hand, signals from other cells reach the satellite glial cells, and on the other hand, the satellite glial cells influence the DRG neurons and respond to signals from their immediate environment. Therefore, it is considered likely that they are involved in the process of transmission in the DRG. Thus, it is now known that satellite glial cells play an important role in the development of neuropathic pain following peripheral nerve injury (Hogan 2010). Evidence shows that they are actively involved in most processes in the peripheral and central nervous system (Aldskogius and Kozlova 1998; Rambourg et al. 1983; Kamiya et al. 2006; Regan et al. 1986; Hjerling-Leffleler et al. 2000). Evidence also shows that they change both morphologically and biochemically after peripheral nerve injury (Lee et al. 1986; Tandrup 1993; Khan et al. 2011).

Nociceptive pain results from the conversion of noxious stimuli and from the transmission of action potentials to the spinal cord and brain. Neuropathic pain following peripheral nerve injury is characterized by hypersensitivity resulting from a reduction in the excitation threshold for action potentials from nociceptors. In neuropathic pain, the decreased excitation threshold is present for both nociceptor activity (hyperalgesia) and non-nociceptor stimuli (allodynia) (Krames 2014).

Neuropathic pain leads to an activation of the immune system (Scholz and Woolf 2007). Thus, when primary sensory neurons are injured and neuropathic pain occurs, a variety of proinflammatory mediators are released,

such as. Eicosanoids, bradykinin, serotonin, neurotrophins, cytokines such as interleukin, tumor necrosis factor-α (TNF-α), interferon, growth factor, chemokines, adenosine triphosphate (ATP), and oxygen radicals from Schwann cells and satellite glial cells within the DRG (Schweitzer et al. 2001; Zalenka et al. 2005; Wagner and Meyers 1996; Ignatowski et al. 1999; Geis et al. 2010; Choi et al. 2010; Segond von Blanchet et al. 2009; Nakamae et al. 2011; Renno et al. 1995; Reyes-Gibby et al. 2009; Brack et al. 2004; Woolf and Mannion 1999; White et al. 2007; Baggioline 1998; Zloznick and Yoshei 2000; Whie et al. 2005; Gao and Ji 2010; Watkins et al. 1995; Kiguchi et al. 2012; Chessel et al. 2005). Activation of these cells leads to the production of pain mediators. They sensitize glial cells by lowering the excitation threshold, thus supporting peripheral and central sensitization (DeLeo et al. 2004; Colburn et al. 1999; Raghavendra et al. 2003; Sommer and Kress 2004; Okamoto et al. 2001). Interestingly, a nerve lesion distal to the DRG results in greater neuronal cell death and TNF-α release, as well as an increased incidence of neuropathic pain than an injury proximal to the DRG (Sekiguchi et al. 2009). This may also explain the development of chronic neuropathic pain after surgical procedures.

Genetic alterations in the DRG caused by peripheral afferent nerve injury are another reason for the development of neuropathic pain. This may involve changes in the genes for neuropeptides, receptors, ion channels, signal transduction molecules and proteins of the synaptic vehicle (Xiao et al. 2002).

24.2 Indications

Given the key role of the spinal ganglion in the generation and maintenance of chronic neuropathic pain, the potential use of DRG stimulation as a newer neuromodulatory therapeutic modality is steadily increasing. Thus, DRG stimulation can be used alone or in combination with other neuromodulatory procedures. Combination with spinal cord stimulation or subcutaneous stimulation is also possible.

Indications for use are:

- chronic post-surgical pain syndromes, such as can occur after thoracotomies, mastectomies or herniotomies,
- chronic pain after hip or knee TEP implantation,
- Phantom limb pain,
- CRPS II of the lower and upper extremities,
- chronic shoulder pain,
- Post-zoster neuralgia,
- Pain in diabetic polyneuropathy in the feet (significant relief of symptoms).

Interestingly, however, peripheral neuropathic pain, such as can occur with peripheral iatrogenic nerve injuries, can be treated so well that the indication for neurolysis of peripheral nerves is now rarely given.

Conventional SCS has been successfully used to treat neuropathic pain of the trunk and extremities since 1967. However, the results are suboptimal in certain patient groups. For example, SCS is a fairly nonspecific treatment method that stimulates a large number of different nerve fibers. Certain body positions and also the possibility of probe dislocation can lead to unstable stimulation. In addition, the decrease in stimulation effect due to the insulating CSF requires higher current levels and thus leads to shortened generator durability due to increased current consumption. Compared to SCS, the energy consumption of DRG stimulation is about 10% (Deer et al. 2017). DRG stimulation offers some advantages in this regard in a select patient population because the DRG has a prominent role in pain processing and modulation in the body. (Deer et al. 2013). Thus, stimulation at the DRG allows for specific stimulation of nociceptive cells while leaving out neurons that are not involved in pain transmission.

The stimulation effect is more predictable due to the prescribed anatomical localization of the spinal ganglion in the neuroforamen, and the absence of the insulating CSF allows effective stimulations in the microampere range, which prolongs the survival time of the generator battery (Hasegawa et al. 1996).

24.3 Preinterventional Diagnostics

A prerequisite for the therapy of chronic neuropathic pain with the aid of spinal ganglion stimulation is – as with therapy using SCS – the exhaustion and documentation of all other conservative procedures in addition to a complete physical history and physical examination of the patient. A neurological assessment and documentation of the status quo must also be considered mandatory.

For pain therapy documentation, we recommend, for example, the DSF (German Pain Questionnaire) of the German Pain Society (formerly DGSS: German Society for the Study of Pain), in which the most important areas of pain quality and spread as well as the effects on the quality of life of the affected person are recorded. An EDP-supported system in which the patients can fill in the questionnaires via a tablet (pain detect, pain-depression index, pain and well-being diary) has proved successful. Prior to the application of an implantable neuromodulative procedure, a multimodal pain therapy should be performed if conservative therapy measures have not yet been exhausted.

Prior to implantation, current imaging of the spinal segment in which the DRG probe is to be implanted is necessary. The imaging diagnosis is completed with a current MRI of the spinal segment relevant for the procedure.

In general, it is also recommended that all patients be presented to a neurologist and psychiatrist prior to indication for full inpatient multimodal pain therapy. Patients with psychiatric concomitant diseases must be stably adjusted and psychological causes of the pain symptoms must be excluded.

Step-by-step diagnostics or so-called pain mapping with BV- or CT-guided diagnostic periradicular therapy (PRT) is indispensable. After successful testing by means of PRT, neuromodulative treatment with pulsed radiofrequency can then be carried out. This procedure is useful for two reasons:

- If a positive effect on pain can be demonstrated using pulsed radiofrequency, it can be assumed with a high degree of probability that chronic pain syndrome can also be alleviated by spinal ganglion stimulation.
- Since, according to the current state of knowledge, the wiring of the afferents cannot always be assigned to the classical dermatomes, pulsed radiofrequency can be used for a more precise pain mapping – and thus a therapeutic success by means of DRG stimulation is more probable.

At the end of the preparations and planning of the intervention, the following questions should be answered:

1. Which ganglion is the target ganglion?
2. Is the patient pre-operated in the area of DRG probe placement? (This may make placement difficult or impossible).
3. Are there anatomical variations that may make implantation difficult?
4. What probe length is required? Do extensions have to be installed, which may prevent a later MRI suitability or should a longer probe be placed in case of doubt?

If points 2 or 3 apply, the implantation of the DRG probe one segment above or below should be considered.

24.4 Necessary Instruments

The following specific instrumentation is required for the implantation of a DRG electrode:

- DRG electrode spinal modulation of the company Spinal Modulation Abbott Jude,
- Extension for percutaneous drainage,
- Puncture kit with Tuohy needle,
- Pulse generator with programmer.

The material can be obtained from Abbott, which is the sole manufacturer of approved systems.

Ordering address: Abbott, St. Jude Medical GmbH, Helfmann-Park 7, D-65760 Eschborn.

Implantation requires a fully equipped operating room with image converter. The patient should be placed on adequate positioning pillows to achieve de-lordosis of the spine. General sterile conditions and precautions apply.

24.5 Preintervention Education

The implantation of a DRG probe requires special information. Information on specific complications and clinical constellations is listed below:

- Bleeding, infections, nerve, vascular and spinal cord injuries, paraplegia, bladder as well as rectal dysfunction, tube dislocation and fractures.
- CSF loss syndrome with severe persistent headache and the need for a blood patch.
- Reoperations and generator replacement (including battery exhaustion).
- Persistent pain in the back, gluteal and genital region, aggravation of the original pain.
- Intervention extension with implantation of additional probes.
- No MRI capability at this time.

24.6 Implementation of the Intervention

In contrast to previous neuromodulation procedures, there are two ways to perform the DRG intervention:

1. After dedicated prediagnostics, complete testing by diagnostic periradicular infiltrations and pulsed radiofrequencies under intubation anesthesia (avoiding medium or long acting muscle relaxants), the efficacy of the method can be predicted relatively well. This in turn allows the procedure to be performed under general anesthesia.
2. Deep analgesia with propofol and remifentanil during the installation of the DRG system. After the subsequent wake-up phase, sensory testing of the probe position is performed.

Before starting the procedure, the team timeout should take place.

24.6.1 Positioning of the Patient

The spinal column is de-lordosed to enlarge the intralaminar windows and facilitate puncture of the epidural space. This can be achieved by positioning the patient on inflatable cushions placed under the abdomen (lumbar spine) or the sternum (cervical spine) (Fig. 24.3). Particularly in the case of a puncture in the cervical spine, flexed positioning of the head is important.

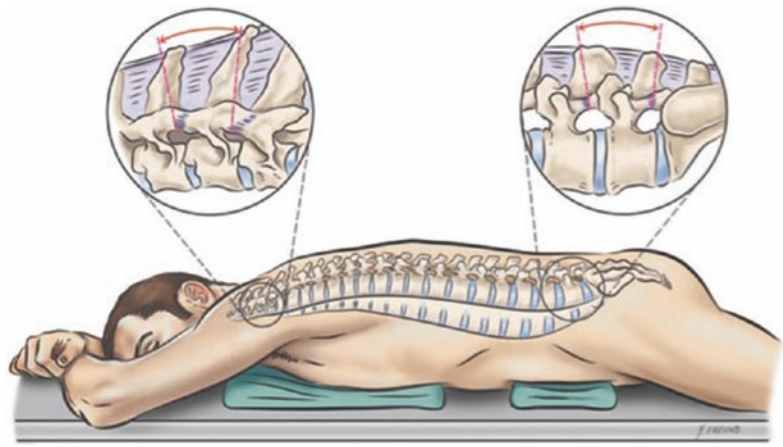


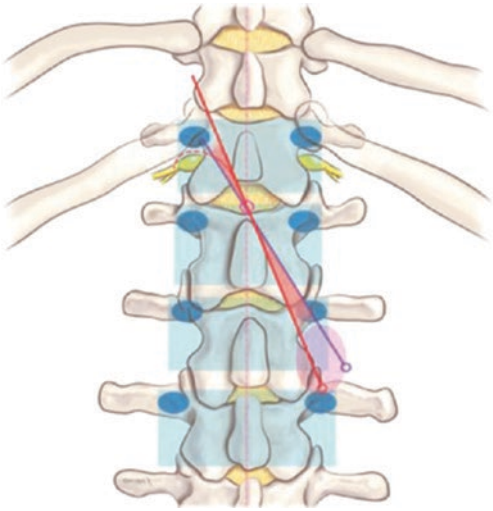
Fig. 24.3 To bring the spine into a mostly straight position prior to the procedure, de-lordosis of the patient occurs during positioning. (Courtesy of the Abbott Company)

24.6.2 C-Arm Positioning and Display of Anatomical Landmarks

Before washing the patient sterilely, it should be checked that the C-arm can be moved freely over the implantation area and that images can be taken in the lateral as well as in the a.p. beam path. This allows the correct probe position to be checked later. In the case of deep lumbar or deep cervical DRG positioning, the interlaminar space can – if necessary – be further enlarged by further de-lodging and epidural puncture facilitated.

24.6.3 Determining the Puncture Route

Under fluoroscopy, the future needle path with skin entry point, epidural access point and target point is determined and recorded on the skin. Care must be taken here to ensure that the target vertebral body is accurately set (◘ Fig. 24.4). Puncture of the intralaminar window is almost always performed in the midline, except for installations at the level of L4 and L5.



◘ **Fig. 24.4** Puncture of the spinal canal: contralateral approach shown schematically. (Courtesy of the Abbott Company)

24.6.4 Sterile Draping of the Patient

When draping, ensure that the area is large enough and that both the skin entry points, the adjacent superior and inferior neuroforamen, probe extensions and the future generator pocket are accessible.

24.6.5 Needle Entry Point and Epidural Approach

The free movement of the C-arm with lateral and a.p. rays is checked again. When piercing the skin, care should be taken to ensure that the skin in the puncture area is taut. Using the "loss-of-resistance technique", the Tuohy puncture needle is advanced slowly in the direction of the previously marked puncture path – through the ligamentum flavum – into the epidural space under constant plunger pressure (◘ Fig. 24.5a, b). This can be done with simultaneous fluoroscopy in order to detect any deviation of the needle from the planned puncture path at an early stage.

After reaching the epidural space, a guide wire is carefully inserted there to check the epidural position.

24.6.6 Inserting the Introducer Sheath

The introducers offered include a more pre-bent 90 ° introducer and a less pre-bent introducer. The probe is inserted into the introducer so that the rounded probe tip protrudes from the introducer tip (◘ Figs. 24.6 and 24.7). The supplied guide stylet should be fully inserted into the probe. Then the probe fixator is screwed shut at the end of the introducer stylet.

The irrigation port runs parallel to the introducer tip and thus serves to orient and control the introducer tip. The target vertebral body is set beam-parallel to the cover and base plate. The introducer tip is inserted under continuous fluoroscopy. When the introducer tip exits the puncture needle, the curved part

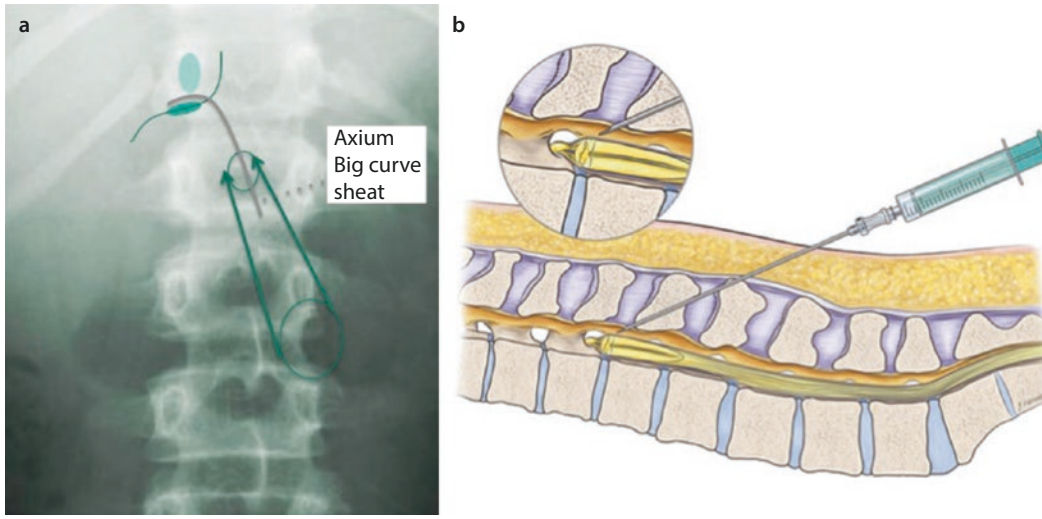


Fig. 24.5 **a** Implantation pathway in radiograph a.p.: introducer (introducer strongly curved) and target structure of the spinal ganglion. **b** Lateral view of puncture pathway. (Courtesy of the Abbott company)

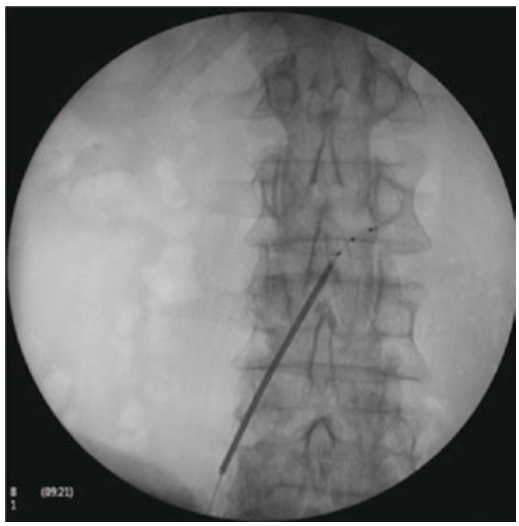


Fig. 24.6 Tuohy needle in final position and electrode during placement procedure. (Courtesy of the Abbott Company)

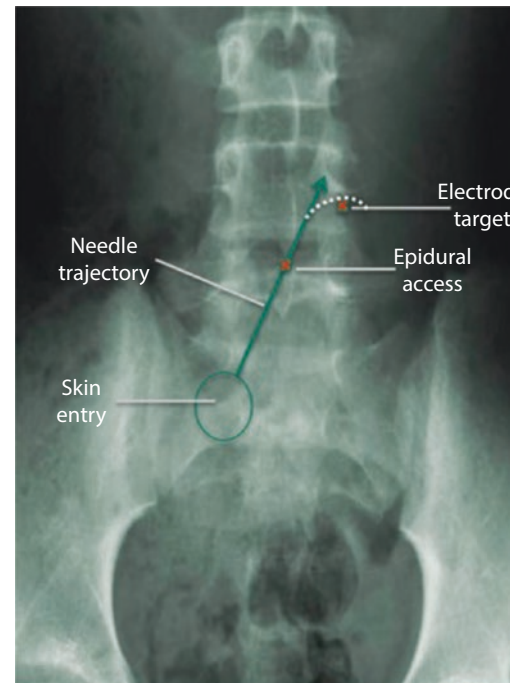


Fig. 24.7 Planning for probe implantation in the lumbar region. (Courtesy of the Abbott Company)

is guided strictly dorsally in the direction of the target pedicle (Fig. 24.8). At the target pedicle, the introducer is rotated to the 03:00 o'clock position so that the tip of the introducer remains in the dorsal portion of the neuroforamen. It is important that the introducer glides along the inferior aspect of the pedicle. At this point, the probe penetrates the intraforaminal ligaments and exits through the neuroforamen. The final position is reached when contacts 2 and 3 of a total of 4 are below the pedicle center (Fig. 24.9a, b).

A lateral X-ray should be taken to check whether the probe is positioned dorsally (Fig. 24.10a, b). It must be taken into account that the nerve roots in the lumbar

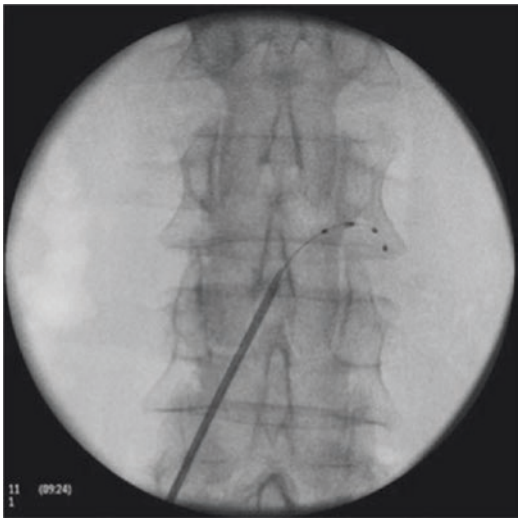


Fig. 24.8 Aimed probe location in the foramen. (Courtesy of Abbott)

spine leave the spinal canal laterally to the front, so that the assessment of a dorsal position of the probes is not always easy.

24.6.7 Placement of Support Loops in the Epidural Space

When the final position is reached, the locking screw at the end of the introducer is loosened. With small movements, the introducer is now pulled about 1 cm out of the neuroforamen, with the free hand fixing the probe in position (Fig. 24.11). This should be done under constant fluoroscopy to avoid dislocation of the probe.

This is followed by pulling the stylet out of the probe, about 5–10 cm, which makes the tip

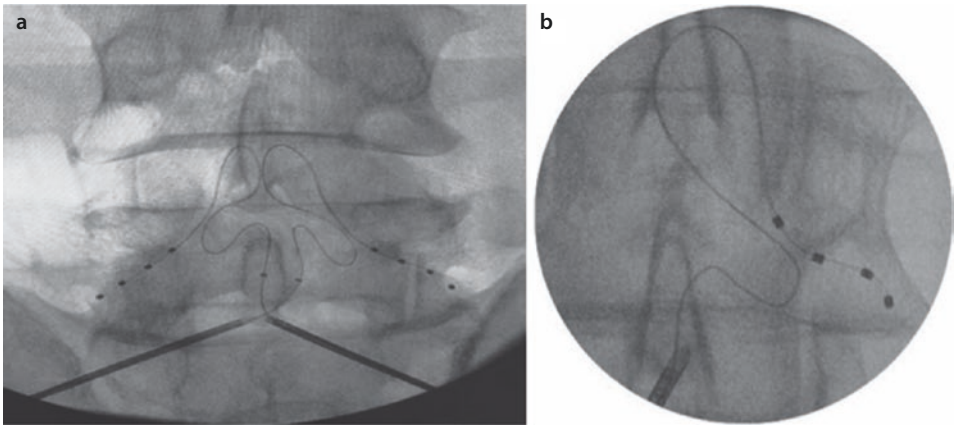


Fig. 24.9 From final bilateral **a** and unilateral **b** probe placement. (Courtesy of Abbott)

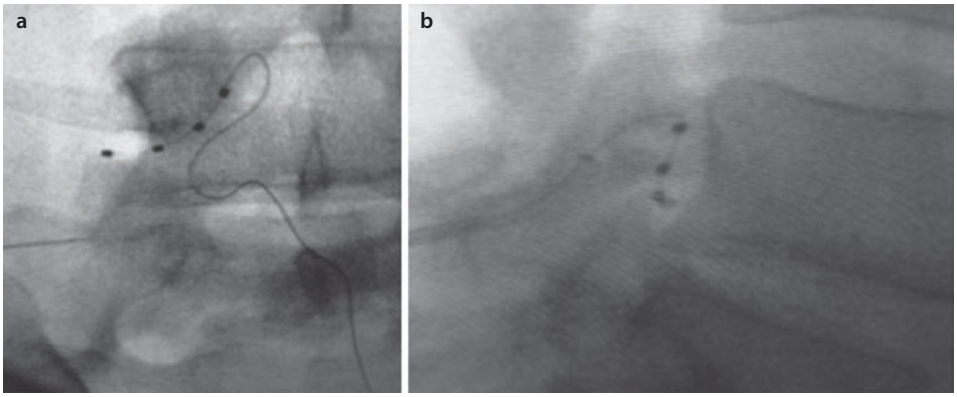


Fig. 24.10 **a, b** Radiological control of the dorsal probe position: a.p. image **a** and lateral **b**. (Courtesy of Abbott)

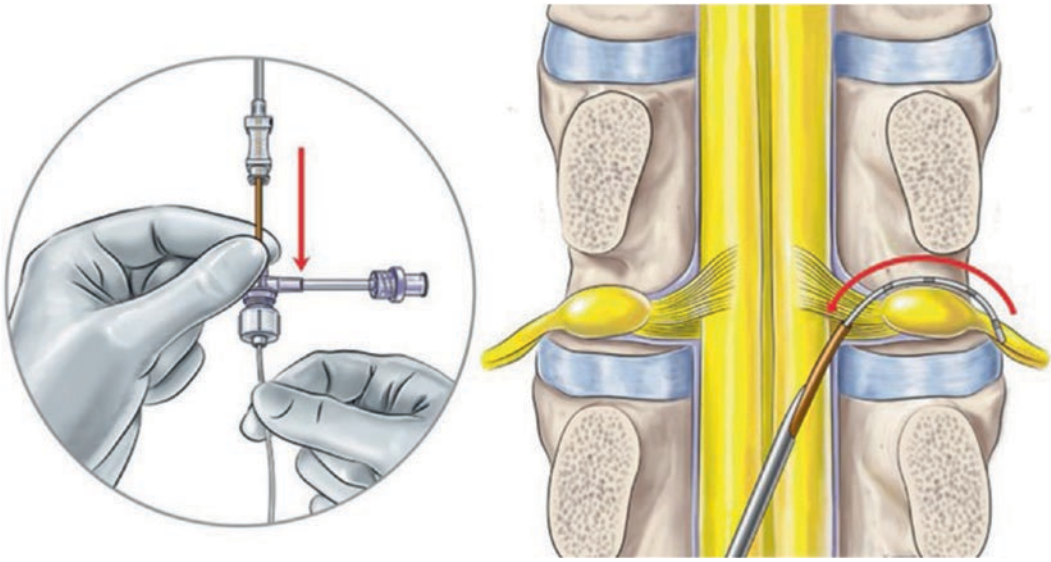


Fig. 24.11 As the introducer sheath is pulled out a small distance from the neuroforamen, the free hand stabilizes the probe position. (Courtesy of the Abbott Company)

of the probe more flexible. The introducer is then moved from the 3:00 o'clock to the 1:00 o'clock position and carefully pushed back further into the epidural space. Here, the probe rests against the medial portion of the pedicle. The probe is advanced until it is approximately at the level of the next higher neuroforamen. Now the introducer is pulled back into the needle and rotated from the 1:00 o'clock position to the 3:00 o'clock position and advanced back into the epidural space along with the probe. This creates the inferior S-loop through which the probe is supported in the epidural space. Next, the introducer is rotated from the 3:00 o'clock position to the 12:00 o'clock position, and the probe is advanced until another opposing support loop has formed.

When putting on the support slings, make sure that the slings are not crossed over.

24.6.8 Testing the Probe Position by Stimulation

To further test the probe position, a stimulation check should be performed. In the awake patient this is the most reliable way to correct the probe position, but in the anesthetized patient this is only possible to a limited extent.

Start with a simulation strength of 4 Hz. This is slowly increased until a muscle contraction is detectable in the associated characteristic muscle and the stimulus threshold is noted. The lower stimulus threshold is then determined by slowly reducing the stimulation intensity until the contractions of the characteristic muscle are no longer perceptible. The stimulus threshold can be used to determine whether the probe is almost certainly dorsal or ventral to the ganglion. If the lower stimulus threshold is above about 1 mA, it can be assumed that the probe is dorsal to the ganglion. To achieve motor stimulation, the entire dorsal portion must be stimulated (Fig. 24.12).

24.6.9 Removal of the Delivery System, Tunnelling and Evacuation

If the probe is positioned correctly, a skin incision of about 2 cm is made cranially and caudally in the area of the skin puncture site of the Tuohy needle. The blunt dissection is then carried out down to the fascia. A subcutaneous pocket is prepared above the muscle fascia (4 × 4 cm). Under constant X-ray control, the introducer system and the puncture

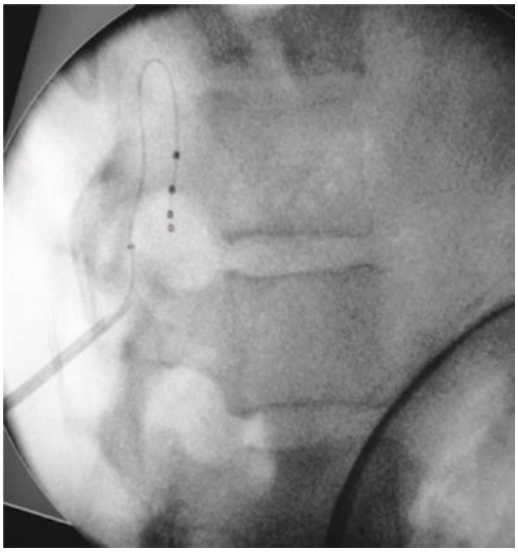


Fig. 24.12 X-ray inspection in the lateral beam path: probe optimally placed. (Courtesy of the Abbott company)

needle are carefully removed. This is followed by the placement of a relief sling that extends to the extreme ends of the prepared pocket.

In the area of the future generator pocket, a skin incision of about 4 cm is made and dissection is again performed down to the fascia. Now the subcutaneous tunneling is made from the future generator pocket in the direction of the cranial skin incision and the probe is guided out into the generator pocket. After applying a further relief sling, the connection is made with the extension, which is tunnelled subcutaneously and passed out percutaneously to the opposite side. This should be fixed with a suture.

At the end of the positive trial phase (about 10 days under stimulation), the percutaneously delivered probe can be pulled out about 2 cm and sterilely shortened to skin level. The remainder of the extension springs back under the skin and is removed in toto during generator implantation.

Antibiotic Regime

To date, there is no clear recommendation on antibiotic prophylaxis during the trial phase. Some colleagues advocate the continuation of antibiotic coverage until 1 day after capping of the percutaneously delivered extension, others limit themselves to perioperative "single-shot coverage".

There is general agreement on the respective perioperative single-shot antibiosis for probes and generator implantations.

Trial Phase

The prescribed positive trial phase should be 3–12 days. During this time, the patient must keep a pain diary to document the therapy effect. In certain cases, however, a subsequent discontinuation trial or a negative trial phase may also be useful: The therapeutic effect can thus be substantiated and an explantation of the system can presumably be reduced in the case of therapy failures.

24.7 Possible Complications

In addition to the typical complications of spinal cord therapy procedures, probe dislocation and cerebrospinal fluid loss syndrome should be mentioned in particular. Following the administration of a Bloodpatch for the treatment of CSF loss syndrome, arachnoiditis may occur after the passage of blood into the CSF, which can be very painful. The likelihood of direct myelon damage is considered low if the correct implantation technique is used, but is still possible.

24.8 Results in the Literature

To better understand the possibilities of dorsal ganglion stimulation, basic pathophysiological knowledge of the spinal ganglion appears to be essential. The spinal ganglion plays a critical role in the transmission of the pain stimulus to the brain. During a pain stimulus, measurable changes in the membrane function of the ganglion occur in the spinal ganglion of the affected spinal nerve. These can be selectively stimulated without stimulating the unaffected neurons. The unique physiology of the spinal ganglion allows selective and controllable stimulation in different regions of the body, e.g. groin, knee, hip and feet, which are difficult to stimulate with conventional SCS. The anatomical

location of the spinal ganglia is predictable within the intraforaminal epidural intraspinal position surrounded by dura.

The ACCURATE trial, which compared the effectiveness of tonic SCS versus DRG stimulation in patients with complex regional pain syndrome (CRPS), demonstrated a clear superiority of DRG stimulation (Levy and Deer 2015). For example, 80% of patients with DRG stimulation had a 69.5% reduction in pain at 3 months (Levy and Deer 2015).

DRG stimulation expands the neuromodulative therapy spectrum and represents a new standard of care for localized chronic neuropathic pain. Spinal ganglion stimulation has also been shown to be effective for various chronic post-surgical pain syndromes. The prevalence of chronic knee pain after surgery is reported in the literature to be 20–50%. In a retrospective multicenter study with 13 patients, a pain reduction of 71.2% was demonstrated after a follow-up of 6 months and 2 patients no longer showed allodynia (Verrils et al. 2015).

In a cohort study of 29 patients suffering from chronic groin pain after surgical procedures, DRG stimulation resulted in a pain reduction of more than 50% in 82.6% of patients (Schu et al. 2015a). The median follow-up was 28 weeks.

There are also data on the treatment of neuropathic visceral pain syndromes, e.g. after multiple surgical abdominal interventions or chronic pancreatitis. Accordingly, in a retrospective single-enter study, spinal ganglion stimulation led to an improvement in the EQ-5D-5L (quality of life questionnaire with 5 dimensions) from 0.004 to 0.569 and to a morphine reduction of 62% (Baranidharan and Das 2014).

Phantom limb pain, which occurs in a large number of adults after limb amputation, can also be successfully treated with DRG stimulation. According to a retrospective multicenter study, 63% of treated patients achieved a pain reduction of more than 50% after a follow-up of 14.4 months (Eldabe et al. 2015).

Similarly, treatment of diabetic polyneuropathy with DRG stimulation resulted in pain reduction according to visual analogue scale (VAS) from 94.4 to 47.1 mm after a follow-up of 12.4 months (Schu et al. 2015b).

24.9 Reimbursement of Costs

While conventional SCS has been used successfully since 1967, spinal ganglion stimulation is a relatively new therapeutic procedure. The material costs of the procedure are mapped in the DRG system (Diagnosis-Related Groups system). The necessary codes, additional charges (ZEs) and grouping examples can be found in ◘ Tables 24.1, 24.2 and 24.3.

◘ **Table 24.1** OPS codes[a]

OPS	Explanation
5-039.j0 or j1	Implantation or change of neurostimulation electrodes for stimulation of spinal ganglia: one electrode for ganglion stimulation or multiple electrodes for ganglion stimulation
5-039.k1	Implantation or change of a neurostimulator for stimulation of spinal ganglia with implantation or change of a neurostimulation electrode: Multi-channel stimulator, fully implantable, non-rechargeable
5-039.m1	Change of neurostimulator for spinal ganglia stimulation without change of neurostimulation electrode: multi-channel stimulator, fully implantable, non-rechargeable
5-039.b	Revision of neurostimulators for epidural spinal cord stimulation and anterior root stimulation
5-039.c6 or c7	Revision of electrodes: spinal ganglion, one electrode or spinal ganglion, several electrodes

[a]Own representation based on data from the German Institute of Medical Documentation and Information (DIMDI), Operationen- und Prozedurenschlüssel (OPS) Version 2017, available at:
► https://www.dimdi.de/static/de/klassi/ops/kodesuche/onlinefassungen/opshtml2017/23.AUG2017

Table 24.2 Additional charges[a]

ZE	Explanation	Amount (in €)
ZE140	Neurostimulators for spinal cord stimulation or for stimulation of the peripheral nervous system, multi-channel stimulator, non-rechargeable, with probe implantation	11,425.21
ZE141	Neurostimulators for spinal cord stimulation or for stimulation of the peripheral nervous system, multi-channel stimulator, non-rechargeable, without probe implantation	10,175.63

[a]Own presentation based on data from Institut für das Entgeltsystem im Krankenhaus gGmbH (InEK) 2017. G-DRG version 2017: Fallpauschalenkatalog, available at: ► http://www.g-drg.de/G-DRG-System_2017/Fallpauschalen-Katalog2/Fallpauschalen-Katalog_2017 (23.AUG2017)

Table 24.3 DRG grouping examples and overall calculation based on the federal base rate of € 3376.11 for the indication knee pain[a,b]

Case	ICD	OPS	DRG	DRG revenue (in €)	ZE proceeds (ZE140) (in €)	Total proceeds (in €)
Testing	M79.66 (knee pain)	5-039.j1	I28A (complex operations on connective tissue)	7265,39	Not specified	7265.39
Implantation	M79.66	5-039.k1 if necessary 5-039.j1	I28A	7265,39	11.425,21	18,690.60
						25,955.99

[a]The second stay takes place after the upper limit length of stay has expired, e.g. after 16 days
[b]Own presentation based on data from the German Institute of Medical Documentation and Information (DIMDI). ICD-10-GM Version 2017: International Statistical Classification of Diseases and Related Health Problems, tenth Revision, German Modification, Version 2017, available at: ► http://www.dimdi.de/static/de/klassi/icd-10-gm/kodesuche/onlinefassungen/htmlgm2017/index.htm. German Institute of Medical Documentation and Information (DIMDI), OPS Version 2017, Operation and Procedure Codes, available at: ► https://www.dimdi.de/static/de/klassi/ops/kodesuche/onlinefassungen/opshtml2017/. Institut für das Entgeltsystem im Krankenhaus gGmbH (InEK) 2017, G-DRG Version 2017: Fallpauschalenkatalog available at: ► http://www.g-drg.de/G-DRG-System_2017/Fallpauschalen-Katalog2/Fallpauschalen-Katalog_2017. 3 M, 3 M Suite, Version 3.5.11, Status: 19.12.2016 (Grouper), 3 M Medica Zweigniederlassung der 3 M Deutschland GmbH in Neuss, 2017

24.10 Conclusion and Clinical Relevance

The prominent role of the dorsal root ganglion in pain processing and its predictable anatomical localization makes it an ideal treatment target for various localized chronic neuropathic pain syndromes.

With careful patient selection and exhaustion of conservative therapy, target SCS or DRG stimulation is now an indispensable treatment for neuropathic pain syndromes. As with all neuromodulative therapy methods, these are non-ablative procedures that allow patients to try out this form of therapy during the positive trial phase.

In our opinion, home testing, i.e. the possibility of testing the therapy method under one's own real living conditions at home, is a special feature that few other therapy methods make possible in this way.

In the hands of the experienced, this therapy method represents a safe and low-complication treatment method. The initially high therapy costs are often offset by higher long-term treatment costs. The primary goal should be a restoration of the ability to work and return to working life of the affected patients and ultimately a gain in quality of life.

References

Aldskogius H, Kozlova EN (1998) Central neuron-glial and glial-glial interactions following axon injury. Prog Neurobiol 55:1–26

Baggioline M (1998) Chemokines and leukocyte traffic. Nature 392(6676):565–568

Ballabh P et al (2004) The blood-brain barrier – an overview: structure, regulation and clinical implications. Neurobiol Dis 16(1):1–3

Baranidharan G, Das S (2014) Dorsal root ganlion (DRG) and visceral pain: sustained quality of life (QoL) improvement and stable pain reliefdemonstrate that targeted spinal cord stimulation is a viable therapy. (Vortrag am Jahrestreffen der North American Neuromodulation Society 2014)

Brack A et al (2004) Mobilization of opioide-containing polymorphonuclear cells by hematopoietic growth factors and influence on inflammatory pain. Anesth 100(1):149–157

Chessel IP et al (2005) Disruption of the P2X7 purinoreceptor gene abolishes chronic inflammatory and neuropathic pain. Pain 114(3):386–396

Choi JL et al (2010) Peripheral inflammation induces tumor necrosis factor dependent AMPA receptor trafficking and AKT phosphorylation in spinal cord in addition to pain behavior. Pain 149(2):243–253

Colburn RW et al (1999) The effect of site and type of nerve injury on spinal glia activation and neuropathic pain behavior. Exp Neurol 157(2):289–304

Deer TR et al (2013) Interventional perspectives on the dorsal root ganglion as a target for the treatment of chronic pain: a review. J Minim Invasive Surg Pain 1:23–33

Deer TR et al (2017) Dorsal root ganglion stimulation yielded higher treatment success rate for complex regional pain syndrome and causalgia at 3 ans 12 months: a randomized comparative trial. Pain 158(4):669–681

DeLeo JA et al (2004) Neuroimmune activation and neuroinflammation in chronic pain and opioid tolerance/hyperalgesia. Neuroscientist 10(1):40–52

Devor M (1999) Unexplained peculiarities of the dorsal root ganglion. Pain Suppl 6:27–35

Eldabe S et al (2015) Neurophysiology of the dorsal root ganglion (DRG): a translational premise for the use of targeted spinal cord stimulation in the treatment of phantom limb pain (PLP). (abstract) neuromodulation Technol neural. Interface 18(7):610–616

Gao YJ, Ji RR (2010) Chemokines, neuronal-glia interactions, and central processing of neuropathic pain. Pharmacol Ther 126:56–68

Geis C et al (2010) Evoked pain behaviour and spinal glia activation is dependent on tumor necrosis factor receptor 1 and 2 in a mouse model of bone cancer pain. Pain 149(2):243–253

Hasegawa T, An HS, Haughton VM (1993) Imaging anatomy of the lateral lumbar spinal canal. Semin Ultrasound CT MR 14(6):404–413

Hasegawa T et al (1996) Morphometric analysis of the lumbosacral nerve roots and dorsal root ganglia by magnetic resonance imaging. Spine 21(9):1005–1009

Hjerling-Leffleler J et al (2000) Emergence of functional sensory subtypes as defined by transient receptor potential channel expression. J Neurosci 27:2430–2435

Hogan QH (2010) Labat lecture: the primary sensory neuron: where it is, what it does, and why it matters. Reg Anaesthesia Pain Med 35:306–311

Hu PM, McLachlan EM (2002) Macrophage and lymphocyte invasion of dorsal root ganglia after peripheral nerve lesions in the rat. Neuroscience 112:23–38

Ignatowski TA et al (1999) Brain derived TNF "nature neuroscience". Brain Res 841(1–2):70–77

Kamiya H et al (2006) Degeneration of the Golgi and neuronal loss in dorsal root ganglia in diabetic bio breeding/Worcester rats. Diabetologia 49:2763–2774

Khan AA et al (2011) Morphological heterogeneity in the cervical dorsal root ganglion neurons of mice. Curr Neurobiol 2(2):125–128

Kiguchi N et al (2012) Chemokines and cytokines in neuroinflammation leading to neuropathic pain. Curr Opin Pharmacol 12(1):55–61

Krames ES (2014) The role of the dorsal root ganglion in the development of neuropathic pain. Pain Med 15(10):1669–1685

Lee KH et al (1986) Correlation of cell body size, axon size, and signal conduction velocity for individually labeled dorsal root ganglion cells in the cat. J Comp Neurol 243:335–346

Levy R, Deer T (2015) A prospective, randomized, multi-center controlled clinical trial to asses the safety and efficacy of the Spinal Modulation Axium TM Neurostimulator System in the treatment of chronic pain. (Vortrag am Jahrestreffen der North American Neuromodulation Society 2015)

Nakamae T et al (2011) Pharmacological inhibition of tumor necrosis factor may reduce pain behavior changes induced by experimental disc puncture in the rat: an experimental study in rats. Spine 36(4):E232–E236

Okamoto K et al (2001) Pro- and anti-inflammatory cytokine gene expressión in rat sciatic nerve chronic constrictive injury Modelo f neuropathic pain. Exp Neurol 169:386–391

Raghavendra V et al (2003) Inhibition of microglial activation attenuates the development but not existing hypersensivity in a rat model of neuropathy. J Pharmacol Exp Ther 306:184–187

Rambourg A et al (1983) Ultrastructural features of 6 types of neurons in rat dorsal root ganglia. J Neurocytol 12:47–66

Regan LJ et al (1986) Selective expression of endogenous lactose-binding lectins and lactoseries glycoconjugates in subsets of rat sensory neurons. Proc Natl Acad Sci U S A 83(7):2248–2252

Renno T et al (1995) TNF-alpha expressión by experimental allergic encephalomyelitis. Regulation by Th1cytokines. J Immunol 154(2):944–953

Reyes-Gibby CC et al (2009) Role of inflammation gene polymorphisms on pain severity in lung cancer patients. Cancer Epidemiol Biomark Prev 18(10):2636–2642

Scholz J, Woolf CJ (2007) The neuropathic pain triad: neurons immune cells and glia. Nat Neurosci 10(11):1361–1368

Schu S et al (2015a) Spinal cord stimulation of the dorsal root ganglion for groin pain – a retrospective review. Pain Pract 15(4):293–299

Schu S et al (2015b) Sustained pain relief in painful diabetic neuropathy (PDN) achieved through target spinal cord stimulation (SCS): a retrospective case series. (abstract) neuromodulation Technol neural. Interface 18:e91

Schweitzer S et al (2001) Intrathecal interleukin-1-recptor antagonist in combination with soluble tumor necrosis factor receptor exhibits an anti-allodynic action in a rat model of neuropathic pain. Neuroscience 103(2):529–539

Segond von Blanchet G et al (2009) Experimental artritis causes tumor necrosis factor-dependent infiltration of macrophages into dorsal root ganglia which correlates with pain related behavior. Pain 145(1–2):151–159

Sekiguchi M et al (2009) Comparison of neuropathic pain and neuronal apoptosis following nerve root or spinal nerve compression. Eur Spine J 18:1978–1985

Sheng SR et al (2010) Anatomy of large animal spines and its comparison to the human spine: a systemic review. Eur Spine J 19(1):46–55

Shimizu F et al (2011) Peripheral nerve pericytes modify the blood-nerve barrier function and tight junctional molecules through the secretion of various soluble factors. J Cell Physiol 226(1):255–266

Sommer C, Kress M (2004) Recent findings on how proinflammatory cytokines cause pain: peripheral mechanism in inflammatory and neuropathic hyperalgesia. Neurosci Lett 361:184–187

Tandrup TA (1993) Method for unbiased and efficient estimation of number and mean volume of specified neuron subtypes in rat dorsal root ganglion. J Comp Neurol 329:269–276

Verrils P et al (2015) A multicenter retrospective review of chronic postsurgical knee pain treated with targeted spinal cord stimulation (SCS). Neuromodulation Technol Neural Interface 18:e85

Wagner R, Meyers RR (1996) Endoneural injection of TMF-alpha produces neuropathic pain behaviors. Neuroreport 7(18):2897–2901

Watkins LR et al (1995) Immune activation: the role of pro-inflammatory cytokines in inflammation, illness responses and pathological pain states. Pain 63(3):289–302

Whie FA et al (2005) Chemokines: integrators of pain and inflammation. Nat Rev Drug Discov 4:834–844

White FA et al (2007) Chemokines and the pathophysiology of neuropathic pain. PNAS 104(51):20151–20158

Woolf CJ, Mannion RJ (1999) Neuropathic pain: aetiology, symptoms, mechanisms, and management. Lancet 353(9168):1959–1964

Xiao HS et al (2002) Identification of gene expressión profile of dorsal root ganglion in the rat peripherals axotomy model of neuropathic pain. Proc Natl Acad Sci U S A 99(12):8360–8365

Zalenka M et al (2005) Interneural injection of interleukin-1beta and tumor necrosis factor alpha into rat sciatic nerve at physiological doses induces signs of neuropathic pain. Pain 116(3):257–263

Zloznick A, Yoshei O (2000) Chemokines: a new classification review system and their role in immunity. Immunity 12(2):121–127

Cervical Disc Prosthesis

R. Firsching

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_25

25.1 Indication

The most common surgical technique used since World War 2 for cervical disc herniations is the evacuation of the herniated disc via a ventral approach and subsequent fusion with or without a placeholder in the intervertebral space. With this technique, motion of the operated segment of the cervical spine is usually lost. This loss of motion is undoubtedly associated with increased stress on the adjacent spinal segments when the cervical spine is moved. As a result of such fusion surgery, radiologically confirmed degeneration has been described in up to 92% of the segments adjacent to the fusion over the course of 60 months (Goffin et al. 2004). Using the same measurements, significant increases in pressure were measured in the intervertebral spaces of the adjacent segments in experimental studies following cervical fusion when the cervical spine was moved compared to non-fused cervical spines (Cunningham et al. 2003; Eck et al. 2002).

Since about 2000, disc prostheses have become commercially available. In the meantime, there is a hardly manageable number of models. Already in 2005, clinically acceptable results over several years after implantation of disc prostheses were reported (Firsching et al. 2005). The indication for implantation will probably be judged and thus made very differently in each individual case. Certainly, a disc prosthesis is not indicated if the segment to be operated on can already be considered fused preoperatively, or if the range of motion is less than 2°. In such patients, it is generally not to be expected that the range of motion will increase after insertion of a prosthesis due to the loss of motion of the small vertebral joints. It is one of the signs of aging that the range of motion of the joints gradually decreases. This also applies to the cervical spine. The advantage of an intervertebral disc prosthesis compared to a fusion is that in the long term an increased load on the adjacent segments is avoided. As a result, the disc prosthesis is more likely to be of benefit to patients who develop a herniated disc at a young age. In a separate prospective study, cervical prostheses were therefore only used up to the age of 60 (Firsching et al. 2005). The indication for surgery for cervical disc herniation is urgent for motor paralysis and relative for pain depending on duration and intensity.

25.2 Preinterventional Diagnostics

The diagnosis of disc disease of the cervical spine requires a neurological examination after careful history taking. The imaging diagnostic tool of choice is magnetic resonance imaging (MRI), alternatively, for example, in the case of non-MRI-compatible implants, e.g. pacemakers, heart valves, etc., computed tomography (CT), if necessary after conventional myelography. Discography seems to be used less frequently in recent years. Conventional lateral functional radiographs can provide information on the preoperative mobility of the affected segments.

25.3 Operational Requirements

For the removal of the cervical intervertebral space, the microsurgical technique is to be regarded as the standard for reasons of safety, particularly because of the proximity to the usually compressed dural sac and the nerve tissue contained therein. In addition to an adequate surgical microscope, intraoperative C-arm fluoroscopy is essential.

Commercial providers of cervical disc prostheses often offer a special set of instruments with prosthesis holders, vertebral spreaders, cutters, etc.

25.4 Implementation of the Intervention

As a rule, after ventral opening via a 4-cm skin incision and an access between the carotid and esophagus, the cervical spine is exposed above the affected intervertebral space and, after incision of the anterior longitudinal ligament, the intervertebral disc is removed from ventrally. After microsurgical resection of the posterior longitudinal ligament and, if necessary, removal of osteophytes across the width of the

spinal canal, the intervertebral space can be spread open over the holding rods inserted into the adjacent vertebral bodies and the appropriately sized prosthesis is inserted. In many models, the prostheses are driven into the intervertebral space. It is also possible to mill the contour of the prosthesis into the adjacent cover plates and then fit the prosthesis into this precisely pre-milled prosthesis bed. As secondary bleeding can also occur from the ground bone, redon drainage is recommended. Extensive wound irrigation and removal of all bone flour is performed to prevent heterotopic ossification. Postoperatively, close monitoring of neurological functions and respiration for 24 h is advisable.

25.5 Possible Complications

Bleeding, inflammation or dislocation of the prosthesis are reported with a frequency <2% (Firsching et al. 2005). Compared to the conventional technique of fusion, implantation of a disc prosthesis does not seem to pose any additional risk (Hahne 2006; Goffin et al. 2002; Zimmerman 2017).

25.6 Results in the Literature

The treatment results in terms of postoperative follow-up, neurological disorders, pain and other risks are by no means less favourable than after conventional procedures (Hahne 2006; Goffin et al. 2003). Deaths or inflammation were not observed in our own experience between 2002 and 2015. Immediate postoperative neurological deterioration or bleeding was observed in <1% of operated patients (Hahne 2006). After surgery on the cervical spine with prostheses and discharge from inpatient treatment, no case was known in the clinic here in which a prosthesis had to be explanted again. In 3 cases, calcification in the area of the prosthesis with dorsal osteophyte formation occurred after one or more years of treatment. In these cases, grinding down the osteophytes in a follow-up operation while leaving the intervertebral disc prosthesis in place contributed to a complete recovery.

The mobility of the vertebral segments fitted with a prosthesis could be compared in some studies over years after the operation. It was found that approximately 20% of prostheses do not move or only move <2° within 2 years. This loss of mobility usually seems to develop within the first postoperative year. If the mobility was still preserved after 1 year, the mobility was usually confirmed to be still preserved in the following years as well (Zimmerman 2017).

The postoperative pain of patients compared to the preoperative state can be estimated, among other things, by analgesic medication. A long-term study (Zimmerman 2017) found a reduction in analgesic medication from 81% preoperatively to 30% postoperatively 10–13 years later. Aghayev et al. (2013) reported a reduction in analgesics from 82% to 2.8% within 5 years postoperatively, Zhang et al. (2014) reported a reduction from 83.2% to 15% within 4 years postoperatively. According to a study by Quan et al. (2011), approximately 50% of patients were pain-free 8 years after surgery. The data in the literature are only comparable to a limited extent, as it is not always apparent how severe the pain was and whether it affected the cervical spine or the arms. A significant improvement in quality of life 3–5 years after surgery has also been reported (Ding et al. 2012).

25.6.1 Connecting Segment Disease

Adjunctive segment disease (ASE) after cervical disc surgery is frequently observed. The exact cause of why one patient develops it and another does not is unclear. After fusion, it is suspected that the development of ASE is promoted by the additional mechanical load on the connecting segments. Since this additional mechanical load is absent in a functioning disc prosthesis, it should be possible to noticeably reduce the frequency of ASE with prostheses compared to fusion surgery after a sufficiently long period of time. However, the sufficient period of time for this is unclear. In the currently longest follow-up in the work of Zimmerman (2017), the observation period is 10–13 years after implantation of

a cervical disc prosthesis. During the median period of 12.2 years, 6 of 73 patients (8.2% of cases) underwent reoperation in an adjacent segment, a rate of 6%.

25

25.7 Reimbursement of Costs

DRG code 5-839.10 "Implantation of intervertebral disc endoprosthesis over one segment" is the billing recommendation of the German Medical Association (as of August 2018) for Germany according to GOÄ for the insertion of an intervertebral disc prosthesis: the insertion of a mostly cervical or lumbar intervertebral disc prosthesis is to be billed according to no. 2287 GOÄ analogously in addition to an underlying main service (e.g. no. 2577 GOÄ).

25.8 Conclusion and Clinical Relevance

Cervical disc prostheses are particularly suitable for disc herniations with sequestra and unrestricted mobility of the affected segment at a younger age. In the seventh decade of life, the range of motion of the cervical spine is often already considerably restricted, so that the benefit of maintaining mobility is limited, but there are exceptions to this (Figs. 25.1 and 25.2). Scientifically, there is no evidence that it is better to preserve mobility of the cervical spine. However, it seems plausible that over decades this will alleviate stress on the adjacent segments. Operationally, the implantation of a cervical disc prosthesis is in no way more risky than the conventional procedure of fusion.

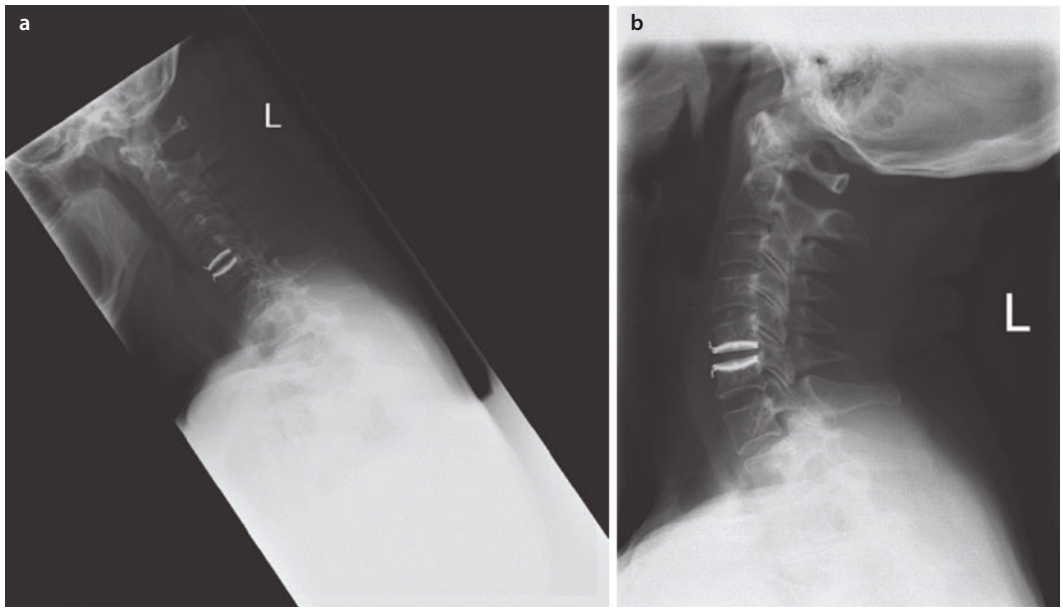


Fig. 25.1 62-year-old female patient who had a cervical disc prosthesis implanted 2 years ago. X-ray images in **a** anteflexion and **b** retroflexion

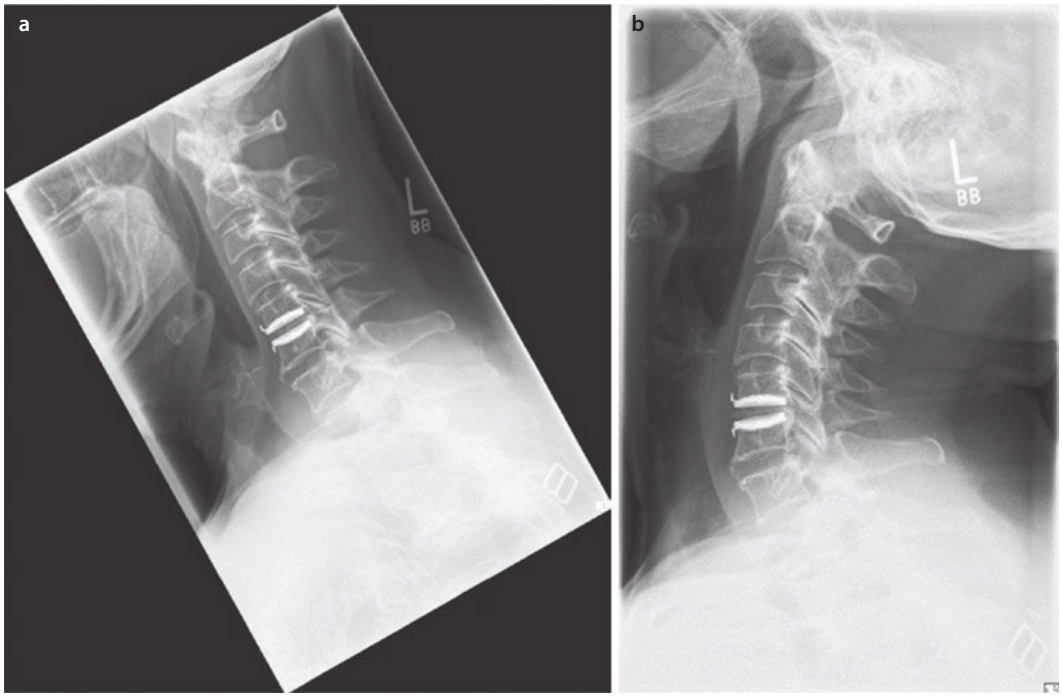


Fig. 25.2 **a, b** Same patient as in Fig. 25.1, even 13 years after the operation the patient is free of complaints. A movement of 8° can be detected in the operated segment. X-ray images in **a** anteflexion, **b** retroflexion

References

Aghayev E, Bärlocher C, Sgier F, Hasdemir M, Steinsiepe KF, Wernli F, Porchert F, Hausmann O, Ramadan A, Maestretti G, Ebeling U (2013) Five-year results of cervical disc prostheses in the SWISSspine registry. Eur Spine J 22(8):1723–1730

Cunningham BW, Gordon JD, Dmitriev AE, Hu N, McAfee PC (2003) Biomechanical evaluation of total disc replacement arthroplasty: an in vitro human cadaveric model. Spine 28(20S):S110–S117

Ding C, Hong Y, Liu H, Shi R, Hu T, Li T (2012) Intermediate clinical outcome of Bryan cervical disc replacement for degenerative disk disease and its effect on adjacent segment disks. Orthopedics 35(6):e909–e916

Eck JC, Humphreys SC, Lim TH, Jeong ST, Kim JG, Hodges SD, An HS (2002) Biomechanical study on the effect of cervical spine fusion on adjacent-level intradiscal pressure and segmental motion. Spine 27(22):2431–2434

Firsching R, Jöllenbeck B, Hahne R (2005) Bandscheibenprothesen für die Halswirbelsäule. Ärzteblatt Sachsen-Anhalt 16:48–51

Goffin J, Casey A, Kehr P, Liebig K et al (2002) Preliminary clinical experience with the Bryan cervical disc prosthesis. Neurosurgery 51(3):840–847

Goffin J, Geusens E, Vantomme N, Quintens E, Waerzeggers Y, Depreitere B, van Calenbergh F, van Loon J (2004) Long-term follow-up after interbody fusion of the cervical spine. J Spinal Disord Tech 17(2):79–85

Goffin J, Van Calenbergh F, van Loon J et al (2003) Intermediate follow-up after treatment of degenerative disc disease with the Bryan cervical disc prosthesis: single-level and bi-level. Spine 28(24):2673–2678

Hahne R (2006) Prospektive klinische Verlaufsbeobachtung von 100 Patienten nach Implantation einer zervikalen Bandscheibenprothese (BRYANTM cervical disc system). Dissertationsschrift Medizinische Fakultät der Universität Magdeburg

Quan GM, Vital J-M, Hansen S, Pointillart V (2011) Eight-year clinical and radiological follow-up of the Bryan cervical disc arthroplasty. Spine 36(8):639–646

Zhang Z, Zhu W, Zhu L, Du Y (2014) Midterm outcomes of total cervical total disc replacement with Bryan prosthesis. Eur J Orthop Surg Traumatol 24(1):275–281

Zimmerman L (2017) Langzeitergebnisse nach zervikaler Bandscheibenersatzoperation bei Verwendung der Bryan-Prothese. Inaugural-Dissertation Medizinische Fakultät der Universität Magdeburg

Vertebro and Kyphoplasty

Jörg Jerosch

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_26

26.1 Indication

Osteoporosis is a metabolic disease of bone characterized by loss of bone substance, changes in bone microarchitecture, and consequent loss of bone strength (Consensus Development Conference 1993). In every person over 40 years of age, bone mass decreases by 0.5–1.5% per year (Minne 1991). However, the WHO only speaks of osteoporosis when measurable bone density falls below −2.5 standard deviations below the peak bone density value for young Caucasian women ("peak bone mass") (Kanis and WHO Study Group 1994). Of all 50-year-old women, approximately 15.6% will suffer vertebral fractures, 17.5% will suffer hip fractures, and 39.7% will suffer some fracture during the life ahead ("lifetime risk"). While femoral neck fractures almost always lead to hospitalization, vertebral body fractures are still often neglected therapeutically.

Since there is no gold standard for the determination of a vertebral fracture (O'Neill and Silman 1997) and since the data are partly based on different determination methods, the incidence of vertebral fractures is reported very differently in the literature. It is therefore very difficult to obtain reliable data on the true prevalence of vertebral fractures. Depending on the definition used, the figures vary between 10% and 25% for women over 50 years of age (Arden and Cooper 1998).

Cooper et al. (1992) report that the age- and sex-adjusted incidence of vertebral fractures is 117 per 100,000 population and that a total of 25% of women over 50 years of age have one or more vertebral fractures. Taking these data into account, there will be a 60% increase in the US population over 50 years of age between 2000 and 2025. Unlike fractures of the proximal femur or radius, osteoporotic-related spinal compression fractures are often not associated with adequate trauma. It is thought that only about 30% of vertebral fractures become clinically apparent (Cooper et al. 1992; Svedbom et al. 2013). Significant morbidity often occurs, manifested by persistent and chronic back pain.

However, irreversible spinal deformities with clinically relevant kyphosis are also found, resulting in a reduction in health-related quality of life (HRQOL) (Silverman et al. 2001). Hallberg showed that HRQOL scores at 3- to 24-month follow-up after osteoporotic fractures in patients aged 55–75 years were significantly worse in terms of both physical and mental limitation than those without relevant kyphosis. Vertebral fractures are further shown to have a significantly greater and longer impact on HRQOL than radial or humeral fractures.

Physical consequences of vertebral fractures are loss of height, hunchback ("widow's hump") and a reduction in the distance between the costal arches and the iliac crest (Leidig-Bruckner et al. 1997; Leidig et al. 1990). Once these changes have occurred, they are irreversible. After fresh vertebral fractures, patients sometimes experience acute pain and thus agonizing discomfort (Huang et al. 1996a, b). Silverman (1992) states that acute fractures cause pain for 4–6 weeks. The causes of this pain are thought to be local mediators transmitted through multiple pain fiber systems in the vertebral body. However, only about 30% of fractures are recorded clinically (O'Neill and Silman 1997; Ross 1997). This complicates the generalizability of study results conducted with patients who already have clinically manifest vertebral fractures. Increasing spinal destruction is associated with limitations in general mobility and weight-bearing capacity in general. In connection with the deformations of the vertebral bodies resulting from bone fractures and the subsequent deformation of the entire axial skeleton, chronic complaints occur, such as pain, restrictions in general functional and performance capabilities and – as is often the case with chronic pain careers – also a reduction in quality of life (Scholz and Minne 1998).

Considerable pain, which significantly reduces the quality of life, is repeatedly named as a leading symptom in patients with osteoporosis (Ross 1997) and is thus regarded as the main burdening factor for health-related quality of life.

The thoracolumbar transition appears to be particularly unfavourable biomechanically. Once a fracture has occurred, rapidly progressive courses are repeatedly observed here, even with only slight deformity (Fig. 26.1).

Osteoporotic vertebral fracture is associated with a significantly increased mortality rate. Lau found that all-cause mortality following vertebral fracture was two times that of age-matched non-injured collectives. Survival after fracture diagnosis was estimated using the Kaplan-Meier method, as follows: after 3 years 53.9%, after 5 years 30.9% and after 7 years only 10.5%. This was significantly lower than in age-matched comparison collectives. Mortality appears to be greater in males than females, with the greatest differences found in younger patients reported that life expectancy is between 2.2 and 7.3 years greater in patients who received cement augmentation compared to non-operatively treated patients. Kado et al. (2003) showed that women with a new fracture had an age-adjusted 32% increased risk of mortality compared to women without a vertebral fracture. The authors concluded that the increased mortality risk is primarily due to weight loss and lack of physical activity. The overall mortality risk is 25% greater for vertebral fractures than for hip fractures (Cauley et al. 2000).

In 2005, there were 2.5 million outpatient physician contacts, 34,000 hospital admissions, and 180,000 nurse home visits in the United States due to osteoporotic-related vertebral fractures, with a total direct cost of $17 billion.

The treatment of osteoporosis-related vertebral body fracture proves to be extremely difficult. The pain is usually a consequence of the acute bone failure rather than the general disease process. Very often the fracture is not initially recognized, so that only the severe pain indicates a bony injury. Basically, numerous and different treatment concepts are offered. The main focus of treatment should be the elimination of the pain phases and the prophylaxis of progressive kyphosis, which in turn can lead to progressive persistent back pain due to unfavourable static changes.

In addition to drug treatment, which is used particularly in prophylaxis, the therapeutic spectrum for manifest fractures ranges from conservative therapy measures with analgesia/bed rest and brace or girdle treatment for

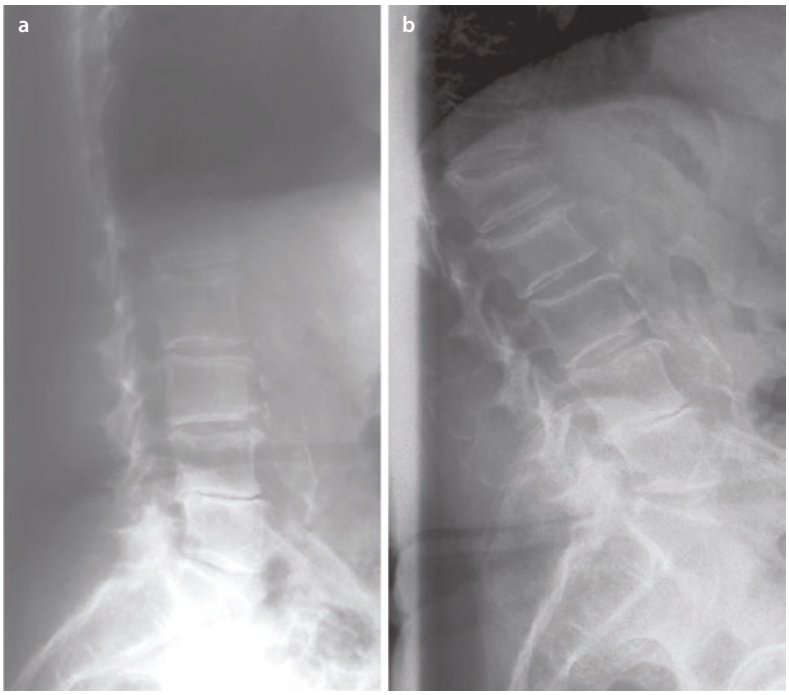


Fig. 26.1 From Progression of osteoporotic fractures in the thoracolumbar transition within 3 months (**a**) T0 (**b**) after 3 months

mobilization to complex stabilizing interventions. For many patients, however, major surgical interventions are no longer reasonable due to significant additional conditions. In addition, the possibility of fixation of implants in osteoporotic bone is significantly reduced.

In recent years, therefore, there has been an intensive search for ways to re-stabilize fractured vertebrae in osteoporosis patients by minimally invasive procedures and possibly even to straighten them again. In principle, there are two different techniques for this:

- percutaneous vertebroplasty (PVP) and
- the percutaneous kyphoplasty (PKP).

Most authors initially recommend a 3-week conservative therapy trial. The complaints after an osteoporotic vertebral body fracture usually last 2–3 months. A meta-analysis of randomized controlled trials (RCT) showed excellent results in both the early group (2–3 weeks) and the late group (2–3 months).

Another indication group represents the patients who are hospitalized due to their pain and functional limitations caused by the osteoporotic fracture. In these patients, cement augmentation can achieve rapid improvement and is a cost-effective measure (Svedbom et al. 2013).

Other less frequent indications are primary bone tumors such as hemangiomas or giant cell tumors, as well as secondary bone metastases with pathological fractures.

Indications and Contraindications for Vertebro- and Kyphoplasty

Indications

- Painful osteoporotic vertebral fractures that do not improve within 2–3 weeks.
- Hospitalized patients due to a painful osteoporotic vertebral body fracture
- Painful pathological fractures
- Aggressive hemangiomas of the spine

Absolute Contraindications

- Asymptomatic fractures
- Anamnestic evidence of vertebral osteomyelitis
- Allergy to bone cement or contrast medium
- Irreversible coagulopathies

Relative Contraindications

- presence of radiculopathy
- Bone protrusions against neurological structures
- More than 70% collapse of the vertebral body height
- Multiple pathological fractures
- Insufficient hospital infrastructure to deal with potential complications

26.2 Preinterventional Diagnostics

The clinical examination is often already decisive for the diagnosis of a vertebral compression fracture. The local pressure pain over an isolated spinous process is typical.

The diagnosis of a vertebral body fracture is usually made by magnetic resonance imaging. Bone scintigraphy or radiographic series in the course may also be helpful. MRI usually shows increased signal in the T2 image or STIR sequence and reduced signal in the T1 image. These changes correspond to acute edema.

26.3 Pre-Intervention Education

Although, according to the studies available to date, the complication rate of kyphoplasty and vertebroplasty is relatively low, there is always the possibility of cement leakage into the spinal canal and, due to the frequently chosen transpedicular approach, a risk of injury to the intraspinal structures. Therefore, as with spinal surgery, the information provided should list the corresponding risks, in particular the risk of neuronal damage and permanent paresis.

The very rare cases in which decompression surgery is necessary in the event of cement leakage must also be explained.

Allergic reactions can occur to the drugs used and the bone cement, and the cement injection in particular can also trigger hypotonic circulatory reactions. Pulmonary embolisms have been described several times. In the case of previously damaged lungs, the indication must be particularly strict. The patient must also be informed about the possibility of developing spondylitis/spondylodiscitis.

The alternative possibilities of conservative therapy should also be mentioned. The same applies to the risk of fractures of previously non-cemented vertebral bodies.

The radiation exposure when performing kyphoplasty or vertebroplasty is low. Nevertheless, in the event of pregnancy, there is a risk of damage to the unborn child from the X-rays.

On the question of when to perform a kyphoplasty, reference should be made to the guidelines of the German Osteological Association (DVO) on the prophylaxis, diagnosis and therapy of osteoporosis. Here it is stated with regard to kyphoplasty and vertebroplasty: "Since both methods can have complications and the indication and effect strength remain unclear in individual cases, centers that use these procedures should only consider them

- after a documented conservative therapy attempt over 3 weeks,
- after consideration (exclusion) of degenerative spinal changes as the cause of the complaint,
- After documented interdisciplinary expert case discussion."

There are corresponding forms available from the companies that produce reconnaissance forms, which should ideally be used.

26.4 Percutaneous Vertebroplasty (PVP)

The technique of percutaneous vertebroplasty (PVP) was first described in 1987 for the treatment of vertebral hemangiomas (Galibert et al. 1987). The filling material used was polymethylmetacrylate (PMMA), which has remained the material of choice to this day. The filling of vertebral bodies with bone cement has also been described several times in the context of tumor surgery (Gangi et al. 1994; Weill et al. 1996; Jensen et al. 1997). After a rapid and significant reduction in pain was usually recorded in these cases, the treatment of osteoporotic vertebral body compressions with cement augmentation also began in the mid-1990s.

26.4.1 Surgical Technique

In PVP, the fractured vertebral body is filled with liquid bone cement (PMMA), thus reinforcing its stability. The operation is performed via a percutaneously inserted hollow cannula, which is placed transpedicularly in the vertebral body. Either a sterile bone cement, which remains fluid for a relatively long time, or injectable biodegradable calcium phosphate is used. As a rule, PVP is performed under local anesthesia, which is therefore less stressful for the often multimorbid patients. Venous access is obligatory, as is monitoring of cardiovascular functions.

In clinical routine, we perform vertebroplasty in the lumbar spine region in the operating room under image converter control. The patient is positioned on the abdomen (Fig. 26.2). The back is surgically washed down sterilely several times and covered sterilely. The level to be augmented is identified under the image converter. The image converter can be sterilely repositioned intraoperatively to allow radiographic control in multiple planes during cement augmentation. The painful segment is identified preoperatively with magnetic resonance imaging. The skin and the stab canal are infiltrated with local anesthetic down to the periosteum of the affected vertebral body.

A puncture cannula is then inserted transpedicularly into the affected vertebral body. The PMMA is injected under continuous X-ray control, paying particular attention to the posterior edge of the vertebral body and potential cement extrusions anteriorly. Ideally, the cement cloud increases continuously start-

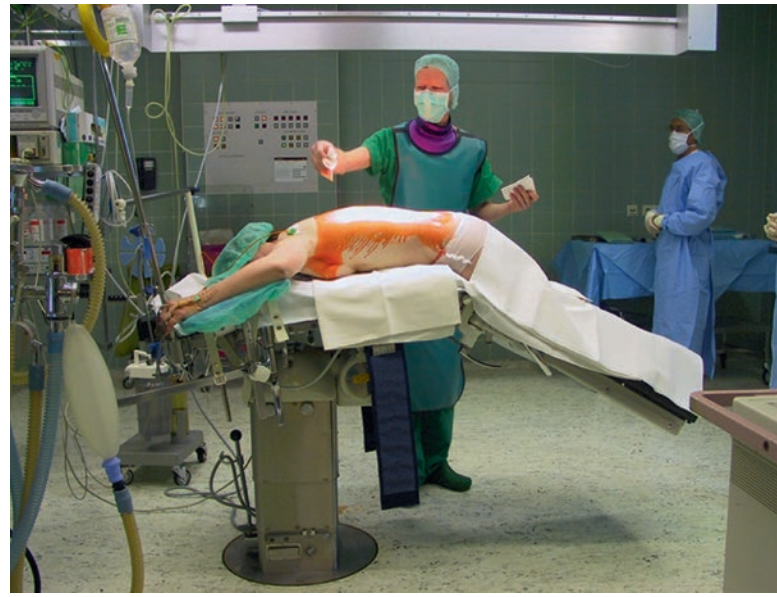


Fig. 26.2 Positioning the patient

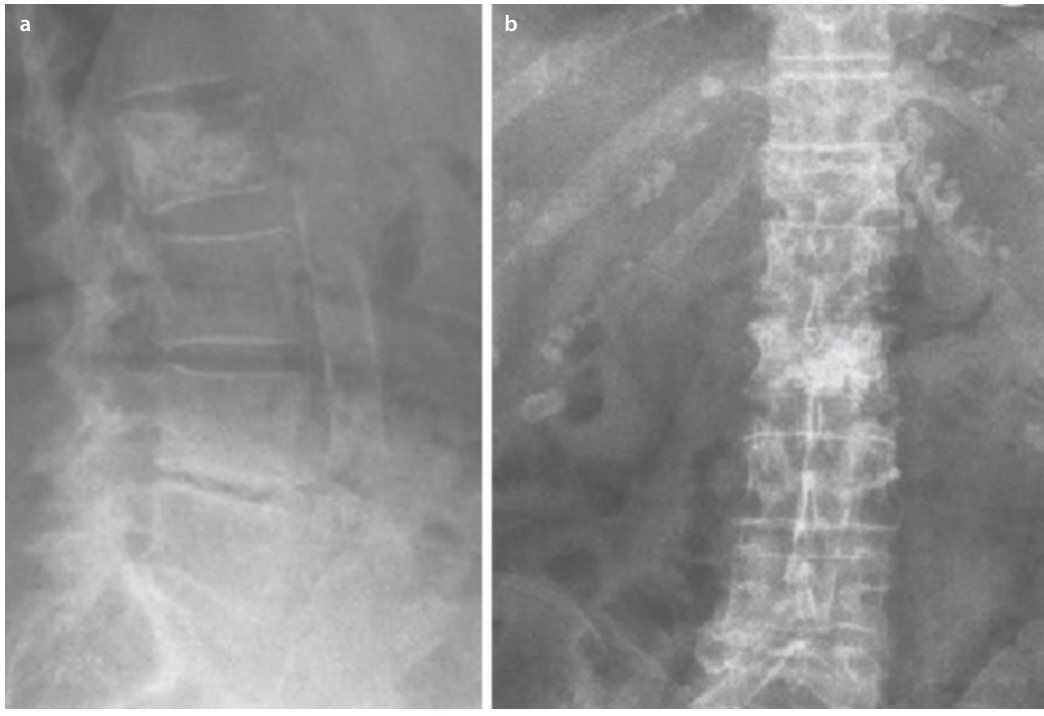


Fig. 26.3 **a, b** Postoperative X-ray in 2 planes after PVP of L2

ing from the needle tip while respecting the vertebral body frame. Cement augmentation must be stopped immediately if cement extrusions are visible and is limited by the increasing viscosity of the material. After the cement has hardened, the needles are removed and the puncture incisions closed. The patient can be mobilized immediately. Postoperatively, an X-ray control is performed (Fig. 26.3).

In the thoracic region, CT-controlled filling is indicated to avoid malpuncture (Fig. 26.4).

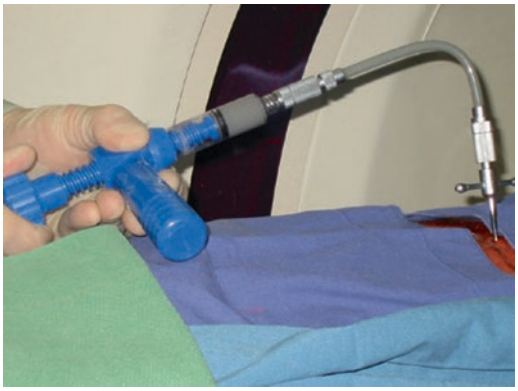


Fig. 26.4 PVP in the thoracic region under CT control

There are already various systems available on the market. These differ partly considerably in price, but especially also in the manageability of the individual systems.

26.4.2 Biomechanics and Biology

Significant stabilization of vertebral bodies after cement filling was demonstrated by Evans et al. (1995). Most studies in the literature compare the biomechanical properties of a single vertebral body after cement filling with those of a non-augmented neighbouring vertebra. As expected, it becomes clear that augmentation significantly increases both the failure strength and the stiffness of a vertebral body (Belkoff et al. 2001; Tohmeh et al. 1999).

This is particularly true for PMMA and to a slightly lesser extent for alternative materials such as calcium phosphate cements (Bai et al. 2000; Heini et al. 2001; Ikeuchi et al. 2001). Stechow and Alkalay (2001) investigated the loading capacity of fractured osteoporotic vertebral bodies before and after PVP with PMMA. The bone structure and density of 20 vertebral bodies (T6-L2) were assessed before and after PVP with X-ray and DEXA. Load capacity to fracture was determined by quasi-static combined axial compression with anterior flexion moment before and after PVP. The results showed that the bone density of the examined vertebral bodies was significantly decreased before PVP (0.52 g/cm^2; norm: 0.55 g/cm^2). Load capacity and axial stiffness were significantly increased after PVP. The authors concluded that percutaneous vertebroplasty with PMMA in fractured vertebral bodies is an effective method to significantly increase the load-bearing capacity of the vertebral bodies.

However, the effects of cementation on the stability of the non-augmented adjacent vertebra were also investigated by not testing individual vertebral bodies in comparison, but rather a motion segment as a whole (Berlemann et al. 2001a). The clinical assumption that a fracture of the adjacent, non-cemented vertebra can be induced by PMMA cementation was confirmed. This assumption has also been expressed in some clinical studies (Grados et al. 2000). However, it is also known that if a fracture is already present, the incidence of a further fracture in adjacent motion segments is statistically increased (Wasnich 1996). In this context, the question arises whether the cementation should not exceed a certain vertebral body volume (optimal augmentation volume), or whether alternative, less rigid materials are available to avoid this effect. In any case, finite element studies indicate that only 3–4 mL of bone cement is required to increase the stiffness of a compressed vertebral body back to normal values (Liebschner et al. 2001).

The experimentally developed fundamentals seem to justify an application on patients. It should be emphasized here that both the material used (bone cement) and the methodology (vertebral body filling) have demonstrated the required safety in clinical use. The use of bone cement is state of the art in arthroplasty. Long-term studies have also shown that with a stable implant position, cancellous bone can remain vital even in the cement embedding.

The question of the potential risk of heat damage in the course of cement polymerization has also been investigated. Wang et al. (1984), for example, were unable to demonstrate any spinal damage in animal experiments on cervical fusions with PMMA in the dog model, even if no insulating layer was used. The authors attribute this to the insulating function of the ligaments obtained and,

above all, to the heat transport capacity of the vascular dural structures.

26.4.3 Clinical Results

The published results of vertebroplasty are consistently positive and have led to great enthusiasm towards this technique in the treatment of osteoporosis (Einhorn 2000). Clinical experience in the literature also shows that when injected into the vertebral body at an early stage, pain relief occurs very rapidly and is permanent in a very large proportion of patients. The extraordinarily high response rate is all the more astonishing because these results are achieved precisely in patients in whom neither bed rest nor analgesics lead to pain relief.

A significant reduction in pain can be expected in 80–90% of patients treated with PVP (Barr et al. 2000; Grados et al. 2000; Heini et al. 2001; Jensen et al. 1997; Martin et al. 1999). It seems remarkable that pain relief already occurs immediately postoperatively and that patients can be treated partially as outpatients. The question of the mechanism of pain reduction remains open. On the one hand, the mechanical stabilization of fractures by the cement seems possible (Belkoff et al. 1999). The fact that the extent of pain reduction does not necessarily correlate with the amount of cement speaks against this mechanism as the sole explanation. In addition, it is possible to achieve improvement even in older fractures by cementing, although these should already be consolidated bony. On the other hand, one theory assumes that heating during polymerization of the cement leads to coagulation at nociceptors, which results in a reduction in pain (Bostrom and Lane 1997). However, this is contradicted by the only slight increase in temperature that can be measured in vitro at the vertebral body surface (Heini et al. 2001).

Surprisingly, Hiwatashi et al. (2003) even reported an increase in height of the 85 treated vertebral body fractures in 37 patients (anterior vertebral body: 2.5 mm; central vertebral body: 2.7 mm; posterior vertebral body: 1.4 mm) during PVP.

PVP thus offers a new therapeutic option in the treatment of painful osteoporotic vertebral compression fractures. Taking into account the available literature, the experimental basis (Jerosch et al. 1999) and clinical experience, PVP is integrated into the therapy algorithm for osteoporosis patients. In addition, painful and/or unstable primary or secondary vertebral body tumors as well as clinically symptomatic hemangiomas represent an indication.

26.5 Percutaneous Kyphoplasty (PKP)

Kyphoplasty is a further development of vertebroplasty and is a minimally invasive surgical procedure to straighten fresh painful vertebral fractures that have resulted in severe wedge or fish vertebrae formation. The emphasis is on fresh (approximately up to 3 weeks old) fracture.

Companies that sell Kyphoplasty sets in Germany are:

Joimax, Joline, Medtronic, MDT, Weick medical, Sika Med, Ulrich medical, Ackermann medical, Andre Surgical, Jotaspine, Maxx Spine, MPI Healthcare, Kroener medical, Libra Kyphoplastie K u. K medical, Depuy/Synthes, Guardian (sold by ▶ Alibaba.com), Aesculap Osseon, Alpatec, Anwerina, Optimed, Panmed, Sikamed, SKY Bone, Soteira andVexim.

26.5.1 Necessary Instruments

The instruments required for kyphoplasty are composed of:

- Cement mixer (◘ Fig. 26.5),
- Kyphoplasty set (◘ Fig. 26.6),
- additional material: hammer, large Kocher clamp, scalpel, bowl with 40 mL contrast medium, marker pen, 2 × 2 mL syringe.

Fig. 26.5 Cement mixer. (Courtesy of Joline GmbH & Co. KG)

Fig. 26.6 Kyphoplasty set

26.5.2 Patient Positioning

The patient is placed on pads under the thorax and pelvis. This position in hyperlordosis relieves the fractured vertebral bodies and facilitates subsequent straightening.

Percutaneous kyphoplasty is performed under general or local anesthesia.

The patient should be positioned high enough under the thorax and pelvis so that the abdomen is not supported on the operating table top.

The standard position is prone with arms extended (Fig. 26.7a). In the case of a high thoracic approach, the abdominal position is used with the arms raised to allow better imaging of T4, T5 and T6 (Fig. 26.7b, c).

26.5.3 Setting up, Adjusting and Setting the C-Arms

Setting Up the C-Arms

The use of 2 C-arms is recommended. This shortens the procedure and the fluoroscopy time is shorter. The image representation in the preselected planes is of consistent quality.

If both C-arms are used, the arch of lateral view is moved over the patient and tilted cranially before covering (Fig. 26.8a). The patient is only covered in the lower region (Fig. 26.8b). A bag can first be pulled over the gondola of the C-arm. Now the covering takes place. Cranially, the cloth is placed over the C-arm (Fig. 26.8c). This setup allows the a.p. arch to be placed in one axis on the opposite side of the patient. It only needs to be inserted laterally.

This allows the surgeon(s) to act with a high degree of freedom on both sides. When treating several levels, both C-arms can be moved in parallel. The new settings only have to be made via one spatial axis. Time savings and simple handling are thus guaranteed (Fig. 26.8d).

Setting Up the C-Arms

The pedicles of the affected vertebral body should be set as parallel as possible. In the axis of the lateral exposure, the second C-arm is inserted for a.p. exposure (Fig. 26.9a). In lateral exposure, for example, a wire is held at right angles to the posterior edge of the affected ER.

This axis (shown in red in Fig. 26.9b) provides the axis for the a.p. image. Now the a.p.C. curve is rotated until the spinous process of the affected vertebral body appears in the middle of the vertebral body.

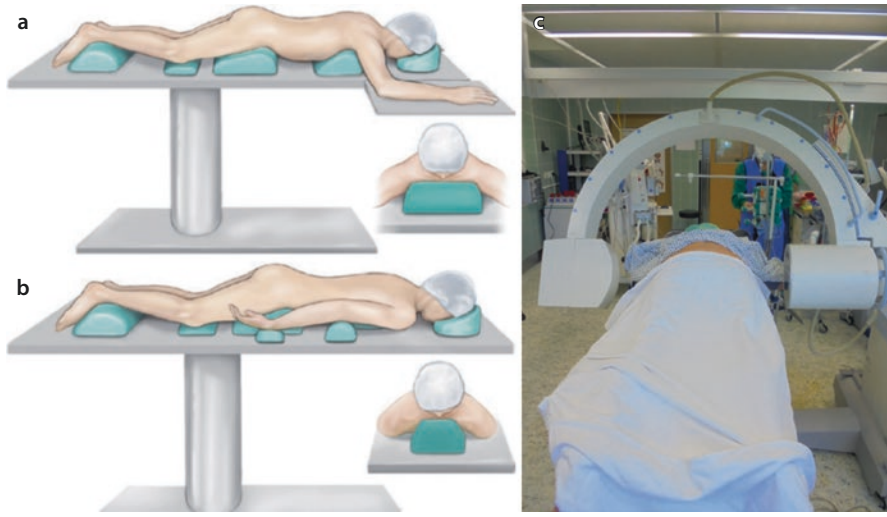


Fig. 26.7 **a–c** Abdominal positioning: standard, arms extended **a**; for high thoracic approach with arms extended in diagram **b** and in OR **c**

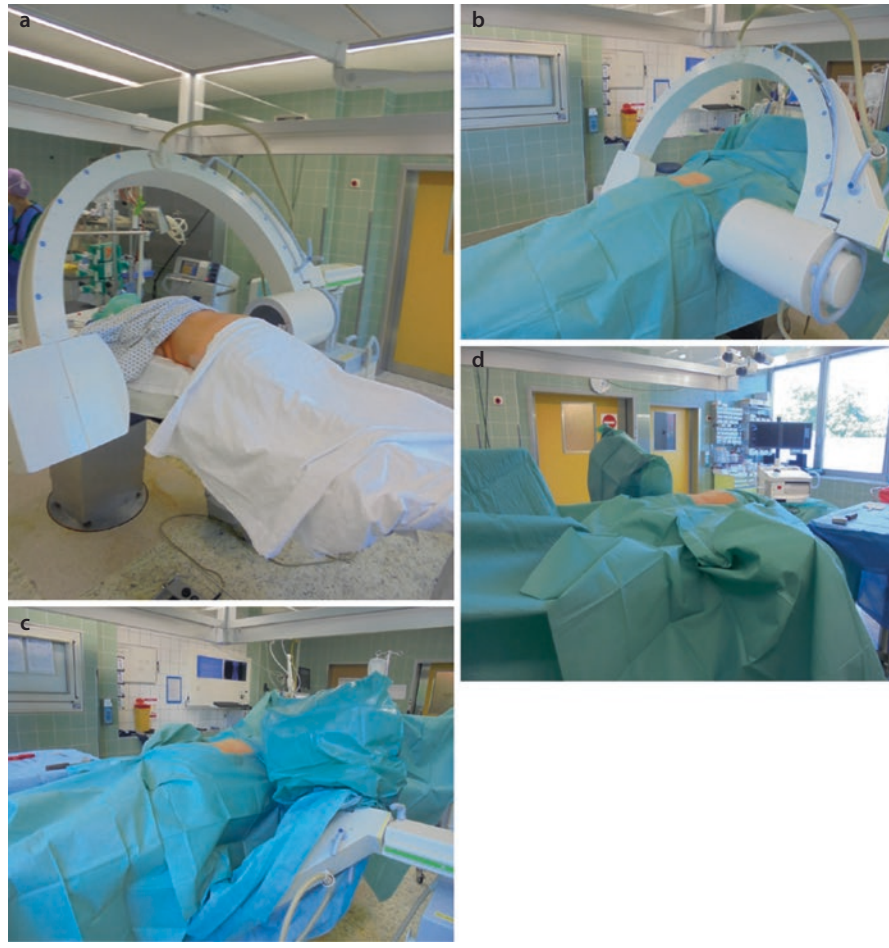


Fig. 26.8 **a–d** Patient positioning and setting up the C-arm before and after sterile draping

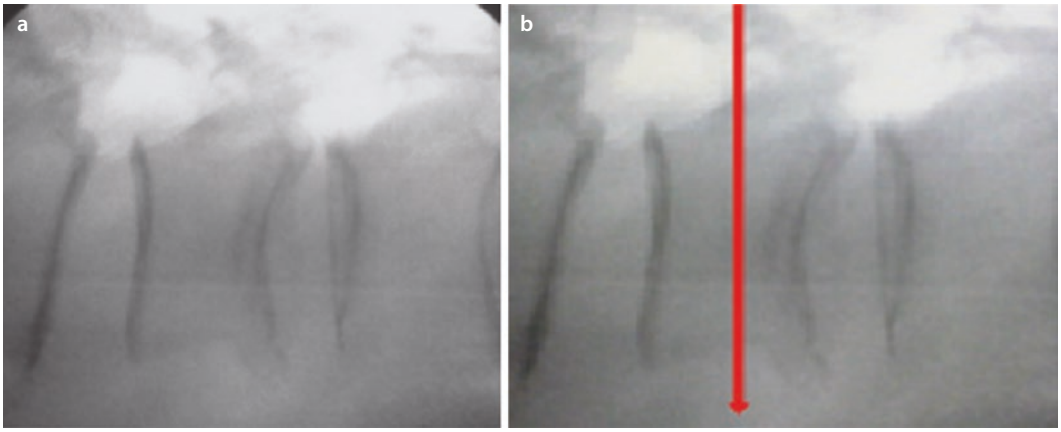


Fig. 26.9 Starting with the C-arm in strict lateral alignment with the affected vertebral body (**a**) lateral x-ray projection; (**b**) red line with the projected ap-view

If only one C-arm is used, the coverage must be selected more generously. The C-arm is repeatedly swivelled from the a.p. position to the lateral position and back during the entire operating time.

- **Adjustment of the C-Sheet**
  - Under a.p. view, the spinous processes should be brought into the center of the vertebral body. To do this, it may be necessary to tilt the operating table with the patient laterally by a few degrees. It should be possible to pick up or pivot the C-arm laterally by 90 °.
  - In lateral view with an instrument in the beam path, the axis course should be visualized at right angles (90 °) through the posterior wall of the vertebral body.

The a.p. axis must be adjusted according to this course (Fig. 26.10).

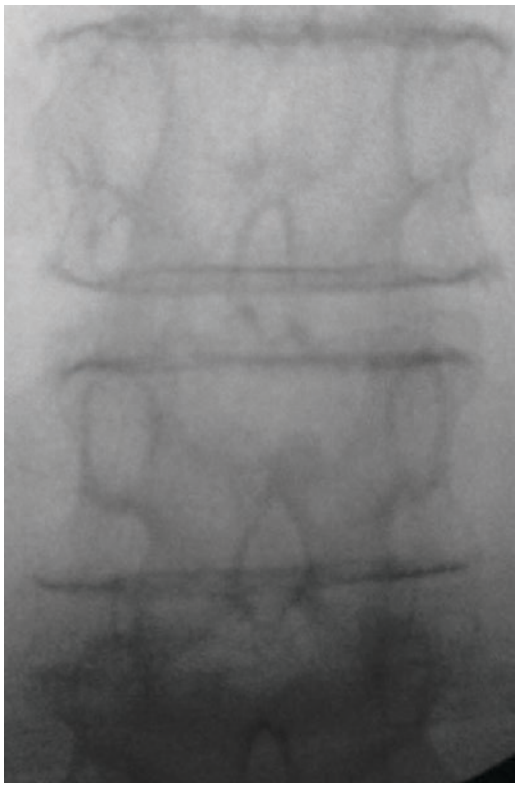


Fig. 26.10 Adjustment of the C-arm: Under a.p. view, the spinous processes are to be brought into the centre of the vertebral body

26.5.4 Implementation of the Intervention

- **Transpedicular Vertebral Body Access**

The starting points on the skin surface of the patient, or the pedicle rings to be targeted, are located

- right (at 13:00) about 1.5 cm lateral and 1.5 cm cranial to the spinous process,
- left (at11:00 o'clock) about 1.5 cm lateral and 1.5 cm cranial of the spinous process.

This is where the stab incision is made. Depending on the deformity of the vertebral body, the entry point at the pedicle eye can move up to left, 09:00, and right, 15:00 (Figs. 26.11, 26.12 and 26.13).

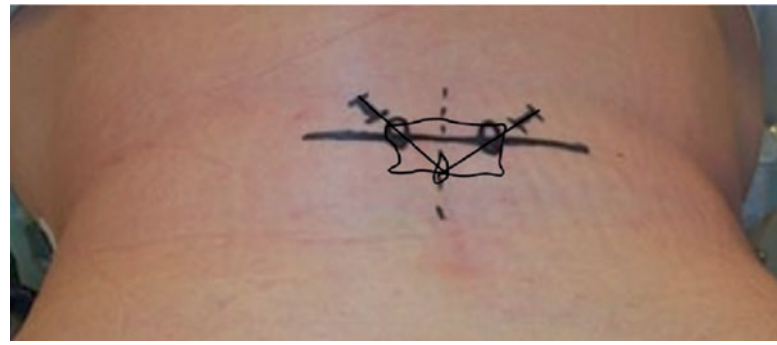


Fig. 26.11 Creation of the skin marking of the starting points of the stitch incision and stitch direction as well as the landmarks during the transpedicular approach

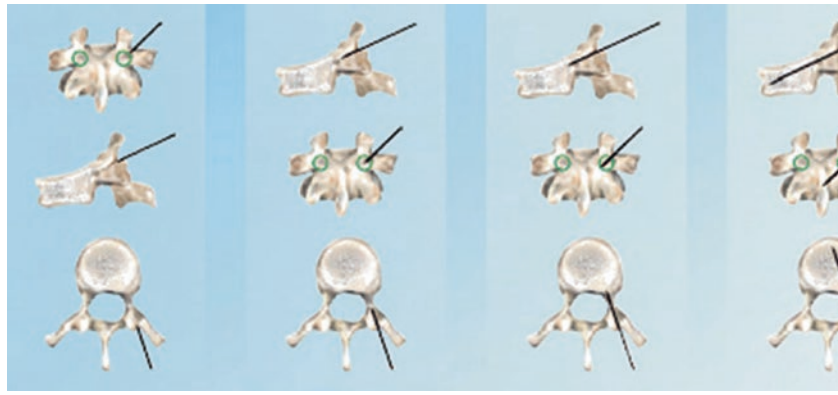


Fig. 26.12 Aiming of needle placement in 3 planes during transpedicular access. (Courtesy of Joline GmbH & Co. KG)

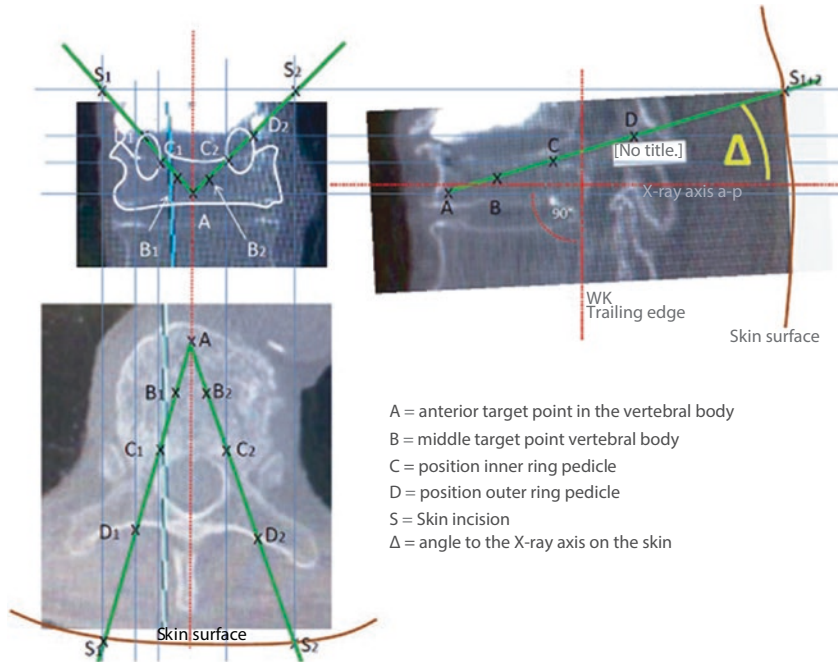


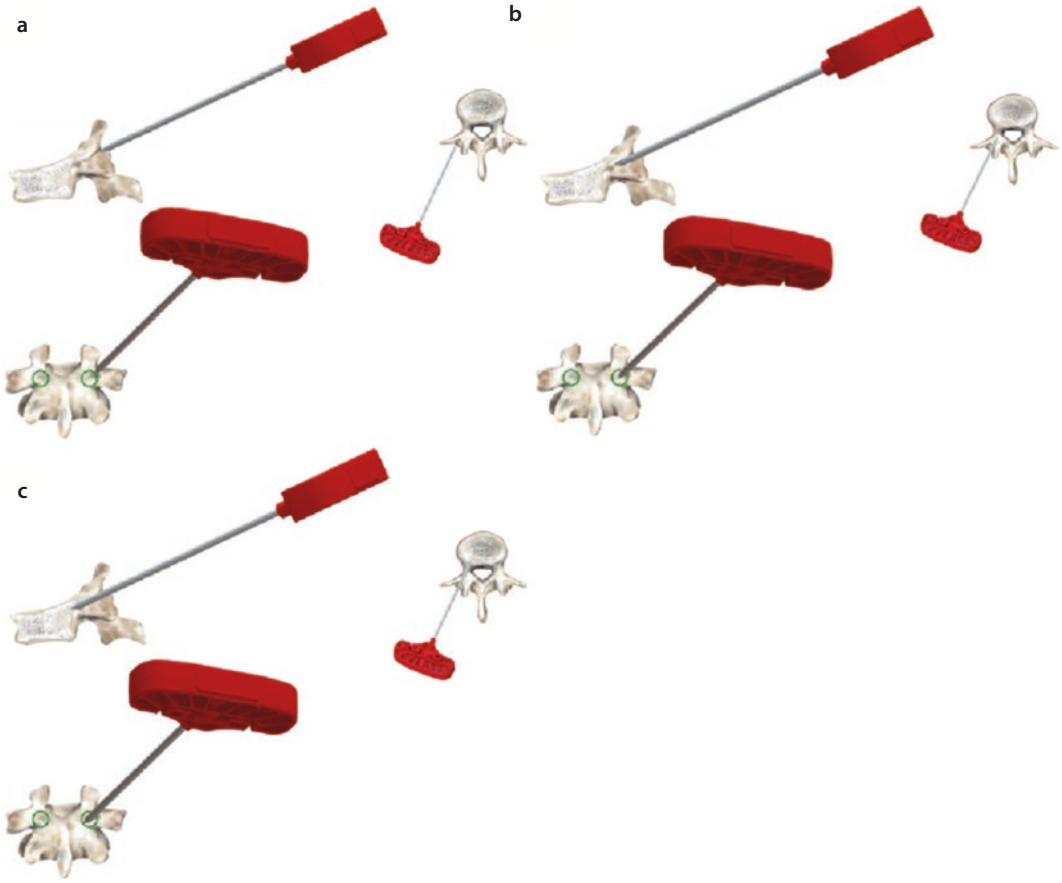
Fig. 26.13 Radiological orientation aids for needle positioning in transpedicular needle placement. (Courtesy of the company Joline GmbH & Co. KG)

The bone puncture needle, shown in red in ◘ Fig. 26.14, is placed on the outer pedicle ring on the vertebral body in a.p. view (◘ Fig. 26.14). Optimally, it is centrally located in the pedicle ring (a.p.) when it has penetrated half of the pedicle canal (lateral view) (◘ Fig. 26.14b). The needle must not reach the pedicle inner ring (a.p.) until it has already passed the posterior edge in lateral view. The puncture needle should only be inserted a few millimetres deep into the WK (◘ Fig. 26.14c).

The needle is now removed, the shaft remains in the vertebral body (◘ Fig. 26.15a). The blunt wire is inserted to the middle of the vertebral body in lateral view. In a.p. view, it now lies optimally halfway between the inner ring and the vertebral body midline. If the wire is pushed almost to the front edge of the vertebral body, it must ideally lie in the middle of the vertebral body in a.p. view (◘ Fig. 26.15b). The shaft is removed, the wire remains in the vertebral body. On the opposite side of the vertebral body, the access is made in the same way (◘ Fig. 26.15c).

The working cannula, shown in yellow in ◘ Fig. 26.16, is positioned in the vertebral body via the wire. It should have passed the posterior edge by about 3 mm (◘ Fig. 26.16a). After removal of the guide wire and the handle of the working channel can now:

- a biopsy can be taken with the Vertebra Biopsy Device,
- be predrilled with the Bone Drill if the substance is hard (◘ Fig. 26.16b).



◘ **Fig. 26.14** **a–c** Path of the bone puncture needle (*red*) during vertebral body puncture: **a** Touchdown at the pedicle outer ring in a.p. view; **b** Penetration to half of the pedicle duct in lateral view; **c** Reaching the pedicle inner ring after passing the trailing edge in lateral view. (Courtesy of the company Joline GmbH & Co. KG)

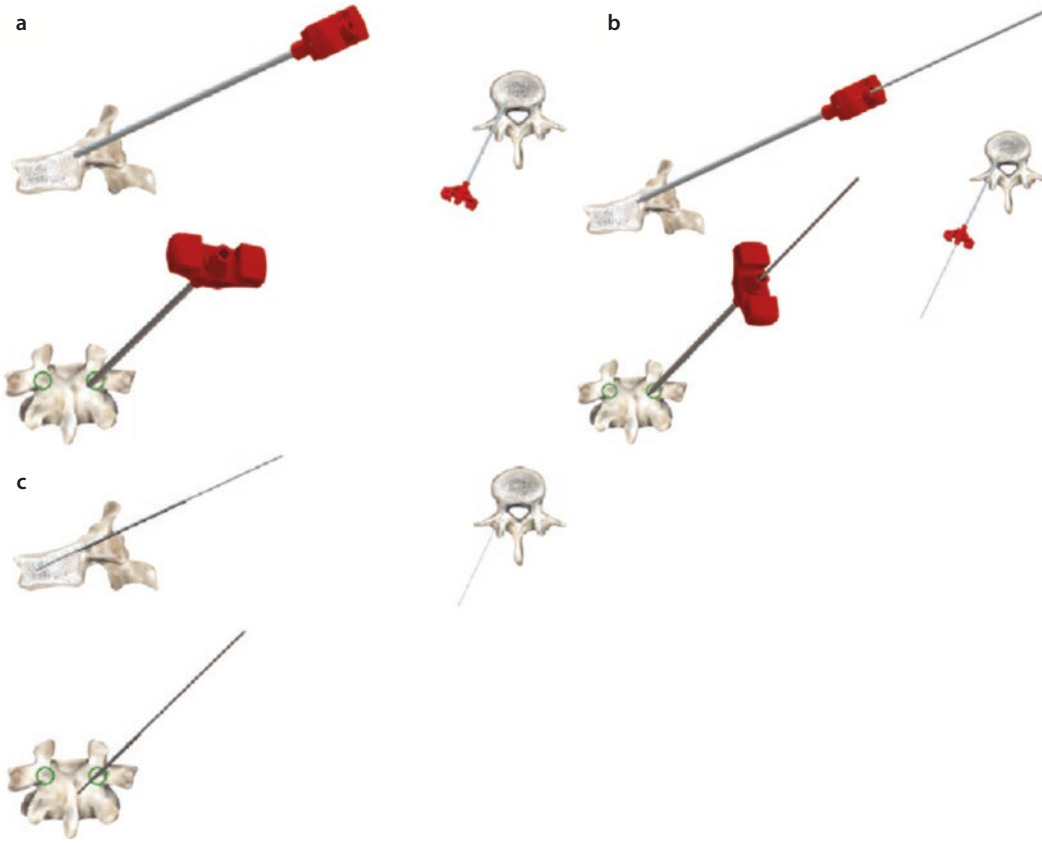


Fig. 26.15 **a–c** Changing the puncture needle to the guide wire. (Courtesy of Joline GmbH & Co. KG)

A cavity for the balloon is created by poking with the Vertebra Biopsy Device (Fig. 26.16c).

The balloons are carefully inserted into the created cavity. The high-pressure syringe is rotated to 4–6 bar or approximately 1 mL stroke. The balloon is controlled in unfolding, taking into account pressure, volume and pictorial representation (Fig. 26.17a).

The balloons should remain in the vertebral body until the cement is applied. They prevent the formation of coagulum in the cavity created. The cement should not drip after about 3 cm has been squeezed out of a syringe. The balloons are not completely evacuated until the cement is ready for use. The working channels are secured by hand while the balloons are pulled out (Fig. 26.17b).

Immediately, the cement is implied in small controlled bursts. The cavity must be completely filled. The cement should interlock with the surrounding cancellous bone. The time window is sufficiently large to be able to imply the cement without stress (Fig. 26.17c, d).

Extrapedicular Vertebral Body Access

The points of the stab incision are based on the position of the upper vertebral body edges (Figs. 26.18 and 26.19). They are located

- right (at 13:00) about 2.5 cm lateral and 2.5 cm cranial to the spinous process,
- Left (at 11:00) about 2.5 cm lateral and 2.5 cm cranial to the spinous process.

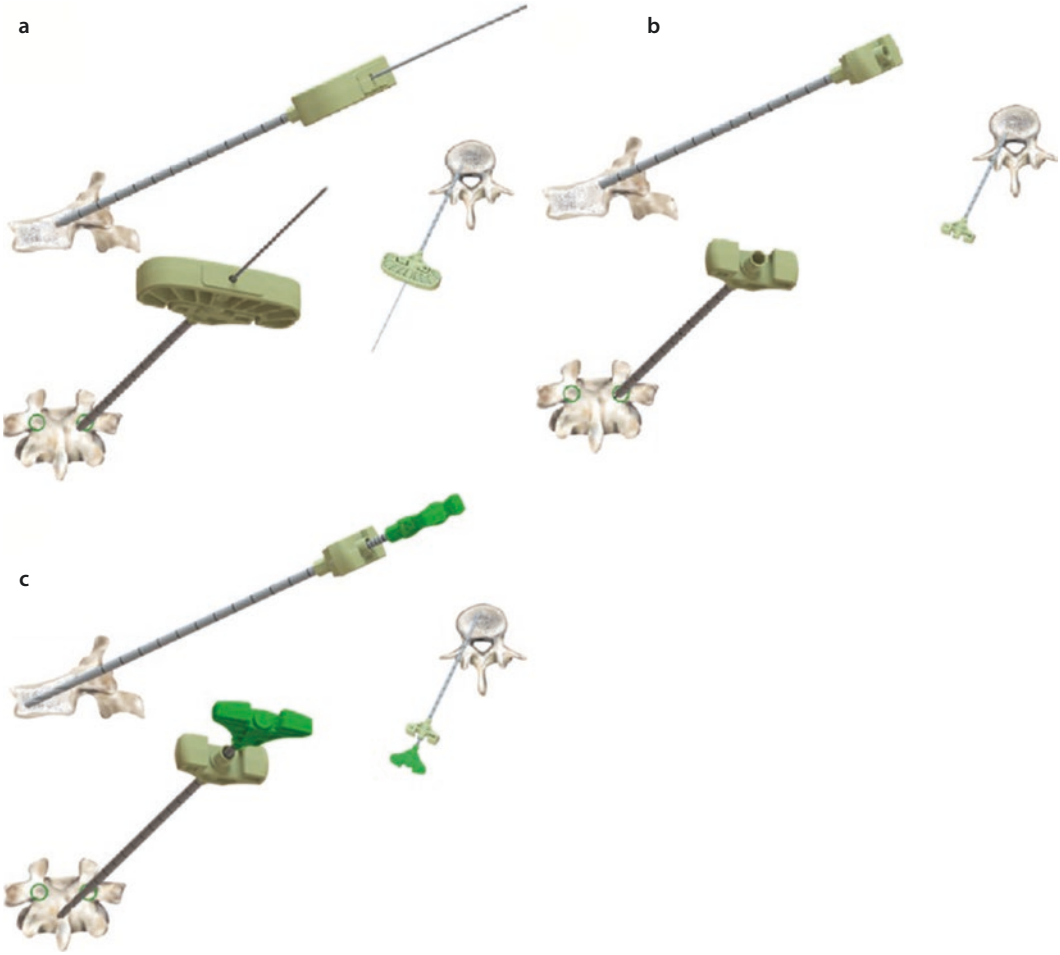


Fig. 26.16 **a–c** Changing the guide wire on the cannula and trocar. (Courtesy of the company Joline GmbH & Co. KG)

With the C-arm correctly adjusted, aim from the intersection of the processus spinosus through the base plate just below the vertebral body edges.

After the working channel has been placed in such a way that it finds sufficient support extrapedicularly, the procedure is continued as already described for the transpedicular approach (Fig. 26.20).

The patient is hospitalized for only one to a few days and can immediately put weight on the spine after the operation. The pain caused by the fresh fracture disappears.

26.5.5 Postoperative Mobilization

The goal in patients with a vertebral compression fracture in the presence of osteoporosis is rapid mobilization. There are no level 1 or 2 studies regarding the need to use braces before or after cement augmentation. This is ultimately left to the discretion of the therapist. However, it is important that adequate osteoporosis drug therapy is started in any case.

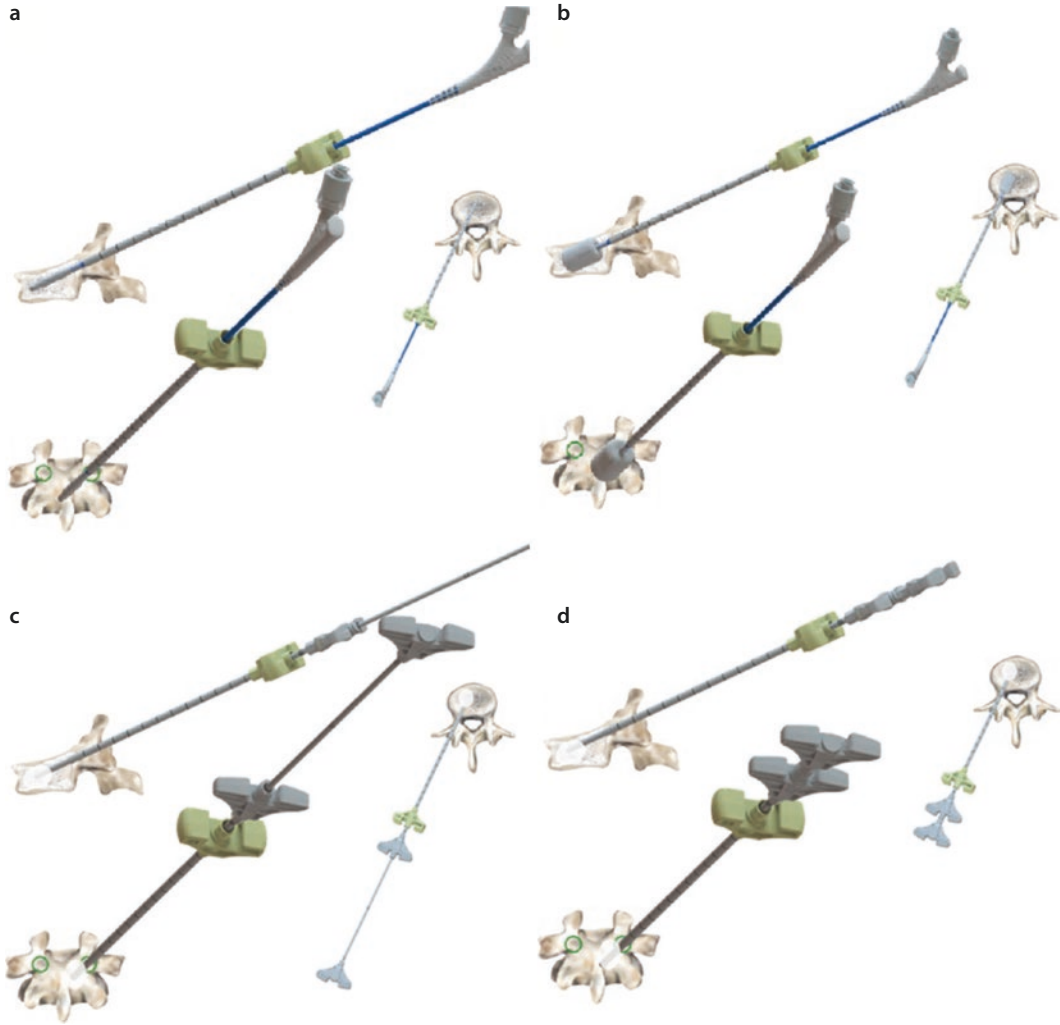


Fig. 26.17 **a–d** Insertion of the balloon catheter. (Courtesy of the company Joline GmbH & Co. KG)

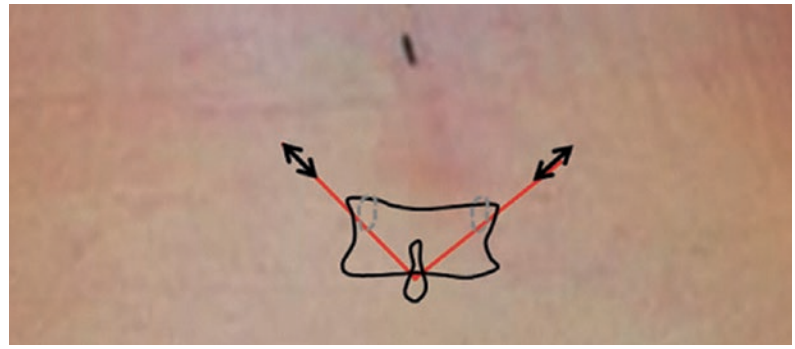


Fig. 26.18 Skin marking of the point of the stab incision and the direction of the stab for extrapedicular access

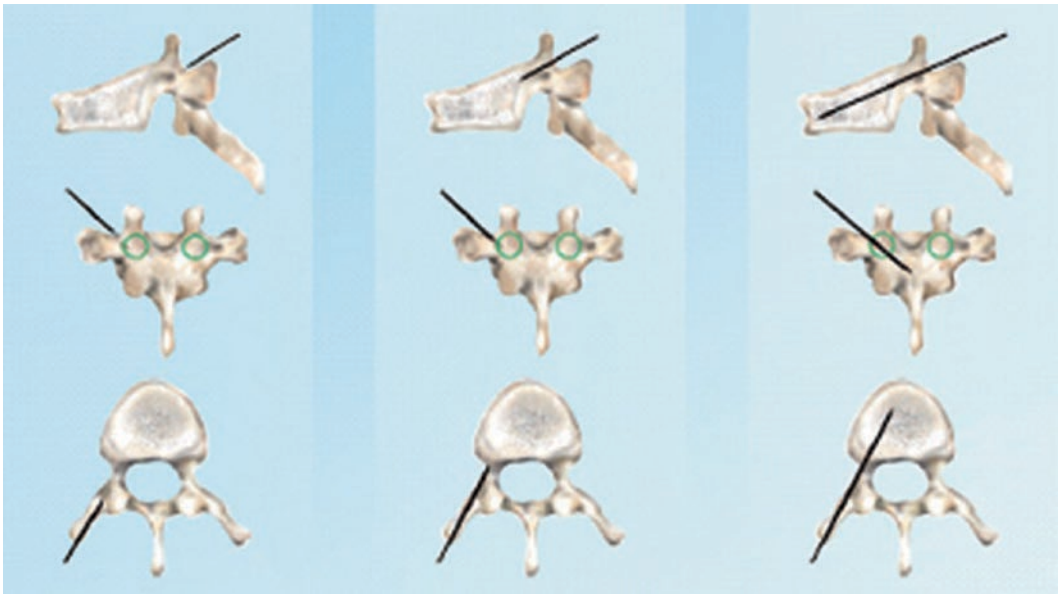


Fig. 26.19 Target direction of needle placement in 3 planes for extrapedicular needle placement. (Courtesy of Joline GmbH & Co. KG)

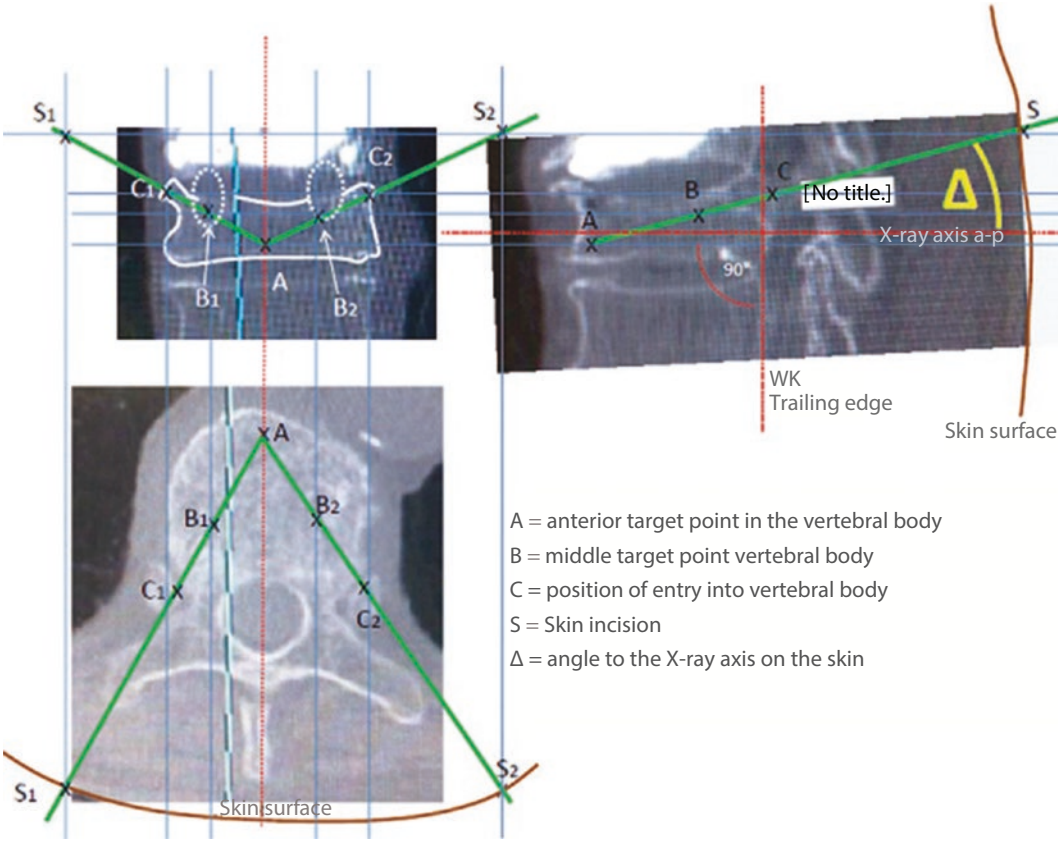


Fig. 26.20 Radiological orientation aids for needle positioning in extrapedicular needle placement. (Courtesy of Joline GmbH & Co. KG)

26.5.6 Clinical Results

In the laboratory, experimental compression fractures can be realigned to 97% of the original height with PKP (Belkoff et al. 2001). The augmentation achieved by cementation is comparable to the effect of vertebroplasty. The first published clinical results are also promising. Lieberman et al. (2001) were able to increase vertebral body height by an average of 47% in 70% of patients treated with PKP, associated with significant pain relief.

Berlemann et al. (2001b) were able to document an uprighting of vertebral body sinterings by up to 18 ° in 20 patients, which corresponded to an expansion of the anterior vertebral body height by 90%. The younger the sintering, the more successful the straightening. Fractures that were younger than 4 weeks could be straightened by an average of 43%. In the case of changes older than 8–10 weeks, significant straightening was only achieved in isolated cases. Garfin et al. (2001) also described an age-dependent reducibility of the fractures, whereby in cases younger than 3 months the kyphosis could be improved by an average of 50%.

Coumans and Liebermann (2003) demonstrated sustained pain reduction and improvement in quality of life (SF-36) at 12-month follow-up in 74 patients with 179 kyphoplasties.

Ananthakrishnan et al. (2003) investigated the intradiscal pressure before and after vertebroplasty and kyphoplasty in an experimental setup. They were able to show that both procedures increase the intradiscal pressure compared to normal findings under load. At the same time, there was no difference in intradiscal pressure between specimens treated with vertebroplasty and those treated with kyphoplasty.

Katzman (2003) examined PVP and PKP in comparison. He saw comparable pain reduction in both groups with 88% (PVP) and 90% (PKP). Correction by PKP was achieved in only 19 of 82 patients. Within the first 2 weeks after fracture, correction could still be achieved with PKP in 57.6%.

26.6 Literature Based on Randomised Controlled Trials

Prior to 2009, no prospective randomized controlled trials (RCTs) can be found that review the effectiveness of cement augmentation for osteoporotic vertebral compression fractures. Since then, 8 prospective RCTs have been published in peer-reviewed journals. These include studies published in the New England Journal of Medicine.

Kallmes et al. (2009) and Buchbinder et al. (2009) compared vertebroplasty with sham procedures and failed to show an advantage of cement augmentation. However, both studies had significant methodological problems. It is generally accepted that cement augmentation results in the most gain in acute fractures that do not respond to conservative measures. However, the above studies included subacute fractures up to 12 months of age. Furthermore, bone edema on MRI was not necessarily an inclusion criterion. Furthermore, bone augmentation was compared only with a sham procedure and not with conservative therapy.

Other prospective randomized controlled trials showed a positive effect of cement augmentation compared to nonoperative therapy (Blasco et al. 2012) and only one study showed no effect to the control group.

In 2013, Anderson et al. conducted a meta-analysis examining vertebral augmentation versus nonsurgical intervention for osteoporotic vertebral fractures (Anderson et al. 2013). They included 6 studies of prospective RCTs, and the studies by Kallmes et al. (2009) and Buchbinder et al. (2009) were also integrated. The primary outcome measured was pain (VAS scale, specific spine function, and HRQOL). The results of this meta-analysis showed that cement augmentation had significantly better pain reduction, functional outcome, and improvement in HRQOL than nonoperative measures or sham procedures. These results were significant with respect to early and late follow-up (6 and 12 months; $p < 0.001$).

The prospective randomized controlled trial by Blasco et al. (2012) was not included in this meta-analysis. Blasco et al. studied 125 patients randomly assigned to vertebroplasty or nonoperative management. The inclusion criteria were osteoporotic vertebral fractures with a history of less than 12 months and concomitant edema on MRI or activity on bone scintigraphy, and with a VAS of ≥4. The authors found significant improvement in the VAS in both groups, occurring at all time points, with significantly greater improvement in the vertebroplasty group at 2 months. In terms of functional outcome, the vertebroplasty group was better at all time points. Improvement in functional outcome in the nonoperatively treated group was not found before 6 months. The authors concluded that vertebroplasty leads to faster pain reduction with a significant improvement in pain scores at 2 months, but that both groups had comparable outcomes at 1 year.

RCTs published by Anderson et al. (2013) and Blasco et al. (2012) present cement augmentation as a valid option for the appropriate patient population.

The adequate timing of cement augmentation remains somewhat controversial, as many patients with vertebral compression fractures also improve with symptomatic conservative treatment. Based on the available literature, cement augmentation should be considered in patients with an acute vertebral compression fracture with edema on MRI who report significant pain and are immobilized or in patients who do not respond to conservative therapy within 3–6 weeks.

26.6.1 Vertebroplasty Versus Kyphoplasty

Kyphoplasty offers the option of correcting vertebral body deformity and kyphosis through cement injection. Radiologically, there seems to be a benefit with this. However, the clinical benefit is controversial. Han et al. published a systematic literature review and compared vertebroplasty with kyphoplasty. Included were 8 studies (1 prospective RCT, 3 clinical controlled trials, 3 prospective cohort studies, and 1 retrospective study) with a total of 848 patients. The authors concluded that vertebroplasty is more effective in terms of pain reduction in the first 7 days. Kyphoplasty, on the other hand, has an advantage when assessing the 3-month functional improvement of patients. There was no long-term difference between the two groups in terms of pain reduction and functional improvement.

Omidi-Kashani compared percutaneous kyphoplasty with vertebroplasty for isolated osteoporotic compression fractures. They found significant improvements in pain on the VAS and health-related quality of life on the SF-36 in both groups. Kyphoplasty radiologically showed an improvement in kyphotic angulation of the fractured vertebral body (3.1 mean correction). However, no difference was found in terms of pain and functional improvement between vertebroplasty and kyphoplasty. The clinical benefit of 3 degrees improvement in focal kyphosis is not clinically significant.

26.7 Possible Complications

Typical complications of cement augmentation are cement extravasation, embolism, and the occurrence of new fractures. Neurological complications are rare but have been described.

Cement extrusion into the spinal canal can have serious neurological consequences, including paraplegia, and require immediate decompression. Furthermore, pulmonary embolisms have been described after cement leakage into vertebral vessels (Padovani et al. 1999). In principle, the balloon pre-expansion in PKP reduces the risk, as the liquid bone cement does not have to be introduced under such strong pressure as in PVP.

A clinically relevant classification (Yeom et al. 2003) distinguishes 3 types of cement leakage (◘ Fig. 26.21):

- Type B: via basivertebral vein (about 40%),
- Type S: via segmental vein (about 40%),
- Type C: via cortical defect (about 20%).

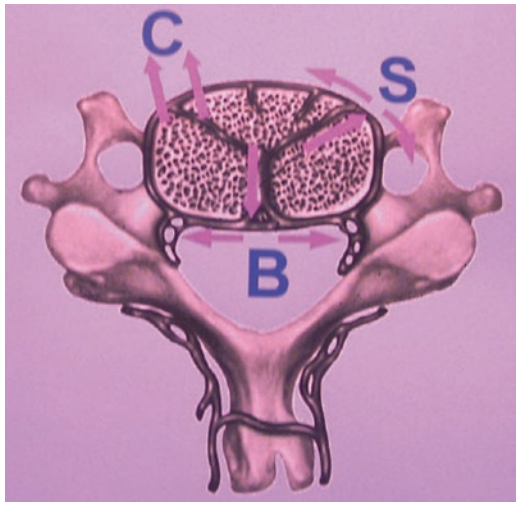


Fig. 26.21 Classification of cement leakage. Type B via basivertebral vein, type S via segmental vein and type C via cortical defect. (Courtesy of the company Joline GmbH & Co. KG)

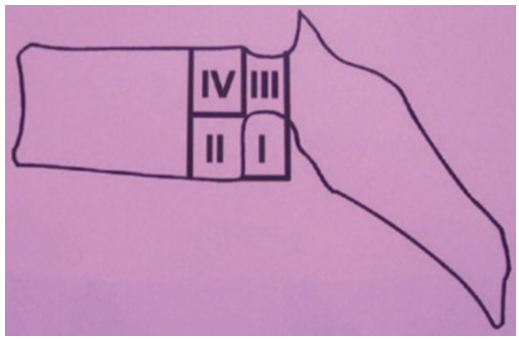


Fig. 26.22 Zoning for potential cement leakage on lateral radiograph. Zone I: Neuroforamen; Zone II: Vertebral body anterior to the neuroforamen; Zone III: Pedicle root; Zone IV: Vertebral body anterior to the pedicle root. (Courtesy of the company Joline GmbH & Co. KG)

A further differentiation can be made here:

- Type BV: up to the foramen vasculare,
- Type BC: into the spinal canal,
- Type SH: horizontal,
- Type SV: vertical or oblique,
- Type SF: into the foramen,
- Type CD: in the disc,
- Type CK: into the spinal canal,
- Type CF: into the foramen,
- Type CWK: lateral or anterior to the vertebral body.

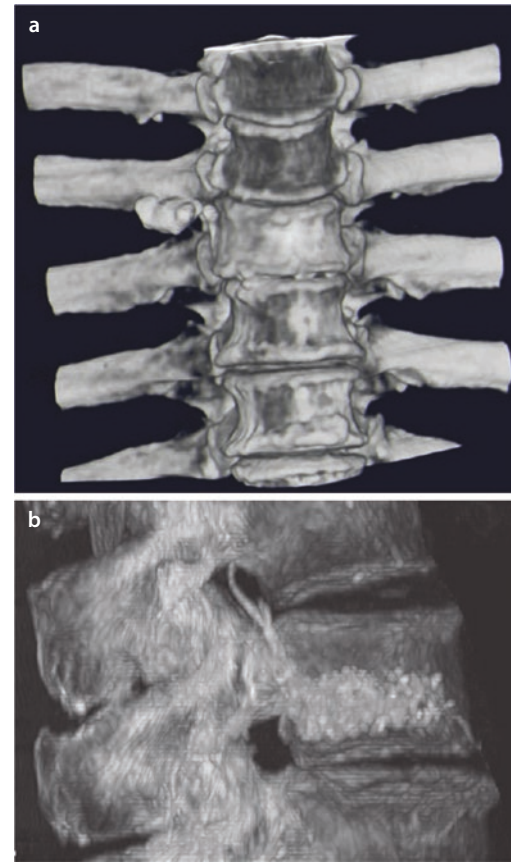


Fig. 26.23 From cement exit in 3D CT: **a** in a.p. projection, **b** in lateral projection

Potentially dangerous leakage sites can already be identified to a certain extent on the lateral X-ray image (Fig. 26.22). It is essential to bear in mind that cement leaks are often overlooked on conventional radiographs. Type B and type S exits in particular are overlooked on a.p. and lateral radiographs, which are only available intraoperatively. On lateral radiographs, cement in zone I is particularly predictive of cement leakage.

In our opinion, many cement leaks cannot be detected or can only be detected inadequately in x-rays in 2 planes. Postoperative computed tomograms often only reveal the extent of the cement leakage (Fig. 26.23).

CT data show that cement extravasation occurs in most patients (18–88%). However, these are usually not clinically relevant

(Martin et al. 2012). The most common cement leakage is into the endplate or disc (45%), followed by paravertebral extravasation (35%), epidural (20%) and perivertebral (18%). CT shows significantly more extravasation here than plain radiographs (Martin et al. 2012). Cement extravasation correlates with lower viscosity, fracture type, and higher injection volumes. Neurological complications are fortunately rare (<1%). However, if such a complication occurs, immediate decompression is necessary. However, cases with permanent neurological deficit have been described in the context of cement augmentation. Leakage into the disc space can lead to increased stress on the adjacent baseplate, causing a successive fracture.

The occurrence of a cement embolism has also been reported. This can even lead to fatal pulmonary embolism. Cerebral insults have also been described. A systematic review on the incidence of cardiopulmonary embolism shows a rate of 2–26%, depending on the diagnostic method (Wang et al. 2012), for symptomatic and hemodynamically relevant events affecting the pulmonary artery circulation and also for impairment of the right heart.

In addition to cement embolization, embolization of fatty marrow from bone can also occur, resulting in transient acute hemodynamic changes.

26.7.1 Cement Leakage

Balloon kyphoplasty (BK) is considered the gold standard, against which newer procedures such as radiofrequency kyphoplasty (RFK) must compete in terms of therapeutic success and complication rate. It is unclear whether the cement leakage rate is lower with RFK compared to BK and whether this is of clinical relevance.

In a prospective randomized study, Riesner et al. (2016) compared RFK with BK in terms of cement leakage rates and associated clinical complications. In 100 patients (76 women and 24 men with an average age of 78.5 years) or 162 fractured vertebral bodies, treatment with BK (79 vertebral bodies) or RFK (83 vertebral bodies) was performed after prospective randomization and subsequent evaluation according to the parameters "localization of cement leakage" (epidural, intradiscal, extracorporeal, intravascular) and "clinical relevance".

On average, BK used more cement (5.2 mL) than RFK with 4.0 mL (p = 0.0001). In BK, cement leakage occurred in 48 of 79 cases (60.8%) and in RFK in 53 of 83 cases (63.9%) (p = 0.420). There was also no significant difference between the two methods with regard to subanalysis by location. Despite the high leakage rates, intravascular leakage into the inferior vena cava with interventional-endovascular salvage occurred in only 2 cases (1 time BK, 1 time RFK) (Table 26.1). No pulmonary complications were observed.

Table 26.1 Distribution of cement leakage in balloon kyphoplasty compared to radiofrequency kyphoplasty. (Riesner et al. 2016)

	Epidural	Intradiscal	Extracorporeal	Intravascular
BK	5	12	9	22
RFK	12	19	7	15
Total	17	31	16	37
p-value	0.086	0.202	0.548	0.152

BK Balloon kyphoplasty; *RFK* Radiofrequency kyphoplasty
Epidural = leaked into the epidural space; intradiscal = leaked into the intervertebral disc; extracortical = leaked across the cortical border, excluding the posterior edge; intravascular = leaked into venous or arterial vessels

The authors were unable to demonstrate any significant difference in cement leakage rates between balloon kyphoplasty and radiofrequency kyphoplasty (Riesner et al. 2016). Furthermore, radiologically detectable major cement leakage into the vascular system (inferior vena cava) occurred only once in both procedures, but without clinical complications.

To date, only a few studies have been published that directly compare the above-mentioned methods. Older studies are primarily concerned with the BK. Prokop et al. (2014) showed minor radiologically visible but asymptomatic cement extravasations in 20% of 1069 kyphoplasties from 2008 to 2013. Neurological deficits due to dorsal cement leakage occurred in 3 cases (0.25%). These were due on the one hand to an excessive amount of cement and on the other hand to an incorrect puncture of the vertebral body. All complications were treated conservatively, mainly with a wait-and-see approach.

In a review by Hsieh et al. (2013) of originally 791 papers dealing with vertebroplasty and kyphoplasty, 14 were ultimately analysed in more detail and cement leakage was reported in 0–15% of these after BK. Differentiated by location, pulmonary embolisms were reported in 0–1.2% after kyphoplasty, and neurological complications due to cement leakage in 0–2.9%. Hsieh et al. were able to work out that most leaks were asymptomatic. However, when symptomatic cement leaks occurred, they were associated with further surgical revisions (Hochegger et al. 2005; Seo et al. 2005).

Schulz et al. (2012) found cement leakage in the extravertebral venous plexus (EVVP) in 8 of 46 cases (17.4%), with 5 of 46 cases (10.9%) confined to EVVP and extravasation beyond the EVVP into the vena cava azygos system in 3 of 46 cases (6.5%) (CT chest control). In 2 patients, in addition to cement extravasation in the EVVP and peripheral pulmonary emboli, residual cement fragments were found in the vena cava, which remained associated with the cement extravasation in the EVVP. In both cases, endovascular extraction of the fragments was considered despite the absence of clinical signs.

Bula et al. (2010) believe that the cause of cement leakage in kyphoplasty is almost always due to early application of the cement, which has not yet reached its optimum viscosity. They also see the application of excessive amounts of cement as a further cause (Bohner et al. 2003).

Regarding the location of cement extrusions during kyphoplasty, Huang et al. (2006) found that the most common locations for unintentional cement extrusions are paraspinal and epidural, while foraminal and intravascular extrusions are much less common. The rate of pulmonary embolism for BK is therefore described as 1.5%. Other papers report the incidence of cement embolism to be much higher at 4.6% (Choe et al. 2004; Nussbaum et al. 2004; Ronge 2005). Cardiac stresses have not been evaluated as significant in the literature (Heini and Orler 2004), even for augmentations of up to 6 vertebral bodies. Thus, only single case descriptions can be found in the literature that describe an endovascular or even open revision procedure to salvage the cement extravasations (Schulz et al. 2012; Agko et al. 2010; Farahvar et al. 2009; Bose and Choi 2010).

26.7.2 Connection Fractures

The increased stiffness of a vertebro- or kyphoplasty vertebral body leads to increased stress on the adjacent segments. This can theoretically lead to an increased fracture rate of these segments. In contrast, a meta-analysis of RCTs comparing vertebroplasty with conservative therapy found no increased risk of secondary fractures (Anderson et al. 2013). About 20% of patients in both groups showed new fractures between 6 and 12 months. However, technical problems such as extravasation into the disc may increase the risk of subsequent fractures. A limitation of this meta-analysis was that it included patients with up to 3 fractures. The risk of sustaining a new fracture after augmentation is increased in patients with multiple fractures or significant kyphotic deformity. Some patients may also experience a new fracture in the same segment due to cement failure.

Zhang et al. performed a systematic review and meta-analysis regarding the risk of a new osteoporotic vertebral compression fracture after vertebroplasty. They found that 21% of patients experienced a new fracture after cement augmentation. Predictive factors here were low body mass index and intradiscal cement leakage.

26.7.3 Cost-Effectiveness of Cement Augmentation

In a prospective randomized controlled trial showed that kyphoplasty is not cost-effective compared to standard therapy in patients with acute and subacute vertebral compression fractures with a QALY COST ("quality adjusted life year") for kyphoplasty of $134,043 based on a 2-year follow-up.

In contrast, kyphoplasty was considered cost-effective in the treatment of hospitalized patients with vertebral compression fractures in England (Svedbom et al. 2013). It is generally accepted that an intervention is considered cost-effective above a cost to QALY ratio of <$50,000. Due to the lack of conclusive data that kyphoplasty results in better outcomes than vertebroplasty in terms of pain and/or HRQOL data, based on the literature, the additional costs of kyphoplasty cannot be justified from a purely economic point of view at the moment.

References

Agko M, Nazzal M, Jamil T, Castillo-Sang M, Clark P, Kasper G (2010) Prevention of cardiopulmonary embolization of polymethylmethacrylate cement fragment after kyphoplasty with insertion of inferior vena cava filter. J Vasc Surg 51(1):210–213. https://doi.org/10.1016/j.jvs.2009.07.110

Ananthakrishnan D, Lotz JC, Berven S, Puttlitz Ch (2003) Changes in spinal loading due to vertebral augmentation: vertebroplasty versus kyphoplasty. (Vortrag am AAOS-Jahrestreffen im Februar in New Orleans, S 593)

Anderson PS, Froyshteter AB, Tontz WL Jr (2013) Meta-analysis of vertebral augmentation compared with conservative treatment for osteoporotic spinal fractures. J Bone Miner Res 28(2):372–382

Arden N, Cooper C (1998) Present and future of osteoporosis: epidemiology. In: Meunier PJ (ed) Osteoporosis: diagnosis and management. Martin Dunitz, London, pp 1–16

Bai B, Jazrawi LM, Kummer FJ, Spivak JM (2000) The use of an injectable, biodegradable calcium phosphate bone substitute for the prophylactic augmentation of osteoporotic vertebrae and the managment of vertebral compression fractures. Spine 24:1521–1526

Barr JD, Barr MS, Lemley TJ, McCann RM (2000) Percutaneous vertebroplasty for pain relief and spinal stabilisation. Spine 25:923–928

Belkoff SM, Maroney M, Fenton DC, Mathis JM (1999) An in vitro biomechanical evaluation of bone cements used in percutaneous vertebroplasty. Bone 25:23S–26S

Belkoff SM, Mathis JM, Fenton DC et al (2001) An ex vivo biomechanical evaluation of an inflatable bone tampused in the treeatment of compression fracture. Spine 26:151–156

Berlemann U, Ferguson SJ, Nolte LR, Heini PF (2001a) Adjacent vertebral failure following vertebroplasty: a biomechanical investigation. J Bone Joint Surg (Br) 84(5):748–752

Berlemann U, Franz T, Heini PF, Krettek C (2001b) Die perkutane Aufrichtung und Zementierung kyphotischer Osteoporosewirbelkörper mittels einer neuen Ballontechnik (Kyphoplastik). (Vortrag an der 65. Jahrestagung der Deutschen Gesellschaft für Unfallchirurgie in Berlin)

Blasco J, Martinez-Ferrer A, Macho J, San Roman L, Pomés J, Carrasco J, Monegal A, Guañabens N, Peris P (2012) Effect of vertebroplasty on pain relief, quality of life, and the incidence of new vertebral fractures: a 12-month randomized follow-up, controlled trial. J Bone Miner Res 27(5):1159–1166

Bohner M, Gasser B, Baroud G, Heini P (2003) Theoretical and experimental model to describe the injection of a polymethylmethacrylate cement into a porous structure. Biomaterials 24(16):2721–2730

Bose R, Choi JW (2010) Successful percutaneous retrieval of methyl methacrylate orthopedic cement embolism from the pulmonary artery. Catheter Cardiovasc Interv 76(2):198–201. https://doi.org/10.1002/ccd.22496

Bostrom MP, Lane JM (1997) Future directions. Augmentation of osteoporotic vertebral bodies. Spine 22(24 Suppl):39S–42S

Buchbinder R, Osborne RH, Ebeling PR, Wark JD, Mitchell P, Wriedt C, Graves S, Staples MP, Murphy B (2009) A randomized trial of vertebroplasty for painful osteoporotic vertebral fractures. N Engl J Med 361(6):557–568

Bula P, Lein T, Strassberger C, Bonnaire F (2010) Balloon kyphoplasty in the treatment of osteoporotic vertebral fractures: indications—treatment strategy—complications. Z Orthop Unfall 148(6):646–656. https://doi.org/10.1055/s-0030-125037

Cauley JA et al (2000) Risk of mortality following clinical fractures. Osteoporos Int 11(7):556–561
Choe DH, Marom EM, Ahrar K, Truong MT, Madewell JE (2004) Pulmonary embolism of polymethyl methacrylate during percutaneous vertebroplasty and kyphoplasty. Am J Roentgenol 183(4):1097–1102
Consensus Development Conference (1993) Diagnosis, prophylaxis, and treatment of osteoporosis. Am J Med 94:646–650
Cooper C et al (1992) Incidence of clinically diagnosed vertebral fractures: a population-based study on Rochester, MN, 1985–1989. J Bone Miner Res 72(2):221–227
Coumans JV, Liebermann IH (2003) A pospective kyphoplasty study. (Vortrag am AAOS-Jahrestreffen im Februar in New Orleans, S 593)
Einhorn TA (2000) Vertebroplasty: an opportunity to do something really good for patients. Spine 25:1051–1052
Evans AJ, Weinhoffer SL, Mathis JM, Kennett KB, Crandall JR, Dion JE (1995) Effectivness of vertebral body stabilisation with percutaneus injection of methylmetacrylate. (Vortrag am Jahrestreffen der American Society of Neuroradiology im April in Chicago)
Farahvar A, Dubensky D, Bakos R (2009) Perforation of the right cardiac ventricular wall by polymethylmethacrylate after lumbar kyphoplasty. J Neurosurg Spine 11(4):487–491. https://doi.org/10.3171/2009.5.SPINE08517
Galibert P, Deramond H, Rosat P, Le Gars D (1987) Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty. Neurochirurgie 33(2):166–168
Gangi A, Kastler BA, Dietemann JL (1994) Percutaneous vertebroplasty guided by a combination of CT and fluoroscopy. AJNR Am J Neuroradiol 15(1):83–86
Garfin SR et al (2001) New technologies in spine: kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. Spine 26(2):1511–1515
Grados F, Depriester C, Cayrolie G et al (2000) Long-term observations of vertebral osteoporotic fractures treated by percutaneous vertebroplasty. Rheumatology 39:1410–1414
Heini PF, Orler R (2004) Kyphoplasty for treatment of osteoporotic vertebral fractures. Eur Spine J 13(3):184–192
Heini PF, Beriemann U, Kaufmann M et al (2001) Augmentation of mechanical properties in osteoporotic vertebral bones: a biomechanical investigation of vertebroplasty efficacy with different bone cements. Eur Spine J 10:164–171
Hiwatashi A, Moritani T, Numaguchi Y, Westesson PL (2003) Increase in vertebral body height after vertebroplasty. Am J Neuroradiol 24(2):185–189
Hochegger M, Radl R, Leithner A, Windhager R (2005) Spinal canal stenosis after vertebroplasty. Clin Radiol 60(3):397–400
Hsieh MK, Chen LH, Chen WJ (2013) Current concepts of percutaneous balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures: evidence-based review. Biomed J 36(4):154–161. https://doi.org/10.4103/2319-4170.112544
Huang C, Ross P, Wasnich R (1996a) Vertebral fractures and other predictors of back pain among older women. JBMR 11(7):1026–1032
Huang C, Ross P, Wasnich R (1996b) Vertebral fractures and other predictors of physical impairment and health care utilization. Arch Intern Med 156(7):2469–2475
Huang MH, Barrett-Connor E, Greendale GA, Kado DM (2006) Hyperkyphotic posture and risk of future osteoporotic fractures: the rancho Bernardo study. J Bone Miner Res 21(3):419–423
Ikeuchi M, Yamamoto H, Shibata T, Otani M (2001) Mechanical augmentation of the vertebral body by caicium phosphate cement injection. J Orthop Sci 6:39–45
Jensen ME, Evans AJ, Mathis JM, Kallmes DF, Cloft HJ, Dion JE (1997) Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects. AJNR Am J Neuroradiol 18(10):1897–1904
Jerosch J, Filler TJ, Peuker ET et al (1999) Perkutane vertebrale Augmentation (PVA) bei osteoporotischen Wirbelkörpern—eine experimentelle Untersuchung. Biomed Tech 44:190–193
Kado DM, Duong T, Stone KL, Ensrud KE, Nevitt MC, Greendale GA, Cummings SR (2003) Incident vertebral fractures and mortality in older women: a prospective study. Osteoporos Int 14(7):589–594
Kallmes DF, Comstock BA, Heagerty PJ et al (2009) A randomized trial of vertebroplasty for osteoporotic spinal fractures. N Engl J Med 361(6):569–579
Kanis JA, WHO Study Group (1994) Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. Osteoporos Int 4:368–381
Katzman SS (2003) Operative treatment of oesteoporotic vertebral body fractures: vertebroplasty versus kyphoplasty. (Vortrag am AAOS-Jahrestreffen im Februar in New Orleans, S 461)
Leidig G, Minne HW, Sauer R, Wüster C, Wüster J, Lojen M, Raue F, Ziegler R (1990) A study of complaints and their relation to vertebral destruction in patients with osteoporosis. Bone Miner 8:217–229
Leidig-Bruckner G, Minne HW, Schlaich C et al (1997) Clinical grading of spinal osteoporosis. Quality of life components and spinal deformity in women with chronic low back pain and women with vertebral osteoporosis. JBMR 12(4):1–13
Lieberman ICH, Dudeney S, Reinhardt MK, Bell G (2001) Initial outcome ad efficacy of kyphplasty in the treatment of painfui osteoporotic vertebral compression fractures. Spine 26:1631–1638
Liebschner MAK, Rosenberg WS, Keaveny TM (2001) Effects of bone cement volume and distribution on

vertebral stiffness after vertebroplasty. Spine 26:1547–1554
Martin JB, Jean B, Sugiu K et al (1999) Vertebroplasty: clinical experience and follow-up results. Bone 25:11S–15S
Martin DJ, Rad AE, Kallmes DF (2012) Prevalence of extravertebral cement leakage after vertebroplasty: procedural documentation versus CT detection. Acta Radiol 53(5):569–572
Minne HW (1991) Lebensqualität im Alter bedroht durch Osteoporose? Pharm Unserer Zeit 3:109–113
Nussbaum DA, Gailloud P, Murphy K (2004) A review of complications associated with vertebroplasty and kyphoplasty as reported to the Food and Drug Administration medical device related web site. J Vasc Interv Radiol 15:1185–1192
O'Neill TW, Silman AJ (1997) Definition and diagnosis of vertebral fracture. J Rheumatol 24(6):1208–1211
Padovani B, Kasriei O, Brunner P, Peretti-Viton P (1999) Pulmonary embolism caused by acrylic cement: a rare complication of percutaneous vertebroplasty. Am J Neuroradiol 20:375–377
Prokop A, Dolezych R, Chmielnicki M (2014) Kyphoplasty in the treatment of osteoporotic spine fractures – experience with 1069 cases. Z Orthop Unfall 152(4):315–318. https://doi.org/10.1055/s-0034-1368448
Riesner HJ, Kiupel K, Lang P, Stuby FM, Palm HG (2016) Klinische Bedeutung von Zementleckagen. Eine prospektive randomisierte Studie: Radiofrequenzkyphoplastie versus Ballonkyphoplastie bei Wirbelkörperfrakturen. (Vortrag an der 64. Jahrestagung der Vereinigung Süddeutscher Orthopäden und Unfallchirugen, 28.–30. April, Baden-Baden)
Ronge R (2005) Multiple sclerosis—correlation between spinal MRT and histopathologic findings. RöFo 177(4):492
Ross PD (1997) Clinical consequences of vertebral fractures. Am J Med 103(2A):30S–43S
Scholz MG, Minne HW (1998) Differential diagnosis: back pain and osteoporosis. In: Geusens P (ed) Osteoporosis in clinical practice: a practical guide for diagnosis and treatment. Springer, London, pp 65–68
Schulz C et al (2012) Erfahrungen mit intravasalen Zementaustritten nach Ballonkyphoplastie. Orthopade 41(11):881–888
Seo JS, Kim YJ, Choi BW, Kim TH, Choe KO (2005) MDCT of pulmonary embolism after percutaneous vertebroplasty. AJR Am J Roentgenol 184(4):1364–1365
Silverman SL (1992) The clinical consequences of vertebral compression fracture. Bone 13:27–31
Silverman SL, Minshall ME, Shen W, Harper KD, Xie S, Health-Related Quality of Life Subgroup of the Multiple Outcomes of Raloxifene Evaluation Study (2001) The relationship of health-related quality of life to prevalent and incident vertebral fractures in postmenopausal women with osteoporosis: results from the multiple outcomes of Raloxifene evaluation study. Arthritis Rheum 44(11):2611–2619
Svedbom A, Hernlund E, Ivergård M, Compston J, Cooper C, Stenmark J, EV MC, Jönsson B, s (2013) Osteoporosis in the European Union: a compendium of country-specific reports. Arch Osteoporos 8:137
Tohmeh AG, Mathis JM, Fenton DC/Levine AM, Boikott SM (1999) Biomechanical efficacy of unipedicular versus bipedicular vertebroplasty for the management of osteoporotic compression fractures. Spine 24:1772–1776
von Stechow D, Alkalay R (2001) Perkutane Vertebroplastik mit Polymethylmethacrylat (PMMA) in frakturierten osteoporotischen Wirbelkörpern. Eine biomechanische Untersuchung. Z Orthop 139:456–462
Wang GW, Wilson CS, Hubbard SL (1984) Safety of anterior cement fixation in the cervical spine: in vivo study of the dog spine. South Med J 77:178–179
Wang LJ, Yang HL, Shi YX, Jiang WM, Chen L (2012) Pulmonary cement embolism associated with percutaneous vertebroplasty or kyphoplasty: a systematic review. Orthop Surg 4(3):182–189
Wasnich RD (1996) Vertebral fracture epidemiology. Bone 18:179S–183S
Weill A, Chiras J, Simon JM, Rose M, Sola-Martinez T, Enkaaoua E (1996) Spinal metastases: injections for and results of percutaneous injection of acrylic cement. Radiology 199:241–247
Yeom JS, Kim WJ, Choy WS, Lee CK, Chang BS, Kang JW, Kim KH (2003) Leakage of cement in percutaneus transpedikular vertebroplasty for painful osteororotic compression fractures. J Bone Joint Surg 85-B:83–89

Further Reading

Aebli N et al (2002) Fat embolism and acute hypotension during vertebroplasty. Spine 27(5):460–466
Belkoff SM, Mathis JM, Erbe EM, Fenton DC (2000) Bipmechanical evaiuation of a new bone cement for use in vertebroplasty. Spine 25:1061–1064
Belkoff SM, Jasper LE, Stevens SS (2002) An ex vivo evaluation of an inflatable bone tamp used to reduce fractures within vertebral bodies under load. Spine 27(15):1640–1643
Berlemann U, Heini PF (2002) Percutaneous balloon kyphoplasty, a treatment of osteoporotic VCF. Unfallchirurg 105:2–8
Coe JD, Warden KE, Herzig MA, McAffee PC (1990) Influence of bone mineral density on the fixation of thoracolumbar implants: a comparative study of transpedicular screws, laminar hooks, and spinous process wires. Spine 15:902–907
Cooper C (1997) The crippling consequences of fractures and their impact on quality of life. Am J Med 103(2A):12–19
Cooper C, Atkinson EJ, Jacobsen SJ, O'Fallon M, Melton U (1993) Population-based study of survival After osteoporotic fractures. Am J Epidemiol 137:1001–1005

Cortet B, Cotten A, Deprez X et al (1994) Value of vertebroplasty combined with surgical decompression in the treatment of aggressive spinal angioma. Apropos of 3 cases. Rev Rhum Ed Fr 61(1):16–22

Cortet B, Cotten A, Boutry N et al (1997) Percutaneous vertebroplasty in patients with osteolytic metastases or multiple myeloma. Rev Rhum Engl Ed 64(3): 177–183

Cortet B, Cotten A, Boutry N et al (1999a) Percutaneous vertebropiasty in the treatment of osteoporotic vertebral compression fractures: an open prospective study. J Rheumatol 26:2222–2228

Cortet B, Houvenagel E, Puisieux F et al (1999b) Spinal curvatures and quality of life in women with vertebral fractures secondary to osteoporosis. Spine 24:1921–1925

Cotten A, Duquesnoy B (1997) Vertebroplasty: current data and future potential. Rev Rhum Engl Ed 64(11):645–649

Cotten A, Dewatre F, Cortet B et al (1996) Percutaneous vertebroplasty for osteolytic metastases and myeloma: effects of the percentage of lesion filling and the leakage of methyl methacrylate at clinical follow-up. Radiology 200(2):525–530

Cotten A, Boutry N, Cortet B et al (1998) Percutaneous vertebroplasty: state of the art. Radiographics 18(2):311–320

Cyteval C, Sarrabere MR, Roux JO et al (1999) Acute osteoporotic vertebral collapse: open study on percutaneous injection of acrylic surgical cement in 20 patients. Am J Roentgenol 173:1685–1690

Deramond H, Depriester C, Toussaint P (1996) Vertebroplasty and percutaneous interventional radiology in bone metastases: techniques, indications, contra-indications. Bull Cancer Radiother 83(4):277–282

Deramond H, Depriester C, Galibert P, Le Gars D (1998) Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications, and results. Radiol Clin N Am 36(3):533–546

Dousset V, Mousselard H, de Monck d'User L et al (1996) Asymptomatic cervical haemangioma treated by percutaneous vertebroplasty. Neuroradiology 38(4):392–394

Dudeney S et al (2002) Kyphoplasty in the treatment of osteolytic vertebral compression fractures as a result of multiple myeloma. J Clin Oncol 20(9):2382–2387

Dufresne AC, Brunet E, Sola-Martinez MT, Rose M, Chiras J (1998) Percutaneous vertebroplasty of the cervico-thoracic junction using an anterior route. Technique and results. Report of nine cases. J Neuroradiol 25(2):123–128

Ettinger B, Black DM, Nevitt MC, Rundle AC, Cauley JA, Cummings SR, Genant HK (1992) Contribution of vertebral deformities to chronic back pain and disability. The Study of Osteoporotic Fractures Research Group. J Bone Miner Res 7(4):449–456

Felsenberg D, Wieland E, Hammermeister C, Armbrecht G, Gowin W, Raspe H, Deutschland DE-G i (1998) Prävalenz der vertebralen Wirbelkörperdeformationen bei Frauen und Männer in Deutschland. Med Klin 93(Suppl II):31–33

Feydy A, Cognard C, Miaux Y, Sola Martinez MT, Weill A, Rose M, Chiras J (1996) Acrylic vertebroplasty in symptomatic cervical vertebral haemangiomas: report of 2 cases. Neuroradiology 38(4):389–391

Fourney DR et al (2003) Percutaneous vertebroplasty and kyphoplasty for painful vertebral body fractures in cancer patients. J Neurosurg Spine 1(98): 21–30

Galibert P, Deramond H (1990) Percutaneous acrylic vertebroplasty as a treatment of vertebral angioma as well as painful and debilitating diseases. Chirurgie 116(3):326–334

Gold DT (1996) The clinical impact of vertebral fractures: quality of life in women with osteoporosis. Bone 18(3):1855–1895

Hardouin P et al (2002) Kyphoplasty. Joint Bone Spine 69:256–261

Harington KD (2001) Major neurological complications following percutaneous vertebroplasty with polymerhylmethacryiate: a case report. J Bone Joint Surg 83-A:1070–1073

Heini PF, Wälchli B, Berlemann U (2000) Percutaneous transpedicular vertebroplasty with PMMA: a prospective study for the treatment of osteoporotic compression fractures. Eur Spine J 9:445–450

Ide C, Gangi A, Rimmelin A, Beaujeux R, Maitrot D, Buchheit F, Sellal F, Dietemann JL (1996) Vertebral haemangiomas with spinal cord compression: the place of preoperative percutaneous vertebroplasty with methyl methacrylate. Neuroradiology 38(6):585–589

Johnell O et al (1997) The hospital burden of vertebral fracture in Europe: a study of national register sources. Osteoporosis Int'l 7:138–144

Johnell O et al (2001) Acute and long-term increase in fracture risk after hospitalization for vertebral fracture. Osteoporos Int 12:207–214

Kado DM et al (1999) Vertebral body fractures and mortality in older women. Arch Intern Med 159(11):1215–1220

Kaemmerlen P, Thiesse P, Bouvard H, Biron P, Mornex F, Jonas P (1989) Percutaneous vertebroplasty in the treatment of metastases. Technic and results. J Radiol 70(10):557–562

Kanis JA, Delmas P, Burckhardt P, Cooper C, Torgerson D (1997) Guidelines for diagnosis and management of osteoporosis. Osteoporos Int 7:390–406

Kaplan FS, Schert JD, Wisneski R, Cheatle M, Haddad JG (1993) The cluster phenomenon in patients who have multiple vertebral compression fractures. Clin Orthop Relat Res 297:161–167

Klöckner C, Weber U (2001) Operative Möglichkeiten zur Behandlung von Erkrankungen und Verletzungen der Wirbelsäule bei Patienten mit manifester Osteoporose. Orthopade 30:473–478

Ledlie JT et al (2003) Balloon kyphoplasty: one year outcomes in vertebral body height restoration, chronic pain, and activity levels. J Neurosurg Spine 1(98):36–42

Lee BJ et al (2002) Paraplegia as a complication of percutaneous vertebroplasty with PMMA. Spine 27(19):E419–E422

Lopes NM, Lopes VK (2004) Paraplegia complicating percutaneous vertebroplasty for osteoporotic vertebral fracture: case report. Arq Neuropsiquiatr 62(3B):879–881

Lyies KW, Gold DT, Shipp KM, Pieper CF, Martinez S, Mulhausen PL (1993) Association of osteoporotic vertebral compression fractures with impaired functional status. Am J Med 94:595–601

Mathis JM, Petri M, Naff N (1998) Percutaneous vertebroplasty treatment of steroid-induced osteoporotic compression fractures. Arthritis Rheum 41(1): 171–175

Matthis C, Raspe H (1998) Burden of illness in vertebral deformities. EVOS-Group in Germany. Med Klin 93(Suppl 2):41–46

Melton LJ III (1997) Epidemiology of spinal osteoporosis. Spine 22(24S):2S–11S

O'Neill TW, Felsenberg D, Varlow J, Cooper C, Kanis JA, Silman AJ, Group a t EVOS (1996) The prevalence of vertebral deformity in European men and women: the European vertebral osteoporosis study. J Bone Miner Res 11:1010–1018

Ratliff J, Nguyen T, Heiss J (2001) Root and spinal cord compression from methyl-methacrylate vertebroplasty. Spine 26:e300–e302

von Strempel A, Kühle J, Plitz W (1994) Stabilität von Pedikelschrauben. Teil 2: Maximale Auszugskräfte unter Berücksichtigung der Knochendichte. Z Orthop 132:82–86

Balloon, Radiofrequency, Vertebro and Cement Sacroplasty for the Treatment of Non-Displaced Insufficiency Fractures

R. Andresen, S. Radmer, J. R. Andresen, and M. Wollny

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_27

27.1 Indication

Percutaneous cement augmentation using balloon sacroplasty (BSP), radiofrequency sacroplasty (RFS), vertebro-sacroplasty (VSP), or cement sacroplasty (ZSP) can be performed as pain therapy for the treatment of non-displaced insufficiency fractures (Andresen et al. 2018) or pathological osseous destruction (Andresen et al. 2014). In the following, only the treatment of insufficiency fractures of the os sacrum will be discussed.

Since the initial description by Lourie (1982), physicians are increasingly aware of this fracture type due to increased clinical awareness and more targeted diagnostic imaging (Cabarrus et al. 2008; Cho et al. 2010; Lyders et al. 2010). Insufficiency fractures of the os sacrum are found in patients with reduced bone quality, rheumatoid arthritis, and after cortisone medication, with older postmeopausal women with osteoporosis having the highest risk profile (Gotis-Graham et al. 1994; West et al. 1994; Lin and Lane 2003; Schindler et al. 2007; Andrich et al. 2015). An incidence of 3–5% is thought to occur in patients in such high-risk groups, but exact figures are not currently available. In patients after pelvic radiotherapy, the fracture rate is significantly higher (Lundin et al. 1990; Ramlov et al. 2017).

Anatomical changes with ossifications of ligamentous structures and a degradation of predominantly spongy bone lead to a loss of elasticity and stability in patients of advanced age, which already causes an increased non-physiological application of force to the massae laterales of the os sacrum during normal walking (Linstrom et al. 2009). The consequences are

- mostly vertical transalar (type 1),
- transforaminal (type 2) or
- central (type 3) fracture zones with possible additional horizontal fracture spurs (Denis et al. 1988),

with bilateral fractures being more common than unilateral fractures (Andresen et al. 2017a). These fractures are often the first site of manifestation on the pelvis, followed by fractures in the ramus ossis pubis, parasymphyseal region, acetabulum, and iliac crest. Severe immobilizing low back, gluteal, and groin pain are clinically prominent (De Smet and Neff 1985; Peh et al. 1996; Aretxabala et al. 2000; Alnaib et al. 2012).

To date, conservative treatment of sacral insufficiency fracture is considered the gold standard, with bed rest with pain and osteoporosis medication and pain-adapted exercise measures individually adapted. However, patients with severe, disabling pain are difficult to mobilize, develop a high rate of complications such as phlebothrombosis and pulmonary artery embolism, infections, pressure ulcers, and further deterioration of the musculoskeletal system (Babayev et al. 2000; Heß 2006). It is not uncommon for clinical improvement to occur only in the long term, and often a higher degree of fracture instability or the development of pseudarthrosis with persistent complaints occurs in the course of the disease. In these patients, the mortality rate is unacceptably high (Andresen et al. 2015b).

In patients with unstable fractures of the sacrum and persistent disabling pain, percutaneous screw (Tjardes et al. 2008), plate (Klineberg et al. 2008), or spinopelvic osteosynthesis (Josten and Höch 2017) should be considered early. For non-displaced fractures, "Fragility Fractures of the Pelvis Type IIa" according to Rommens and Hofmann (2013), percutaneous cement placement (Butler et al. 2005; Whitlow et al. 2007a; Bayley et al. 2009; Lyders et al. 2010; Trouvin et al. 2012; Andresen et al. 2017b) is an alternative to percutaneous surgical procedures as a minimally invasive, effective and sustainable pain treatment.

27.2 Preinterventional Diagnostics

In the case of sudden onset of severe back pain, a sacral insufficiency fracture should be considered as a causative factor in elderly patients, in

addition to degenerative changes and lumbar fractures (Lourie 1982; Grasland et al. 1996; Dasgupta et al. 1998; Na et al. 2017).

Fractures in the os sacrum are difficult to diagnose on conventional radiographs, being missed prospectively by up to 70% and retrospectively by up to 50% (Gotis-Graham et al. 1994; Grasland et al. 1996).

In skeletal scintigraphy, with a sensitivity of >90%, there is a strong increase in enrichment in the area of the fracture (Fujii et al. 2005), but an exact representation of the fracture lines or reliable differentiation from pathological fractures is not possible.

On CT, the fractures show lines of illumination with sclerosis, whereby the fractures usually running sagittally in the os sacrum are not infrequently overlooked in the axial sectional image. A coronal section, whether reformed or directly acquired with appropriate gantry inclination, improves sensitivity to >70% and visualizes the fracture process in full extension (Peh et al. 1996). Occult insufficiency fractures show edema with a significant increase in density in the area of the fracture zone. This can be reliably recorded by means of density measurement in the CT and thus further improve detection (Henes et al. 2012).

MRI, with its highly T2-weighted and partially fat-suppressed sequences, allows early edema detection with a sensitivity approaching 100% and is thus superior to skeletal scintigraphy and CT in the detection of fatigue fractures (Cabarrus et al. 2008; Nüchtern et al. 2015). As in CT, a coronally angulated image plane best visualizes fractures that are usually sagittal (Brahme et al. 1990). T1-weighted spin echo sequences with fat suppression, before and after administration of gadolinium-DTPA, provide additional discrimination of pathological destruction (Featherstone 1999).

For conservative, interventional or surgical treatment planning, the classification of "Fragility Fractures of the Pelvis" according to Rommens and Hofmann (2013) is very helpful; this can be reliably done with CT and MRI imaging (Lyders et al. 2010; Wagner et al. 2015).

27.3 Costs and Possible Reimbursement

Depending on the therapeutic objective and the underlying technique (vertebroplasty or kyphoplasty), sacroplasties are primarily assigned to the base DRG I10 "Other spinal procedures […]" or I09 "Certain spinal procedures […]" in the 2017 billing period. Within the base DRG, the final allocation is defined by the number of vertebral bodies treated and the PCCL (= total patient severity).

In the case of **vertebroplasty,** an OPS code from 5–839.9_ is to be used to classify the intervention, whereby the number of augmented levels is defined via the sixth digit. In this case, 1–2 vertebral bodies are assigned to DRG I10F (approx. €3900) and the treatment of 3 levels to DRG I10D (approx. €4600). Four or more levels are assigned to DRG I10B (approximately €6700). Patients with a PCCL ≥4 and an augmented vertebral level are also found in this DRG. From the treatment of ≥2 floors and a PCCL 4, the vertebroplastic procedure for the treatment of insufficiency fractures of the sacrum is allocated to DRG I10A (approx. €13,400).

The **kyphoplastic procedure** must be classified with an OPS code from 5–839.a_, which is mainly assigned to the basic DRG I09. Here, the assignment of the treatment of one vertebral body height is to I09F (approx. 6000€), while 2- and 3-level fittings result in DRG I09E (approx. 7900€). An augmentation of ≥4 levels heads to DRG I09D (approximately €10,400). Here, too, the PCCL represents a split criterion, whereby in the case of augmentation of only one vertebral body, only chronic para- or tetraplegia as secondary diagnoses (ICD codes from G82.0- to G82.5- and G95.-, G04.1, P11.51) trigger the assignment to the higher-reimbursed I09E. Otherwise, the PCCL has no effect here for the treatment of only one vertebral body. The augmentation of 2 vertebral bodies in patients with a PCCL 4 as well as the treatment of 3 vertebrae and a PCCL ≥3 result in DRG I09D. A treatment of ≥4 vertebrae and a PCCL 4 or more results in assignment to DRG I09C (approximately €14,600). ◘ Table 27.1 schematically illus-

Table 27.1 Schematic representation of DRG assignment conditions (2017) depending on the sacroplasty technique and the overall severity of the patient

		Number of vertebral bodies supplied for sacroplasty							
		1		**2**		**3**		**≥4**	
	Technology	Kyphoplastic	Vertebroplastic	Kyphoplastic	Vertebroplastic	Kyphoplastic	Vertebroplastic	Kyphoplastic	Vertebroplastic
	OPS	5–839.a0	5–839.90	5–839.a1	5–839.91	5–839.a2	5–839.92	5–839.a3	5–839.93
PCCL	0	I09F	I10F	I09E	I10F	I09E	I10D	I09D	I10B
	1								
	2								
	3					I09D			
	4		I10B	I09D	I10A		I10A	I09C	I10A

OPS operation and procedure code; *PCCL* patient-related total severity code

trates the DRG assignment conditions of sacroplasties in the context of the underlying vertebroplasty or kyphoplasty technique and depending on the number of floors treated and the patient status (PCCL).

In the following, economic results are outlined in the context of the **4 sacroplasty techniques** presented **here,** whereby the key figures presented are based on the 2017 accounting period and may deviate from those of other clinics. For example, in the case of procurement costs, it was possible to fall back on network partners and to achieve purchase prices for the various systems of between (€580.72 and €2434.75) via corresponding volumes (Table 27.2). The expenditure for operating theatre infrastructure (= cost centre 4 with cost type group 7) and operating theatre personnel (= cost centre 4 with cost type group 1–3) was derived from key figures of the G-DRG Report Browser 2017 (InEK 2015/2017) and calculated according to the average incision-suture time, incl. Set-up time, equal to the standard procedure of the cost unit accounting of the Institute for Hospital Remuneration System (InEK 2016). The data shown in the G-DRG Report Browser 2017 are in the context of the reference value and

Table 27.2 Description of the four compared sacroplasty techniques with manufacturer, system and implant details as well as listing of material costs, incision-suture times, classification and revenues

	Balloon sacroplasty (1)	**Radiofrequency sacroplasty (2)**	**Sacroplasty/ vertebroplasty technique (3)**	**Cement sacroplasty (4)**
Manufacturer/ distributor	Medtronic	Merit medical	Optimed	Merit medical
Augmentation technique	Balloon kyphoplasty (BKP)	Radiofrequency kyphoplasty (RFK)	Vertebroplasty (VP)	Kyphoplasty (KP)
System name	Kyphon Xpander II inflatable bone tamp (IBT)	StabiliT® vertebral augmentation system	Cemento plus	StabiliT® vertebral augmentation system
Implant name	KYPHON HV-R® bone cement	StabiliT® ER2 bone cement	Cemento Fixx-M	StabiliT® bone cement
Cost of materials (average)	2434.75€	1666.00€	580.72€	1011.50€
Cut-sew time (average)	150 min	120 min	90 min	90 min
Notes	Very time-consuming, as many small parts (balloon, contrast medium, syringe, etc.) have to be assembled individually. Filling of the 5 injectors filled with cement is time-consuming.	Time expenditure rather normal, coherent system in structure and application of the cement, unfortunately now and then problems in the activation module	Time expenditure low with easy to use system, unfortunately the consistency of the cement is not continuous over a long period of time	Time expenditure low, simple coherent system in structure and application

(continued)

Table 27.2 (continued)

	Balloon sacroplasty (1)	Radiofrequency sacroplasty (2)	Sacroplasty/ vertebroplasty technique (3)	Cement sacroplasty (4)
OPS coding (5-digit)	5–839.a_	5–839.a_	5–839.9_	5–839.a_
G-DRG (2017)	I09E	I09E	I10F	I09E
Relative weight (2017)	2355	2355	1157	2355
G-DRG revenue (inlier)[a]	7881.01 €	7881.01 €	3871.90 €	7881.01 €

[a]Based on state base rate € 3346.50

were applied to the values of the state base case value of €3346.50 for Schleswig-Holstein using the rule of three with the aid of the G-DRG Excel cost tool (Version 2017.3; Thieme 2017).

One of the sacroplasty techniques is based on the concept of vertebroplasty (Cemento Plus, Optimed) and 3 on the concept of kyphoplasty (Kyphon Xpander II Inflatable Bone Tamp, Medtronic; StabiliT® Vertebral Augmentation System, Merit Medical), with one manufacturer offering two systems based on the kyphoplastic principle with different application systems and implant properties (StabiliT® ER2 Bone Cement and StabiliT® Bone Cement, Merit Medical).

The respective system applied for sacroplasty with the associated technique has an impact on the classification according to OPS 2017 and thus ultimately also on the assignment of the respective G-DRG. The presentation here is limited to the G-DRGs I10F and I09E, as two floors were always treated in the patient collective presented and any comorbidities present had no influence on the final G-DRG assignment. Also, for ease of economic comparison, the entire patient population was mapped to 2017 billing results. This means that with the 2017 valid state base rate of €3346.50, G-DRG revenues of €3871.90 or €7881.01 were generated per case (inlier) in our hospital (Table 27.2). The average length of stay of 4 days was medically justified in all cases and there were no cases where the length of stay fell below the lower limit.

In our hospital, the **balloon acroplasty** method (Medtronic) represents the technique with the highest expenditure of resources (Table 27.2). This is true both in terms of the average procurement price of €2434.75 and in terms of the expenditure of €2975.32 for performing the intervention (= operating theatre personnel costs and operating theatre costs for medical infrastructure). Based on the G-DRG revenue of €7881.01, after deduction of the total costs for the intervention of €5410.07, our hospital still has €2470.94 to cover all other expenses, e.g. for accommodation, pre- and postoperative measures, etc. The costs of the intervention are not covered by the G-DRG. In addition, the approx. ¼ to approx. ½ h longer intervention time compared to the other techniques for the often elderly patients must be taken into account.

The method of **radiofrequency sacroplasty** (Merit Medical) shows an expenditure of 4046.25€ in terms of procurement (1666.00€) and operating theatre personnel including the medical infrastructure of the operating theatre (2380.25€). As a result, an amount of

€3834.75 remains to cover all other expenses for an average 4-day stay (Table 27.2). The economically better result of radiofrequency sacroplasty in the amount of €1363.81 compared to balloon sacroplasty is based not only on better procurement costs but also on the shorter use of the operating theatre (Δ €595.06).

The **sacroplasty/vertebroplasty technique** (Optimed) distorts the economic view here due to the different classification and thus final G-DRG assignment. The Cemento Plus System (Optimed) is based on the concept of vertebroplasty (OPS 5–839.9) and therefore triggers G-DRG I10F with revenue of €3871.90. From this amount, the cost of materials (€580.72), the cost of operating theatre staff and the use of the medical infrastructure of the operating theatre (€1115.79) must be deducted, resulting in a total cost of €1696.51 for performing the intervention (Table 27.2). This also shows the inadequacies of the comparison of ratios with the cost matrix of the G-DRG Report Browser, which other authors have already pointed out (Krüger et al. 2012). This is because, although our standard clinical approach does not differ from the cyphoplastic concepts with regard to the resources OR staff as well as the use of the medical infrastructure of the OR, the imputed expense based on ratios of the G-DRG Report Browser 2017 is completely distorted for these two items. This becomes particularly clear in the direct comparison of methods 3 and 4 with regard to the operating theatre personnel costs and operating theatre medical infrastructure costs calculated on the basis of InEK ratios (Table 27.2).

The kyphoplastic technology of **cement acroplasty** (Merit Medical) has an average resource cost of €1011.50 for materials and an additional €1785.19 for operating theatre staff, including the use of the medical infrastructure of the operating theatre, resulting in a total cost of €2796.69 in our hospital. To cover all further expenses, the hospital thus has €5084.32 of the generated G-DRG revenue amounting to €7881.01 (Table 27.2).

Based on the key figures presented here, cement acroplasty (Merit Medical) is the most economically tolerable intervention for the treatment of insufficiency fractures of the os sacrum in our clinic. Compared to the most resource-intensive balloon acroplasty (Medtronic), cement acroplasty (Merit Medical) leaves approx. 2613.38€ more to cover expenses such as diagnostics, accommodation and further care.

It should be pointed out once again at this point that the economic values here merely convey trends and have no general validity. In addition, inadequacies in the comparison based on cost data from the InEK must be taken into account (Krüger et al. 2012). This becomes particularly clear with regard to the imputed expense of operating room personnel costs and the use of the operating room infrastructure of sacroplasty/vertebroplasty technology (Optimed) or cement sacroplasty (Merit Medical) with otherwise clinically identical standard procedures. This is illustrated in Table 27.3 in particular by the lines Operating theatre personnel costs (total) and Operating theatre medical infrastructure costs (total). Despite identical personnel costs and identical use of the operating theatre infrastructure in terms of time, the G-DRG Report Browser 2017 produces widely differing key figures. Expressed casually and measured in euros, on the basis of these figures a sacroplasty technique based on the vertebroplasty concept is worth less than a kyphoplastic concept and this is not related to the material.

Order Address

Only those companies are listed whose materials have been previously used and discussed. There are other competitors to some of the listed suppliers.

- For balloon acroplasty (BSP): Medtronic GmbH, Earl-Bakken-Platz 1, D-40670 Meerbusch.
- For radiofrequency sacroplasty (RFS) and cement sacroplasty (ZSP): Merit Medical GmbH, Mergenthalerallee 10–12, D-65760 Eschborn.
- For vertebro-sacroplasty (VSP): Optimed Medizinische Instrumente GmbH, Ferdinand-Porsche-Strasse 11, 76,275 D-Ettlingen.

Table 27.3 Presentation of expenses[b] and revenues as well as the result per sacroplasty technique

		Balloon acroplasty	Radiofrequency sacroplasty	Sacroplasty/ vertebroplasty technique	Cement sacroplasty
Pos.	**Effort**	**Revenues (in €)**			
1	Material	2434.75	1666.00	580.72	1011.50
2	Operating theatre personnel costs (total)	2304.03	1843.22	873.35	1382.42
3	OP costs med. Infrastructure (total)	671.29	537.03	242.44	402.77
4	Total OP (∑ pos. 2 + 3)	2975.32	2380.25	1115.79	1785.19
5	*Subtotal (expense)* (∑ items 1 + 4)	5410.07	4046.25	1696.51	2796.69
6	**G-DRG revenue**[a]	7881.01	7881.01	3871.90	7881.01
7	**Result** after intervention[b] (Δ Pos. 6–5)	**2470.94**	**3834.75**	**2175.39**	**5084.32**

[a]Inlier at state base rate 3346.50€;[b]without hotel and other costs

27.4 Preinterventional Education

Sacroplasty procedures are elective minimally invasive procedures that require informed consent at least 24 h prior to intervention.

After clarification of bleeding risks and, if necessary, a necessary drug change or discontinuation, the possibility of localized bleeding must be pointed out. Even after compliance with all the usual sterile conditions, infections cannot be completely ruled out. Wound healing disorders should be mentioned.

Reference should be made to possible cement leakage with possible consecutive sensory and motor nerve damage. In this context, a possible open neurosurgical revision should be mentioned.

The primary goal of the intervention is a rapid, significant and lasting reduction in pain. This cannot be completely guaranteed in the case of frequently additionally present degenerative diseases of the axial skeleton or additional vertebral body sintering fractures.

27.5 Implementation of the Intervention

The intervention can be performed under analgosedation or intubation anaesthesia. To avoid infection, a single-shot antibiotic, e.g. cefazolin 2 g i.v., should be routinely given approx. 30 min before the intervention to ensure that sufficient antibiotic is in the tissue.

Cement placement can be performed under fluoroscopy (Pommersheim et al. 2003; Frey et al. 2008) or CT guided (Andresen et al. 2012a). Due to the complex anatomy of the os sacrum in the pelvis and a usually reduced, osteopenic bone structure in patients with an insufficiency fracture, CT-guided intervention allows better visualization of anatomical boundaries, needle systems and the inserted cement plug, which leads to higher safety compared to C-arm-controlled intervention (Grossterlinden et al. 2009; Prokop et al. 2016). Therefore, only CT-guided cement augmentation will be discussed below.

This can be performed with sufficient accuracy using the low-dose technique to minimize the radiation dose.

The access route for reaching the corresponding fracture zone in the os sacrum is probing either from dorsal to ventral (via the so-called short axis) (Garant 2002; Butler et al. 2005), from lateral to medial, transiliac (via the so-called transiliac axis) (Lüdtke et al. 2013) or in a caudocranial, longitudinal direction (via the so-called long axis) (Binaghi et al. 2006; Smith and Dix 2006). For a summary of access routes, see Andresen et al. (2012b) (Fig. 27.1). In our opinion, the access routes via the short and transiliac axis are technically the most feasible. All fracture zones according to Denis et al. (1988) can be easily reached (Andresen et al. 2017b).

For the **BSP** (Kyphon® HV-R bone cement, Medtronic company), the balloon catheter is in- and deflated 1–3 times in the fracture zone. The cavity thus created is then filled with polymethyl methacrylate (PMMA) cement using the low-pressure method (Andresen et al. 2012a) (Fig. 27.2).

For **RFS** (StabiliT® ER2 bone cement, DFINE Europe), as with BSP, a Jamshidi needle is first inserted into the corresponding fracture zone of the os sacrum. After removal of the internal needle, the cancellous space in the fracture zone is then expanded using the horizontal hollow needle with a flexible osteo-

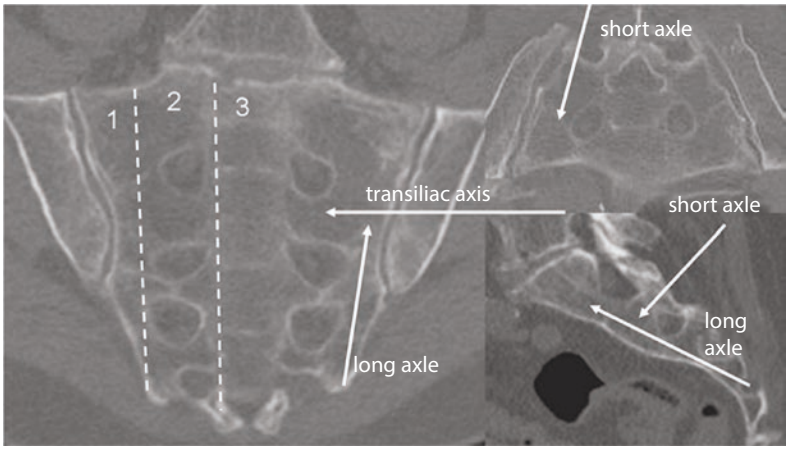


Fig. 27.1 Representation of the Os sacrum in plan and lateral view. Denis fracture zones 1, 2, and 3 are shown on the *left* side. Access routes via the short, transiliac, and long axes are shown on the *right* side. (Modified after Denis et al. 1988 and Andresen et al. 2012b)

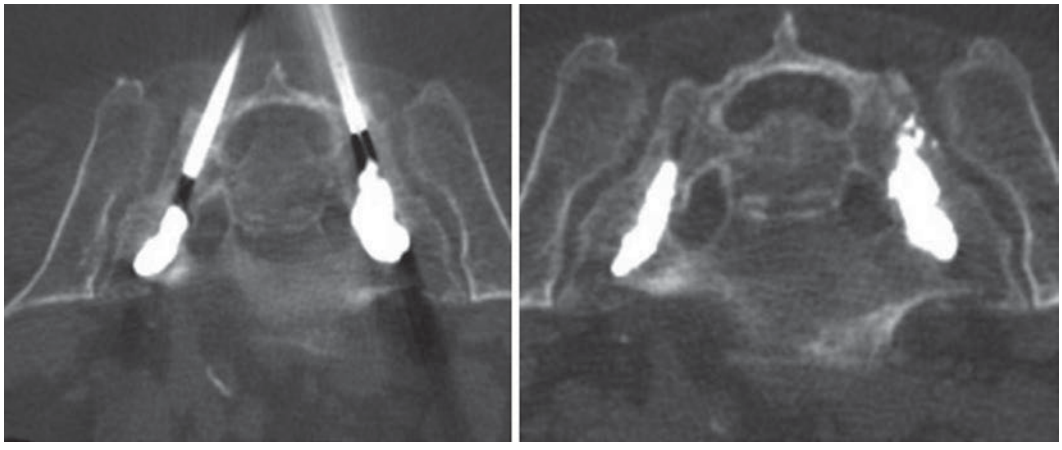
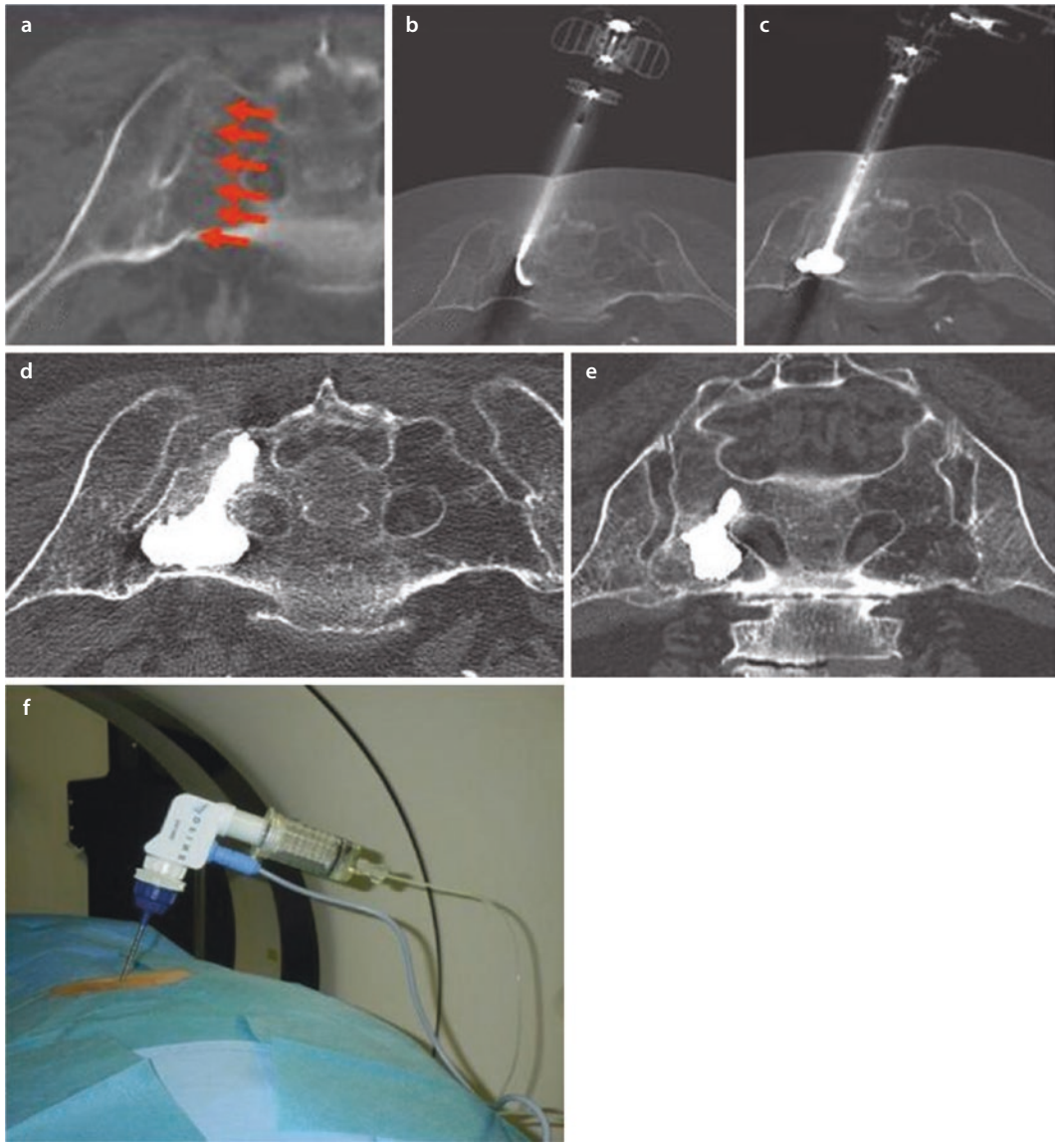


Fig. 27.2 Axial CT slice images. On the *left,* inflated balloon catheters inserted via the short axis in the Denis 1 fracture zone of the os sacrum on both sides. *On the right,* PMMA cement plugs placed centrally in the created cavities; cement leakage can be ruled out

tome, thus preparing a cavity. The highly viscous, radiofrequency-activated PMMA cement is then introduced into the prepared fracture zone through an exchanged screw cannula. The cement is filled discontinuously and instrumentally controlled at 1.3 mL/min under CT control (Andresen et al. 2015a) (■ Fig. 27.3).

For the **VSP** (Cemento Fixx-M, Optimed) and ZSP (StabiliT® bone cement, DFINE Europe), the cement is inserted discontinuously via a hollow needle inserted into the fracture zone in a controlled manner using a pressure manometer. In the case of CSP, the cancellous space is expanded beforehand with a flexible osteotome. The inserted PMMA



■ **Fig. 27.3** **a** Fracture in the massa lateralis left type Denis 1. **b** Using a flexible osteotome, the cancellous space in the fracture zone is expanded, thus preparing a cavity. **c** Highly viscous PMMA cement activated by radiofrequency is introduced into the prepared fracture zone through an exchanged screw cannula. **d** and **e** Axial and coronal CT section, PMMA cement plug lying centrally in the fracture zone, cement leakage can be ruled out. **f** Patient lies in prone position in the CT, display of the cement activator connected to the hollow needle

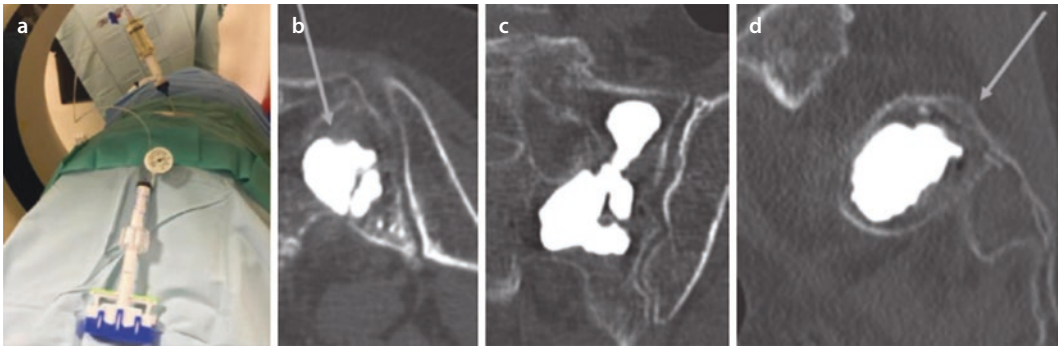


Fig. 27.4 **a** Patient lying prone in CT, showing the cement reservoir connected to the inserted hollow needle with pressure gauge. **b–d** In axial, coronal and sagittal CT section image of PMMA cement plug lying centrally in the fracture zone (Denis 1–2 insufficiency fracture), cement leakage can be excluded

cement in CSP is approximately twice as viscous as in VSP (Andresen et al. 2017b) (Fig. 27.4).

27.6 Possible Complications

Overall, complication rates after sacroplasty are extremely low, with the risk of leakage being highest with VSP compared with BSP, RFS, and ZSP. In our own comparative study (Andresen et al. 2018), approximately 23% leaks developed with VSP, approximately 14% leaks with ZSP, 0% with BSP, and 0% with RFS; all leaks were asymptomatic. For cement placement using the VSP method, Bastian et al. (2012) reported cement leakage from the fracture zone of 27%, into adjacent veins of 6%, into the neuroforamina of 3%, and into the adjacent L5/S1 disc space of 2%, with only one patient developing temporary L5 radiculopathy out of 33 patients treated. Regardless of the different methods used, most cement leaks are localized in extent and do not cause symptoms.

Localized hematomas are possible and are reported to be up to 10% with a transiliac approach (Prokop et al. 2016). The risk of infection is considered to be extremely low; no scientific data exist on this.

A necessary and successful second cement placement for the treatment of a recurrent fracture has only been reported in one case (Simon et al. 2017).

Since patients with an insufficiency fracture of the os sacrum usually have clinically manifest osteoporosis with the risk of further fractures, additional drug therapy should be given after appropriate clarification according to the guidelines of the scientific umbrella association osteology of 2009 (DVO 2011).

27.7 Results in the Literature

As a rapid analgesic effect with a positive effect on mobility and activities of daily living after sacroplasty has been shown several times (Strub et al. 2007; Bayley et al. 2009; Lyders et al. 2010; Andresen et al. 2012a; Trouvin et al. 2012; Talmadge et al. 2014; Onen et al. 2015), this therapy option should be considered after a frustrated conservative therapy attempt with persisting invalidating pain in non-displaced sacral fractures. Methodologically, cement augmentation analogous to vertebroplasty is used here with VSP (Garant 2002; Butler et al. 2005; Heron et al. 2007; Bastian et al. 2012) and ZSP (Andresen et al. 2017b), balloon kyphoplasty with the BSP (Deen and Nottmeier 2005; Briem et al. 2008; Andresen et al. 2012a; Prokop et al. 2016), or radiofrequency kyphoplasty with the RFS (Eichler et al. 2014; Andresen et al. 2015a) may be considered.

The clinically greatest experience is in cement placement via an inserted hollow needle corresponding to vertebroplasty (Garant

2002), although symptom-free cement leakage may not always occur here (Bastian et al. 2012). Although described as safe procedures (Andresen et al. 2017a), BSP (Prokop et al. 2016) and RFS (Eichler et al. 2014) are also not invariably free of leakage, without or with symptoms. In our own comparative study, approximately 14% leakage developed in the CSP, approximately 23% in the VSP, 0% in the BSP, and 0% in the RFS; all leakage was without symptoms (Andresen et al. 2018). Probably due to the use of a PMMA cement twice as viscous in the ZSP as in the VSP, the leakage rate dropped from about 23% to about 14% (Andresen et al. 2018). With the use of a high viscosity PMMA cement as used in the RFS, the leakage rate can be further reduced. Creating a widening of the cancellous space in the fracture zone with a balloon or flexible osteotome prior to cement application appears to further minimize unintentional cement leakage.

The inserted PMMA cement blocks the fracture zone and thus reduces micromovements (Anderson and Cotton 2007), resulting in pain relief. Biomechanical studies on cadaveric specimens were able to show that the stability achieved could be significantly increased after cement augmentation (Whitlow et al. 2007b). However, it made no difference whether 3 mL or 6 mL were injected per side (Richards et al. 2009). Since 3 mL of cement is already biomechanically effective for stabilization (Richards et al. 2009) and good pain reduction can also be achieved with 4 mL of cement (Heron et al. 2007), it may be possible to further reduce the risk of leakage for the VSP and CSP with a volume reduction to well below 6 mL. Another advantage is that with a smaller cement plug, the contact surfaces for possible bony consolidation in the respective fracture zone are larger.

In addition, cement leakage can be further reduced by differentiated access routes, entry via the so-called short or transiliac axis. In particular, Denis type 2 fracture zones can be easily reached transiliacally (Lüdtke et al. 2013). In two studies on RFS (Eichler et al. 2014; Andresen et al. 2015a), increased leakage is found in the study with the access route via the long axis (Eichler et al. 2014).

Good visualization of the bony boundaries, the fracture zone, and the inserted hollow needle as well as the expanding cement seal is imperative to avoid leakage; in this regard, CT-guided cement insertion is clearly superior to C-arm-controlled cement insertion in terms of safety (Grossterlinden et al. 2009; Prokop et al. 2016).

With regard to a significant and sustainable pain reduction, the chosen methods show no difference. Due to the significant pain reduction, it is possible to mobilize the elderly patients immediately postoperatively and to discharge them with a high level of satisfaction after a short period of hospitalization (4 hospital days on average) (Trouvin et al. 2012; Prokop et al. 2016; Andresen et al. 2018).

27.8 Conclusion and Clinical Relevance

If conservative measures in the treatment of disabling, non-displaced os-sacrum fractures (fracture type IIa according to Rommens and Hofmann [2013] and fracture zones 1–3 according to Denis et al. [1988]) do not lead to clinical improvement, percutaneous cement augmentation is an interesting therapy option. With BSP, RFS, VSP and ZSP, interventional, minimally invasive procedures are available with which an equally good, rapid and lasting reduction in pain can be achieved.

References

Alnaib M et al (2012) Combined pubic rami and sacral osteoporotic fractures: a prospective study. J Orthop Traumatol 13:97–103

Anderson DE, Cotton JR (2007) Mechanical analysis of percutaneous sacroplasty using CT image based finite element model. Med Eng Phys 29:316–325

Andresen R et al (2012a) Interventionelle Schmerztherapie mittels Ballon-Kyphoplastie bei Patienten mit osteoporosebedingten Insuffizienzfrakturen des Os sacrum. Fortschr Röntgenstr 184:32–36

Andresen R et al (2012b) Treatment of Denis 1, 2 and 3 insufficiency fracture zones of the os sacrum. Individual approaches adapted to the course of the fracture in CT-assisted balloon sacroplasty. Osteologie 21:168–173

Andresen R et al (2014) Balloon sacroplasty as a palliative pain treatment in patients with metastasis-induced bone destruction and pathological fractures. Fortschr Röntgenstr 186:881–886

Andresen R et al (2015a) Radiofrequency sacroplasty (RFS) for the treatment of osteoporotic insufficiency fractures. Eur Spine J 24:759–763

Andresen R et al (2015b) Vergleich von konservativer Therapie vs. CT-gesteuerter Ballonsakroplastie bei der Behandlung von Insuffizienzfrakturen des Os sacrum. Osteologie 24:92–98

Andresen R et al (2017a) Comparison of the 18 months outcome after the treatment of osteoporotic insufficiency fractures by means of balloon sacroplasty (BSP) and radiofrequency sacroplasty (RFS) in comparison: a prospective randomised study. Eur Spine J 26:3235–3240

Andresen R et al (2017b) CT-guided cement sacroplasty (CSP) as pain therapy in non-dislocated insufficiency fractures. Eur J Orthop Surg Traumatol 27:1045–1050

Andresen R et al (2018) CT-gesteuerte Ballonsakroplastie (BSP), Radiofrequenzsakroplastie (RFS), Vertebrosakroplastie (VSP) und Zementsakroplastie (ZSP) bei nichtdislozierten Insuffizienzfrakturen – ein Methodenvergleich hinsichtlich Outcome, Kosten und Rückerstattung. Die Wirbelsäule 2:75–84

Andrich S et al (2015) Epidemiology of pelvic fractures in Germany: considerably high incidence rates among older people. PLoS One 10:e0139078

Aretxabala I et al (2000) Sacral insufficiency fractures. High association with pubic rami fractures. Clin Rheumatol 19:399–401

Babayev M, Lachmann E, Nagler W (2000) The controversy surrounding sacral insufficiency fractures: to ambulate or not to ambulate? Am J Phys Med Rehabil 79:404–409

Bastian JD et al (2012) Complications related to cement leakage in sacroplasty. Acta Orthop Belg 78: 100–d105

Bayley E, Srinivas S, Boszczyk BM (2009) Clinical outcomes of sacroplasty in sacral insufficiency fractures: a review of the literature. Eur Spine J 18:1266–1271

Binaghi S et al (2006) A new, easy, fast, and safe method for CT-guided sacroplasty. Eur Radiol 16: 2875–2878

Brahme SK et al (1990) Magnetic resonance appearance of sacral insufficiency fractures. Skelet Radiol 19:489–493

Briem D et al (2008) CT-gesteuerte Sakroplastie unter Verwendung insufflierbarer Ballons: Ergebnisse einer Machbarkeitsstudie. Unfallchirurg 111: 381–386

Butler CL et al (2005) Percutaneous sacroplasty for the treatment of sacral insufficiency fractures. Am J Roentgenol 184:1956–1959

Cabarrus NC et al (2008) MRI and CT of insufficiency fractures of the pelvis and the proximal femur. Am J Roentgenol 191:995–1001

Cho CH, Mathis JM, Ortiz O (2010) Sacral fractures and sacroplasty. Neuroimaging Clin N Am 20: 179–186

Dasgupta B et al (1998) Sacral insufficiency fractures: an unsuspected cause of low back pain. Br J Rheumatol 37:789–793

De Smet AA, Neff JR (1985) Pubic and sacral insufficiency fractures: clinical course and radiologic findings. Am J Roentgenol 145:601–606

Deen HG, Nottmeier EW (2005) Balloon kyphoplasty for treatment of sacral insufficiency fractures. Report of three cases. Neurosurg Focus 18:1–5

Denis F, Davis S, Comfort T (1988) Sacral fractures: an important problem. Retrospective analysis of 236 cases. Clin Orthop Relat Res 227:67–81

DVO (2011) Guideline 2009 for prevention, diagnosis and therapy of osteoporosis in dults. Osteologie 20:55–74

Eichler K et al (2014) Outcome of long-axis percutaneous sacroplasty for the treatment of sacral insufficiency fractures with a radiofrequency-induced, highviscosity bone cement. Skelet Radiol 43: 493–498

Featherstone T (1999) Magnetic resonance imaging in the diagnosis of sacral stress fracture. Br J Sports Med 33:276–277

Frey ME et al (2008) Percutaneous sacroplasty for osteoporotic sacral insufficiency fractures: a prospective, multicenter, observational pilot study. Spine J 8:367–373

Fujii M et al (2005) Honda sign and variants in patients suspected of having a sacral insufficiency fracture. Clin Nucl Med 30:165–169

Garant M (2002) Sacroplasty: a new treatment for sacral insufficiency fracture. J Vasc Interv Radiol 13: 1265–1267

Gotis-Graham I et al (1994) Sacral insufficiency fractures in the elderly. J Bone Joint Surg (Br) 76: 882–886

Grasland A et al (1996) Sacral insufficiency fractures: an easily overlooked cause of back pain in elderly women. Arch Intern Med 156:668–674

Grossterlinden L et al (2009) Sacroplasty in a cadaveric trial: comparison of CT and fluoroscopic guidance with and without ballon assistance. Eur Spine J 18:1226–1233

Henes FO et al (2012) Quantitative assessment of bone marrow attenuation values at MDCT: an objective tool for the detection of bone bruise related to occult sacral insufficiency fractures. Eur Radiol 22:2229–2236

Heron J, Connell DA, James SL (2007) CT-guided sacroplasty for the treatment of sacral insufficiency fractures. Clin Radiol 62:1094–1100

Heß GM (2006) Sakroplastie zur Behandlung von Insuffizienzfrakturen des Sakrums. Unfallchirurg 109:681–686

InEK (2016) Kalkulation von Behandlungskosten. Handbuch zur Anwendung in Krankenhäusern. Version 4.0, 10. Oktober 2016, DKVG mbH

Institut für das Entgeltsystem im Krankenhaus (InEK) (2015/2017) G-DRG-Report-Browser 2017, G-DRG Report-Browser für HA V (2015/2017). http://www.g-drg.de/Datenbrowser_und_Begleitforschung/G-DRG-Report-Browser/G-DRG-Report-Browser_2017. Accessed on 25.09.2017

Josten C, Höch A (2017) Sakruminsuffizienzfrakturen: operativ/konservativ. Die Wirbelsäule 1:31–40

Klineberg E et al (2008) Sacral insufficiency fractures caudal to instrumented posterior lumbosacral arthrodesis. Spine 33:1806–1811

Krüger A et al (2012) Ertrag und Verlust bei vertebralen Augmentationen im G-DRG-System 2012 – Ein Vergleich des Versorgungsaufwands bei Vertebroplastie und Kyphoplastie. Z Orthop Unfall 150:539–546

Lin JT, Lane JM (2003) Sacral stress fractures. J Women's Health 12:879–888

Linstrom NJ et al (2009) Anatomical and biomechanical analysis of the unique and consistent locations of sacral insufficiency fractures. Spine (Phila Pa 1976) 34:309–315

Lourie H (1982) Spontaneous osteoporotic fracture of the sacrum. An unrecognised syndrome of the elderly. JAMA 248:715–717

Lüdtke CW, Kamusella P, Andresen R (2013) CT-gesteuerte transiliacale Ballonsakroplastie zur Versorgung einer isolierten Denis-II-Insuffizienzfraktur des Os sacrum. Fortschr Röntgenstr 185:664–665

Lundin B et al (1990) Insufficiency fractures of the sacrum after radiotherapy for gynaecological malignancy. Acta Oncol 29:211–215

Lyders EM et al (2010) Imaging and treatment of sacral insufficiency fractures. Am J Neuroradiol 31: 201–210

Na WC et al (2017) Pelvic insufficiency fracture in severe osteoporosis patient. Hip Pelvis 29:120–126

Nüchtern JV et al (2015) Significance of clinical examination, CT and MRI scan in the diagnosis of posterior pelvic ring fractures. Injury 46:315–319

Onen MR, Yuvruk E, Naderi S (2015) Reliability and effectiveness of percutaneous sacroplasty in sacral insufficiency fractures. J Clin Neurosci 22: 1601–1608

Peh WC et al (1996) Imaging of pelvic insufficiency fractures. Radiographics 16:335–348

Pommersheim W et al (2003) Sacroplasty: a treatment for sacral insufficiency fractures. Am J Neuroradiol 24:1003–1007

Prokop A, Andresen R, Chmielnicki M (2016) Ballonsakroplastie: C-Bogen kontrolliert oder CT gesteuert? Erfahrungen bei 46 Patienten. Unfallchirurg 119:929–935

Ramlov A et al (2017) Risk factors for pelvic insufficiency fractures in locally advanced cervical cancer following intensity modulated radiation therapy. Int J Radiat Oncol Biol Phys 97:1032–1039

Richards AM et al (2009) Biomechanical analysis of sacroplasty: does volume or loacation of cement matter? Am J Neuroradiol 30:315–317

Rommens PM, Hofmann A (2013) Comprehensive classification of fragility fractures of the pelvic ring: recommendations for surgical treatment. Injury 44:1733–1744

Schindler OS, Watura R, Cobby M (2007) Sacral insufficiency fractures. J Orthop Surg 15:339–346

Simon JI et al (2017) Successful repeat sacroplasty in a patient with a recurrent sacral insufficiency fracture: a case presentation. PMR 9(11):1171–1174

Smith DK, Dix JE (2006) Percutaneous sacroplasty: long axis injection technique. AJR 186:1252–1255

Strub WM et al (2007) Sacroplasty by CT and fluoroscopic guidance: is the procedure right for your patient? Am J Neuroradiol 28:38–41

Talmadge J et al (2014) Clinical impact of sacroplasty on patient mobility. J Vasc Interv Radiol 25:911–915

Thieme M (2017) G-DRG excel Kostentool version 2017.03. www.medinfoweb.de/toolbox.html. Accessed on 25.09.2017

Tjardes T et al (2008) Computer assisted percutaneous placement of augmented iliosacral screws. Spine 33:1497–1500

Trouvin AP et al (2012) Analgesic effect of sacroplasty in osteoporotic sacral fractures: a study of six cases. Joint Bone Spine 79:500–503

Wagner D et al (2015) Fragility fractures of the sacrum: how to identify and when to treat surgically? Eur J Trauma Emerg Surg 41:349–362

West SG et al (1994) Sacral insufficiency fractures in rheumatoid arthritis. Spine 19:2117–2121

Whitlow CT et al (2007a) Sacroplasty versus vertebroplasty: comparable clinical outcomes for the treatment of fracture-related pain. Am J Neuroradiol 28:1266–1270

Whitlow CT et al (2007b) Investigating sacroplasty: technical considerations and finite element analysis of polymethylmethacralate infusion into cadaveric sacrum. Am J Neuroradiol 28:1036–1041

Transiliac Internal Fixator

M. Herwig

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_28

28.1 Indication

The indication for a transiliac internal fixator is the sacral insufficiency fracture which leads to immobility of the patient despite adequate analgesia.

Sacral insufficiency fracture was first described by Lourie in 1982.

In the coming years, it is expected that there will be a further increase in the prevalence of sacral insufficiency fractures. This is due to the demographic development with an increase in the elderly population over 60 years of age (Kandziora and Yildiz 2017; Federal Statistical Office 2015).

According to the Federal Statistical Office, there will be 28.6 million people over the age of 60 in 2050. The number of people over 80 will rise from 4.4 million in 2013 to 9.9 million in 2050. Due to existing comorbidities, the frequent presence of osteoporosis and increasingly better diagnostics, there will be an increase in sacral insufficiency fractures (Kandziora and Yildiz 2017; Federal Statistical Office 2015).

Patients complain mainly of deep lumbar pain radiating to the buttocks, thigh and groin. In most cases, the patient is unable to stand or walk; neurological deficits are extremely rare. The pain is often triggered by a minor trauma and lasts for several weeks, but can also occur without previous trauma.

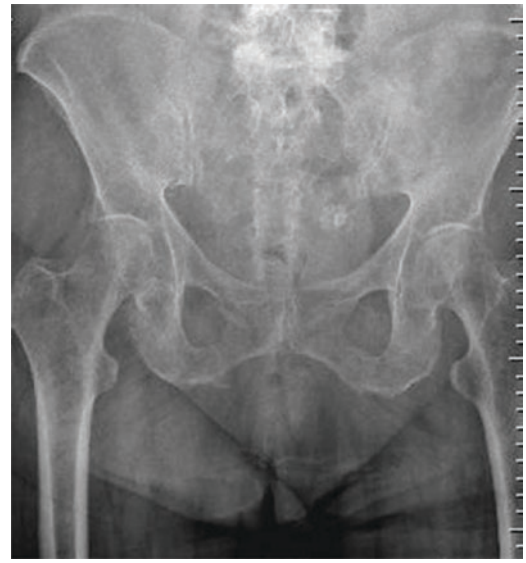


Fig. 28.1 X-ray of the pelvis for possible sacral fracture

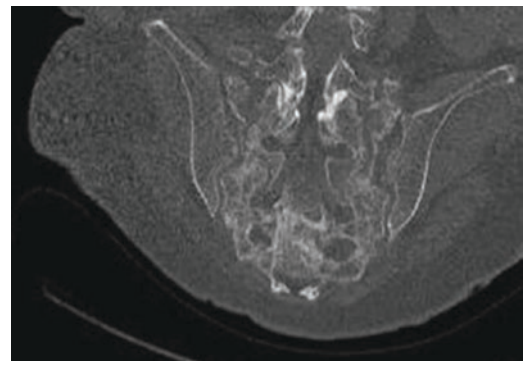


Fig. 28.2 CT diagnosis with bilateral sacral fracture

28.2 Preinterventional Diagnostics

Patients usually do not remember an accident, occasionally there is a history of a fall. They complain of gradually increasing pain in the region of the lower lumbar spine with radiation into the groin and thigh. Often there is an unrecognized osteoporosis.

28.2.1 Diagnostic Algorithm

As a rule, an X-ray of the pelvis with the lower lumbar spine is taken first. Here, the sacral fracture usually remains undetected in 60–80% of cases (Fig. 28.1).

One study showed that in a retrospective examination of radiographs of sacral insufficiency fractures confirmed by sectional imaging, only 50% of fractures could be diagnosed (Finiels et al. 1997; Gotis-Graham et al. 1994; Schneider et al. 1985; Ries 1983).

In the subsequent diagnostic phase, a CT scan is usually performed. This is highly specific, but has a sensitivity of only 50–70% for identifying a sacral insufficiency fracture (Figs. 28.2 and 28.3). If symptoms remain unclear, an MRI examination is useful. This has a sensitivity of 100% and reliably indicates a fracture of the os sacrum without showing the morphology well, as is the case with CT

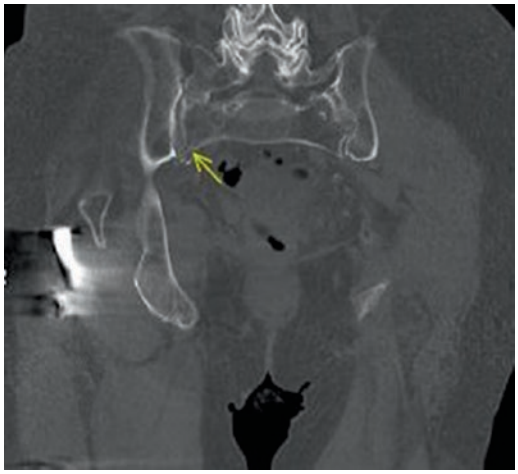


Fig. 28.3 CT diagnosis showing a small detachment of the caudal massa lateralis of the os sacrum (*yellow arrow*)

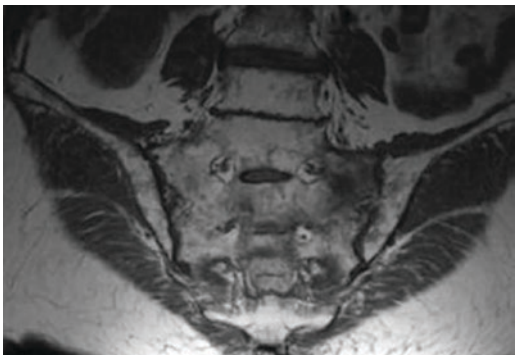


Fig. 28.4 MRI diagnosis with typical edema of the left lateral massa

(Cabarrus et al. 2008; Fujii et al. 2005; Fig. 28.4).

Scintigraphy also has its value with a sensitivity of 96% and a positive predictive value of 92%. It makes sense to perform an X-ray and subsequently a cross-sectional imaging. If the findings are still unclear, a scintigraphy should be performed if necessary (Fig. 28.5).

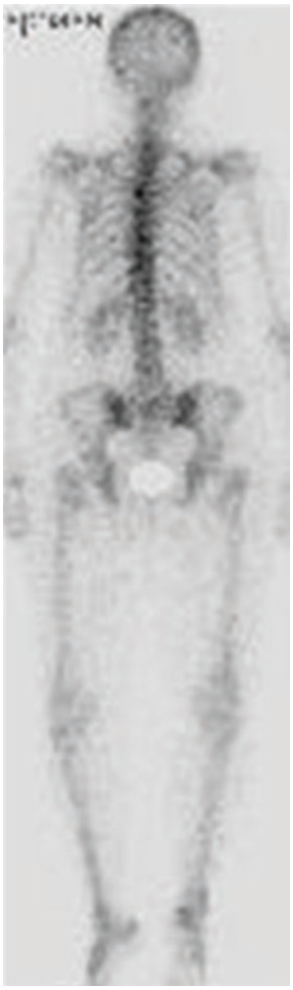


Fig. 28.5 Scintigraphy in the case of unclear symptoms: typical accumulation in the massa lateralis on both sides

28.3 Necessary Instruments

During the operation, the patient is placed in the prone position. The operating table should be radiolucent. A basic bone sieve, awl, awl, pedicle probe, bolt cutter and a screwdriver for polyaxial screws should be available.

The consumables required are 2 polyaxial screws and a Harrington rod. As a rule, the screws have a length of 60 mm and a diameter of 8 mm. The Harrington rod is shortened according to the required length.

28.3.1 Costs

The total cost of the materials is about 400 €. Per screw (depending on the company) is about 100–150 € and for the rod 50–100 €.

Ordering address: The material can be ordered from any company that manufactures material for spondylodesis.

28.4 Pre-intervention Education

Before intervention, the findings should be discussed in detail with the patient and the alternatives pointed out to him. The first priority is always to try to mobilize the patient under appropriate analgesia. If this is not possible, a surgical measure is recommended.

28.4.1 Therapeutic Algorithm

After diagnosis by means of the above-mentioned imaging, the findings are discussed with the patient. As a rule, the patient is allowed to bear weight in a pain-adapted manner under appropriate analgesia. If this is possible, the conservative procedure is continued and the patient is transferred to outpatient treatment.

If the patient cannot be mobilized after 5 days despite adequate analgesia, we recommend treatment with a transiliac internal fixator.

28.4.2 Operations Reconnaissance

Patients should be informed about the general and usual risks of surgery. In particular, patients should be informed about a foreign body sensation/pressure feeling over the surgical area, since the soft tissue coverage between the skin and the pelvis varies and is often relatively low in this region in older patients. Information should also be given about possible screw malpositioning and wound healing disorders with possible infection.

Aftercare includes pain-adapted mobilisation with full body weight one day after the operation, if necessary still on the day of the operation.

28.5 Implementation of the Intervention

An approx. 3 cm long paravertebral skin incision is made over the posterior iliac spine on both sides. This is followed by sharp, partially blunt dissection down to the iliac crest. A self-spreader is inserted and then the thoracolumbar fascia is cut. This is followed by further dissection of the iliac spine, which is digitally traced 1–2 cm laterally. Subsequently, the correct positioning in the os ilium is determined with the aid of the awl under image converter control in 2 planes. It is important to ensure that the screw or awl is inserted approx. 1–2 cm lateral to the sacroiliac joint. Then enter with the awl and advance the awl to about 5 cm. Then palpate with the pedicle probe and check whether there is a bony boundary everywhere. This is important in order to avoid incorrect positioning of the screws. Now insert the polyaxial pedicle screw, which is usually 60 mm long and has a diameter of 8 mm. The same procedure is performed on the opposite side, also through a paravertebral skin incision. A grain forceps is then passed through the subcutaneous tissue close dorsal to the spinous processes and the measuring rod is inserted. The length of the rod is then measured. The rod should protrude about 1 cm beyond the screw on both sides. After determining the length, an appropriate rod is cut to size with the help of the bolt cutter and bent into the corresponding shape with the help of the bending iron. With the help of the grain forceps and by tunneling the subcutaneous tissue, the cut rod is pulled

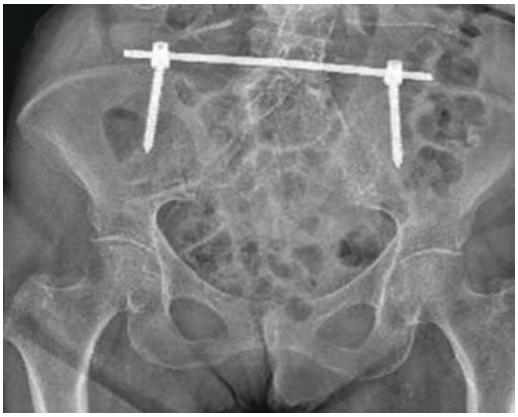


Fig. 28.6 Inserted transiliac internal fixator

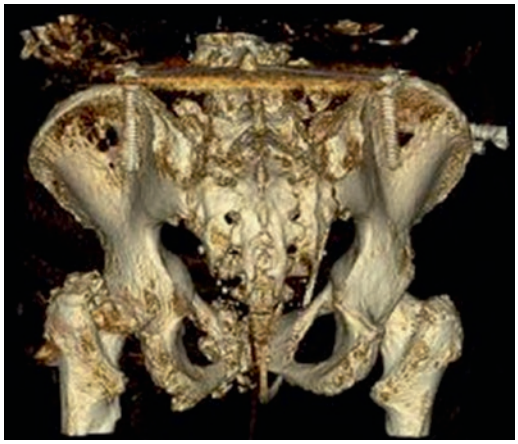


Fig. 28.7 CT reconstruction showing the two misplaced screws

through into the surgical area. The rod is inserted into the tulips of the multiaxial screws. The grub screws are inserted and tightened with the torque wrench. Finally, an image intensification check is performed in 2 planes (Fig. 28.6). This should show the correct positioning of the internal fixator. After rinsing, the fascial suture, subcutaneous suture and skin suture are performed using the Donati back stitch technique.

28.6 Possible Complications

Overall, fitting with a transiliac internal fixator has few sources of error. In clinical practice, 2 main complications have occurred during surgical treatment.

A total of 55 patients treated from 2010 to 2016 showed 2 screw malpositions and 2 wound healing disorders with evidence of Staphylococcus aureus.

Screw malpositioning was diagnosed on the basis of persistent pain gluteally and CT section imaging (Figs. 28.7 and 28.8). In both cases, the screws were revised and repositioned. Postoperatively, this resulted in a rapid mobilization ability of the affected patients.

The patients affected by a wound healing disorder were surgically debrided and treated with antibiotics. This led to a satisfactory outcome in the course in both cases.

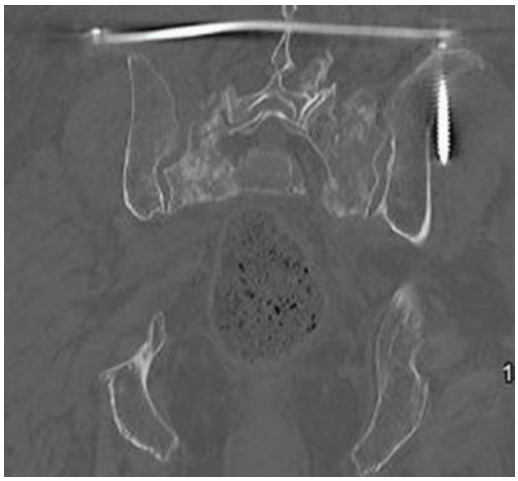


Fig. 28.8 CT image of a malpositioned screw

28.7 Results in the Literature

The literature search did not find any scientific papers on the transiliac internal fixator presented here. There are also no comparative studies on sacroplasty or transiliosacral screw fixation.

In an in-house retrospective data analysis at the Johanna Etienne Hospital in Neuss, the following observations were made regarding the surgical procedure presented: In the years 2010–2016, 55 patients with an average age of 78.2 years and the

main diagnosis of an insufficiency fracture of the os sacrum were treated using transiliac internal fixator. They were 52 women (94.5%) and 3 men (5.5%). Retrospectively, the duration of surgery, the material used, blood loss measured by preoperative and postoperative hemoglobin levels, the length of stay after surgery, and complications were recorded.

The average duration of surgery was 53.7 min. In the operation, polyaxial screws of length 60 mm with a diameter of 8.0 mm were chosen on average. Hemoglobin levels on the first day postoperatively showed a decrease of 1.3 g/dL. The average hospital stay from surgery to discharge was 11 days. Four complications were recorded, including 2 screw malpositioning and 2 postoperative wound healing disorders.

Compared to sacroplasty and transiliac screw fixation, the application of a transiliac internal fixator virtually excludes nerve lesions. The superiority of one of the three procedures mentioned in the surgical treatment of sacral insufficiency fracture has not yet been scientifically proven.

28.8 Reimbursement of Costs

In terms of reimbursement, this type of treatment is not easy to code, as there is no adequate code for closed reduction and osteosynthesis using an internal fixator. As a DRG code, S32.1 can be coded as a fracture of the os sacrum. As a surgical procedure, 5–790.0d can be coded as closed reduction and osteosynthesis with screw. GOÄ code 2329 appears to be the most appropriate.

28.9 Conclusion and Clinical Relevance

The transiliac internal fixator is an alternative to sacroplasty and sacroiliac joint screw fixation. This procedure has few complications and offers an easy-to-learn surgical technique with low risks for the elderly patient. It allows the elderly patient to mobilize quickly with a minimally invasive procedure that requires minimal surgery and materials.

However, further studies comparing the different procedures are desirable to identify the best treatment method in an evidence-based manner.

References

Cabarrus MC, Ambekar A, Lu Y et al (2008) MRI and CT of insufficiency fractures of the pelvis and the proximal femur. Am J Roentgenol 191:995–1001

Finiels H, Finiels P, Jaquot J et al (1997) [Fractures of the sacrum caused by bone insufficiency. Meta-analysis of 508 cases]. Presse Med (Paris, France: 1983) 26:1568–1573

Fujii M, Abe K, Hayashi K et al (2005) Honda sign and variants in patients suspected of having a sacral insufficiency fracture. Clin Nucl Med 30:165–169

Gotis-Graham I, McGuigan L, Diamond T et al (1994) Sacral insufficiency fractures in the elderly. J Bone Joint Surg Br 76:882–886

Kandziora F, Yildiz U (2017) Sakruminsuffizienzfrakturen: operativ/konservativ. Die Wirbelsäule 1:41–50. https://doi.org/10.1055/s-0043-102582

Ries T (1983) Detection of osteoporotic sacral fractures with radionuclides. Radiology 146:783–785

Schneider R, Yacovone J, Ghelmann B (1985) Unsuspected sacral fractures: detection by radionuclide bone scanning. Am J Roentgenol 144:337–341

Statistisches Bundesamt (2015) Bevölkerung Deutschlands bis 2060. 13 koordinierte Bevölkerungsvorausberechnung. Broschüre des Statistischen Bundesamtes, Wiesbaden

Treatment Options for Sacral Insufficiency Fractures

A. Hölzl

Contents

J. Jerosch (ed.), *Minimally Invasive Spine Intervention*,
https://doi.org/10.1007/978-3-662-63814-9_29

29.1 History and Epidemiology

For many years, sacral insufficiency fracture (SIF) was a poorly known and frequently undiagnosed pathology. It has only received increasing attention since it was first described in 1982 (Lourie 1982). The exact incidence of SIF is not known, but is probably in the range of 1–5% in the at-risk population (Weber et al. 1993; West et al. 1994). The trend is upward with an increase in patients with osteoporosis. An increase of 56% is expected within the next 10 years (Kannus et al. 2000). It is important to separate insufficiency fractures from other types of fractures. The insufficiency fracture, like the fatigue fracture, belongs to the stress fractures. In this case, the insufficiency fracture occurs on the weakened bone under physiological stress. Whereas the fatigue fracture occurs on the healthy bone due to repetitive stress, an example of which is the marching fracture in soldiers. Traumatic fracture, on the other hand, requires pathological loading. Traumatic fracture can also occur on weakened/osteoporotic bone, but should then be referred to as traumatic fracture on osteoporotic bone. Of course, the transitions are fluid, because at what point of force does one speak of an adequate trauma? Is a stumbling step or sitting firmly on a chair already a trauma? There are also special forms, such as SIF in pregnancy. Especially from the third trimester on, the bone is weakened. But does the additional weight due to the child now represent a physiological or pathological strain? In the case of a SIF after spondylodesis in the lumbar spine, a pathological load, often in combination with poor bone quality, must certainly be assumed. In this chapter, a SIF is assumed if no trauma can be determined at the time of the onset of the complaint and no other injuries to the pelvic ring are present.

29.2 Anatomy and Development

Evolutionarily, the os sacrum belongs to the spine, although there is currently a dispute between "spine surgeons" and "pelvic surgeons" as to who is responsible for the care of sacral insufficiency fractures.

Like the bony components of the spine, the os sacrum develops from the somites. These form from the end of the third week of pregnancy parallel to the chorda dorsalis. While resegmentation leads to a differentiation of the movement segments in the area of the spinal column, the vertebral anlagen in the area of the sacrum fuse. The fusion of the 5 vertebral anlagen with the associated rib anlagen and the mesenchyme forms the os sacrum. Centrally, the fused vertebral bodies and vertebral arches enclose the canalis sacralis. The pars lateralis develops from the rib attachments. The transverse processes give rise to the crista sacralis lateralis, the articular processes to the crista sacralis intermedia, and the spinous processes to the crista sacralis mediana. Of the original attachments for the intervertebral discs, the horizontally running lineae transversae remain. These often do not ossify until after the age of 20. The ossification of the vertebral bodies and rib systems takes place in accordance with the spinal column via bone nuclei between the fourth month and fifth year of life (Cheng and Song 2005).

The main function of the Os sacrum is to connect the spine and the pelvis and thus to transmit power from the upper body to the lower extremities.

The os sacrum has approximately the shape of a triangle standing on its tip. This is due to the decreasing height and width of the sacral vertebrae towards the caudal, corresponding to the decreasing load. The ventral surface is concavely curved in the vertical and horizontal planes, thus increasing the volume of the pelvis. On the ventral surface, the 4 lineae transversae, as fusion points of the original 5 vertebral bodies, can be seen. At the lateral ends of each of these lineae lies one of the 8 anterior neuroforamina. These are laid out in a slight anterolateral orientation and contain the ventral branch of the corresponding sacral nerve and lateral sacral artery. The pars lateralis, usually called ala sacralis in the clinic, which lies lateral to the neuroforamina and bears the facies articularis of the sacroiliac joint (SIG), is striking.

Three powerful muscles arise symmetrically on the ventral surface of the sacrum. Superiorly lateral the M. iliacus is attached, inferiorly lateral the M. coccygeus and lateral to the neuroforamina the M. pirifomis. In the region of the ala, the psoas major muscle arises. The lumbar plexus runs ventral to the ala.

The dorsal surface is divided by the prominent crista sacralis mediana as a continuation of the spinous process. Lateral to this lies the crista sacralis intermedia, which opens caudally into the cornu sacrale. Now follow the posterior neuroforamina as points of passage for the dorsal parts of the corresponding sacral nerves. They are important anatomical landmarks, e.g. for the entry point of S2 screws. Lateral to the neuroforamina is the crista sacralis lateralis followed by the sacral tuberosity, where the reinforcing ligaments of the sacroiliac joint insert. Strong muscles arise on the dorsal surface. The gluteus maximus muscle inserts in the inferior lateral area. The multifidus muscle, sacrospinalis muscle, erector spinae muscle and latissimus dorsi muscle originate in the area between the median crest and the intermedia.

The base of the os sacrum is the cranially directed surface of S1. It is hinged to the fifth lumbar vertebra via an intervertebral disc and the superior articular proc. The "vertebral notch" forms the caudal portion of the L5/S1 neuroforamen.

The ventral upper edge of S1, which extends far into the pelvis, is called the promontorium and serves, among other things, as the aiming point for the S1 pedicle screws. The apex of the sacrum (apex ossis sacri) is connected to the os coccygis either via an intervertebral disc or synostotically.

The vertebral canal is called the sacral canal in the sacral region and opens caudally at the level of the third–fourth sacral vertebra as the sacral hiatus, which is flanked by the sacral cornua. These are easy to palpate percutaneously and can be used for orientation during infiltrations such as sacral flooding.

29.3 Biomechanics of the Fracture

The simplest form of insufficiency fracture of the os sacrum runs in a vertical fracture line, just medial to the SIG, in the ala of the sacrum. Often the fracture occurs bilaterally. The complex form of SIF still has a vertical component at the level of S2. The fracture is then called H-shaped. In extreme cases, a ventral dislocation of S1 can occur. This is then referred to as a lumbopelvic dissociation. The vertical component runs lateral to the neuroforamina. This distinguishes it, among other things, from traumatic fractures, which often also run transforaminal. In my opinion, the Denis classification is therefore not suitable for SIF.

But how does this fracture occur? Biomechanical studies have shown that peak loads occur in the lateral os sacrum parallel to the SIG during walking. At first glance, the os sacrum appears to be thickest in this region, but it consists mainly of cancellous bone and only a little cortical bone. In addition, the cancellous bone in the lateral region is significantly less dense than in the central region; this is also referred to as "alar void" (Peretz et al. 1998). However, the cortical bone is largely responsible for force transmission. In the central region of the sacrum, there is significantly more cortical bone due to the limitation of the neuroforamina and the canalis sacralis. Therefore, approximately 50 times more force can be transmitted in this area than in the area of the ala. In the context of osteoporosis, significantly more cancellous bone than cortical bone is degraded (Richards et al. 2010). For this reason, osteoporotic fractures also commonly occur in the predominantly cancellous vertebral bodies. Thus, the lateral region of the sacrum is a kind of predetermined fracture site. The area of the horizontal fracture component at the level of the S2 corpus is primarily not such a weak point, and no load peaks occur there in the intact pelvis. After the occurrence of the vertical fractures, force peaks can be measured in this area in finite element analyses. Thus, a progressive fracture can be assumed overall, which first occurs vertically on one

side, then vertically on two sides and then H-shaped. It must now be discussed whether the opposite side should also be treated in the case of a unilateral fracture. However, there is no clear evidence for this in the current literature. In our own patient population, the opposite side is always treated as well.

29.4 Symptoms

There are no typical complaints for the insufficiency fracture of the os sacrum. This is one of the reasons why the fractures were and are often diagnosed late or not at all. Patients usually complain of load-dependent deep lumbar back pain, pain in the buttocks or hip area. Occasionally also with radiation into the legs without radicular assignment. Often the complaints are superimposed or intensified by pre-existing back and hip complaints. The examiner should be alert if the patient can state the onset of the complaints relatively precisely, but without reporting adequate trauma. Suspicious are also credible complaints that cannot be explained by a pathology of the lumbar spine or the hip joint.

29.5 Diagnostics

Sudden onset of deep lumbar back pain may be an indication of SIF. Clinically, there is a local pressure pain over the lateral sacrum. Single-leg stance is painful on the fractured side. Patients with bilateral fractures are often immobile. The classic SIG tests, such as quad sign, compression pain, hyperextension pain are positive. Neurological examination is usually unremarkable. Nerve extension signs such as Lasègue are also unremarkable. The exception is the spinopelvic dissociation, here should be examined especially for damage to the roots S2–S5.

A pelvic overview image should be performed as imaging. The fracture itself can only be detected there in 12.5% of cases and is frequently overlooked (Gotis-Graham et al. 1994; Grasland et al. 1996). However, it is necessary to diagnose concomitant injuries of the pelvic ring e.g. pubic branch or acetabular fractures. A radiograph of the lumbar spine is also useful to evaluate for possible associated pathology, such as vertebral body fracture or degenerative changes.

The diagnostic tool of choice is magnetic resonance imaging (MRI). Fracture edema can be seen as a hyperintense area in the T2 and STIR ("short tau inversion recovery") sequence and as a hypointense area in T1. Care should be taken to run the STIR sequence in coronary stratification. The sensitivity is then close to 100%. In addition to bone edema, the hypointense fracture line can also be visualized in 93% of cases (Cabarrus et al. 2008) (Fig. 29.1a).

Computed tomography (CT) is clearly inferior to MRI for primary diagnosis, with a

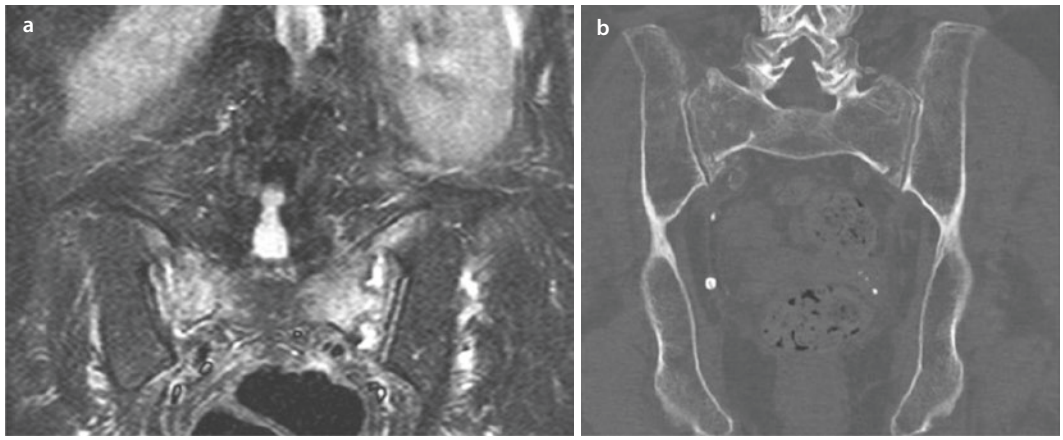


Fig. 29.1 **a** and **b** MTR and CT of a fresh bilateral sacral insufficiency fracture. **a** MRI with coronary STIR sequence shows a fresh fracture bilaterally. **b** CT shows fracture trajectories parallel to the SIG joints

sensitivity of 60–75% (Cabarrus et al. 2008; Lyders et al. 2010). However, CT is sometimes necessary for differentiation from an osteolytic event. CT is indispensable for planning surgery. Fracture progression is best followed up on CT. For iliosacral screws, for example, the S1 and, if necessary, S2 corridor must definitely be examined on CT (◘ Fig. 29.1b).

If it is not possible to perform an MRI, e.g. due to a pacemaker, skeletal scintigraphy is the method of choice. This has a sensitivity of 96%. In principle, it is not possible to distinguish between a tumorous event and an insufficiency fracture in the case of an accumulation. However, if there is no indication of a tumour in the history and no other suspicious deposits in the scintigram, a SIF must be assumed. The typical Honda sign is then conclusive. The Honda sign is formed by the vertical fractures and the horizontal component, which form an "H" (Fujii et al. 2005). However, scintigraphy is not suitable for assessing progression because the uptake of radionuclides varies greatly over time. It can range from a decrease in storage to normal levels to an increase in storage.

29.6 Therapy Options

As almost everywhere in orthopaedics/trauma surgery, the treating physician is faced with the decision between conservative or surgical therapy. As these are mostly older patients, the advantages and disadvantages of both options should be weighed up critically.

29.6.1 Conservative

Conservative therapy should always be considered in the geriatric patient. To date, there are too few studies on conservative therapy to make evidence-based recommendations. The following suggestions are based on the available literature, expert discussions in various working groups and our own experience. The decisive criterion for conservative therapy is the patient's ability to mobilize. Short-term bed rest for 1–2 days, accompanied by pain therapy, is initially acceptable. However, long-term bed rest should be avoided at all costs, as bed rest leads to a drastic reduction in the already reduced bone mass, especially in old osteoporotic patients. One week of bed rest corresponds to about one year's loss of bone mass. Muscle strength decreases by 1–3% per day due to bed rest. Immobility after pelvic fractures causes thrombosis, embolism, pneumonia or urinary tract infections in up to 43% of patients (Taillandier et al. 2003).

It is therefore imperative that the patient be mobilized quickly. Initially, mobilisation on a walking frame is often helpful for elderly patients. The goal is mobility on 2 forearm poles. These should be used for 6 weeks. It is questionable whether unilateral unloading is useful in the case of a unilateral fracture or whether this only provokes the fracture of the opposite side. For this reason, we do not use unilateral unloading in our own procedure. An orthosis that stabilizes the SIG (e.g. SacroLoc®, Bauerfeind) is helpful in cases where the complaints are strongly load-dependent (◘ Fig. 29.2).

Bone densitometry should be performed and antiosteoporotic drug therapy may need to be started or ongoing therapy reevaluated. The SIF should be evaluated similarly to the osteoporotic vertebral body fracture, so that one must assume a manifest osteoporosis after a fracture has taken place. Antiosteoporotic therapy should be administered according to the guidelines of the Scientific Association of Osteology (DVO) for vertebral body fractures. Current studies show good results with the osteoanabolic agent teriparatide in SIF (Hohenberger 2017; Yoo et al. 2017).

In general, close cooperation between the physician, nursing staff, and physiotherapists is required in the conservative treatment of SIF, and surgical therapy should be considered if there is no improvement in symptoms (◘ Figs. 29.2 and 29.3).

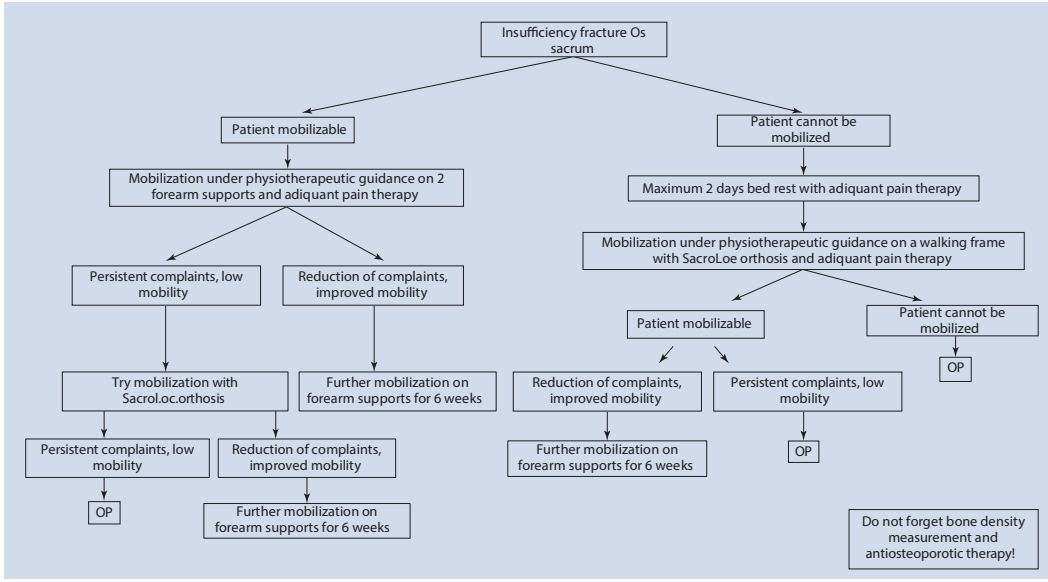


Fig. 29.2 Therapy scheme for sacral insufficiency fracture

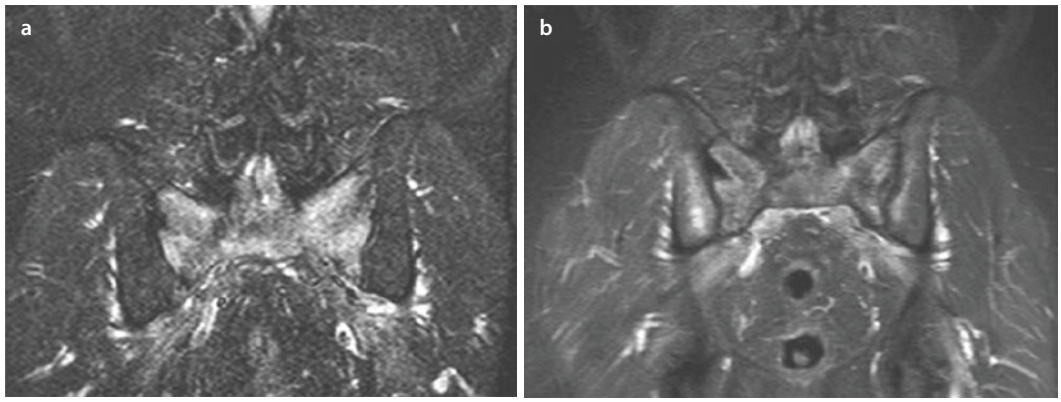


Fig. 29.3 MRI of a fresh sacral insufficiency fracture **a** and after 6 months of conservative therapy with reduction of the edema **b**

29.6.2 Operational

Surgical treatment should be indicated in patients who cannot be mobilized due to pain or who are at risk of further dislocation of the fracture. The aim of surgical treatment must be primary stability and thus immediate weight-bearing capacity. A minimally invasive procedure is to be favoured in the often multimorbid patient population. The main problem with any type of surgical treatment is the osteoporotic bone and thus the load-stable treatment of the fracture. In the surgical procedures described below, optimal planning and preparation is essential. Due to the complex and varied anatomy of the sacrum, a preoperative CT is highly recommended to assess the fracture process and plan the osteosynthesis. Care must be taken to obtain the best possible intraoperative imaging. This is facilitated by a carbon table, as ala and obturator images in particular are often complicated by metal attachments to the table. Preoperative laxative measures reduce the build-up of intestinal gas during fluoroscopy.

Sacroplasty/Balloon Sacroplasty/ Radiofrequency Sacroplasty

Percutaneous cement augmentation has become a standard procedure for the treatment of osteoporotic vertebral body fractures. Balloon kyphoplasty is predominantly used here, followed by vertebroplasty and radiofrequency vertebroplasty. It is now obvious to transfer these procedures to the treatment of SIF. These procedures are discussed in detail in ► Chap. 27, which is why only a brief overview is given here.

In sacroplasty, highly viscous cement is introduced percutaneously into the fracture gap via a needle. The theory behind this is that the cement interlocks with the adjacent cancellous bone and thus creates stability. There are two established access routes. Directly from the dorsal, referred to as the short axis, or from the lateral through the SIG, referred to as the long axis. Corresponding to the treatment at the spine, there is also the possibility of balloon sacroplasty. In this case, a balloon is first inserted via the above-mentioned accesses, which is filled and deflated several times in the fracture area. The highly viscous cement is then applied into this preformed cavity. Radiofrequency sacroplasty is performed in a similar way. The space for the cement is created with a flexible osteotome. The cement is activated by radiofrequency and is available for a defined period of time with a constant viscosity. Cement augmentation is possible under image intensifier control. However, authors advocate a CT-controlled procedure, as this can significantly reduce unintentional cement leakage (Prokop et al. 2016). The advantage of these techniques is their minimally invasive nature. Many studies have demonstrated significant pain reduction with cement augmentation (Kortman et al. 2013; Talmadge et al. 2014). No significant difference in pain reduction exists between sacroplasty and balloon sacroplasty (Andresen et al. 2017). The question of biomechanics has not yet been conclusively resolved. Does the cement stabilize the fracture when placed in a vertically running fracture gap, in an area where bone density is lowest?

Transiliosacral Screw Connection

In trauma surgery, transiliosacral screw fixation is considered the standard procedure for stabilizing the posterior pelvic ring. This procedure is also used to stabilize a SIF. The operation can be performed in the prone or supine position. Percutaneously, a guide wire is first inserted from the lateral side through the ilium and the SIG into the vertebral body of S1 under X-ray control. The entry point is located in lateral projection on the middle third of S1. This is located in a strictly lateral fluoroscopic image. Care must be taken to ensure that the incisura ischiadica major or the femoral heads are projected one above the other. This is the only way to ensure that the sacrum is strictly lateral. During predrilling, the position of the wire is checked in both the inlet and outlet projections (Matta and Saucedo 1989). Passage through the SIG is also felt in ostoporotic bone. If the position is correct, the wire is overdrilled and a cannulated screw of 6.5–8.5 mm thickness with washer is inserted. The tip of the screw should cross the center of the S1 vertebral body. Typically, screws of length 95–115 mm are used. Compression can be applied to the fracture by using a short thread. The complex anatomy and sometimes limited assessability in the imager require an experienced surgeon. The use of 3D imaging and navigation systems can reduce screw malposition and radiation exposure for the surgeon (Thakkar et al. 2017). Advantages of transiliosacral screw fixation include the percutaneous approach, the ability to apply compression to the fracture, and immediate weight bearing. If necessary, a screw can also be inserted into the S2 corridor in the same manner. This not only increases stability but also secures rotation. With this type of restoration, the zone with the weakest bone is bridged and the screw tip usually finds sufficient bone substance in the vertebral body of S1 or S2. Nevertheless, osteoporosis makes stable anchoring of the screws difficult. For this reason, the screws are often cemented using various techniques. Special cementable screws are now also available on the market. Although studies show an increased tear-out force of the screws, this

only partially reflects reality. The weak point of the osteosynthesis is shifted laterally and the screws may collapse on the lateral wall of the os ilium. It is also shown in biomechanical studies that the stiffness of the construct and the rate of screw loosening are not significantly affected by augmentation (Gruneweller et al. 2017; Höch et al. 2017; Osterhoff et al. 2016).

Transsacral Positioning Rod

The transsacral positioning rod has evolved from the bilateral transiliosacral screw fixation. Similar to the transiliosacral screw fixation, a guide wire is inserted percutaneously from the lateral side through the ilium and the sacroiliac joint into the vertebral body of S1, but now further predrilled through the SIG and the ilium of the opposite side. This is done under image converter and/or navigation control. In the image converter, care must be taken to accurately adjust the lateral, inlet and outlet projections. It also requires an experienced surgeon and accurate planning of the trajectories preoperatively on the CT. The guide wire is overdrilled and the implant is inserted under image converter control. Nuts and washers are now placed percutaneously from both sides, thus applying compression to the fracture. The aim is to achieve increased compression and primary stability compared to iliosacral screw fixation. However, the weak point of the lateral cortex remains. Larger washers should reduce the collapse of the lateral cortex. Already during preoperative planning it has to be taken into account that in 20–26% of all cases a sufficient corridor through S1 is not available (Mendel et al. 2013). It is then possible to switch to a corridor through S2, which is almost always available, but significantly narrower (Mendel et al. 2013; Wagner et al. 2017). A second positioning rod or a classic transiliosacral screw can also be inserted to secure rotation. Advantages of the method are the percutaneous approach, the possibility to apply compression to the fracture, and the immediate load-bearing capacity.

Ilioiliac Internal Fixator with Transiliosacral Screw Fixation

In our own practice, the ilioiliac internal fixator with bilateral transiliosacral screw fixation is performed as standard treatment. First, a guide wire is placed laterally from the right and left through the SIG into the vertebral body of S1 under image converter control. The wires are placed so that they are parallel in opposite directions in the S1 vertebral body (Fig. 29.4a). It is essential to check during pre-drilling in both the inlet and outlet projections. Then, the guide wires are overdrilled and cannulated screws with a diameter of 7.5 mm and short thread are inserted over the guide wire. Washers are always used. The screws are sized so that the threads interlock to strengthen the hold and provide sufficient compression on the fracture. Iliac screws are also inserted through 3 cm horizontal skin incisions to secure rotation and increase stability. The entry point is just above the posterior superior iliac spine at the medial edge of the ilium. The cortex is opened with a luer to allow the screw head to be countersunk and minimize soft tissue irritation. A blunt awl is now used to create the screw channel. The target is the spina iliaca anterior inferior. In the lateral image intensification, care is taken to keep the awl cranial to the foramen ischiadicum. In the ala and obturator image, attention is paid to possible perforation of the internal and external tabula. The screw corridor can be visualized well by a projection in which the image intensifier is tilted by approximately 30° to the opposite side and 30° cranially (Fig. 29.4b). It must be possible to palpate the canal securely. The screw finds its hold by jamming between the tabula interna and externa of the os ilium. For this reason, sufficiently thick fully threaded screws must be used (e.g. 10.5 × 115 mm). A 5.5-mm titanium rod is bent in a w-shaped fashion and inserted subcutaneously over the S1 spinous process. Due to the w-shaped pre-bending, the rod does not lie disturbingly under the skin and does not affect the spinous process. In very slender patients, soft tissue irritation may occur if the heads of the ilium screws are not

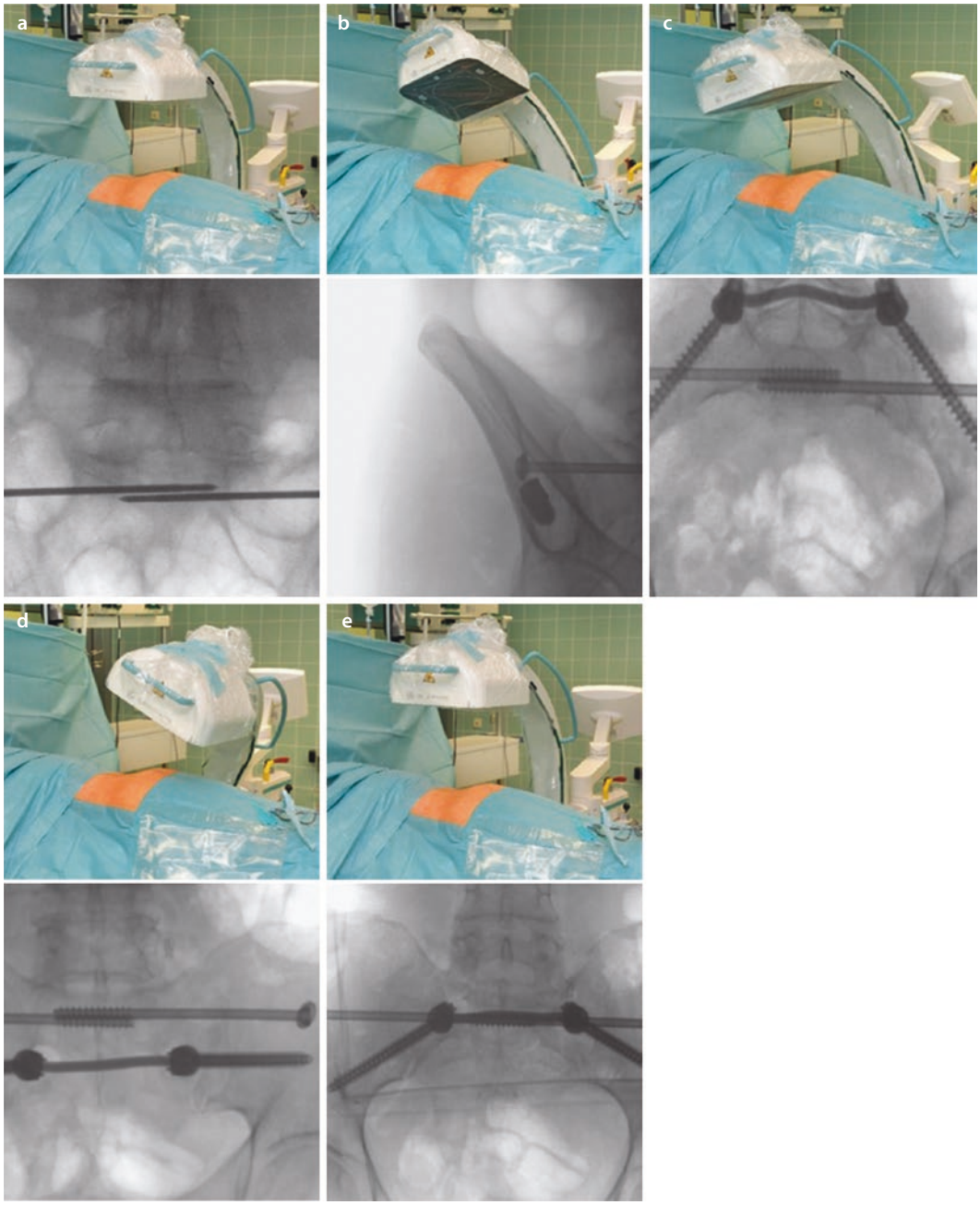
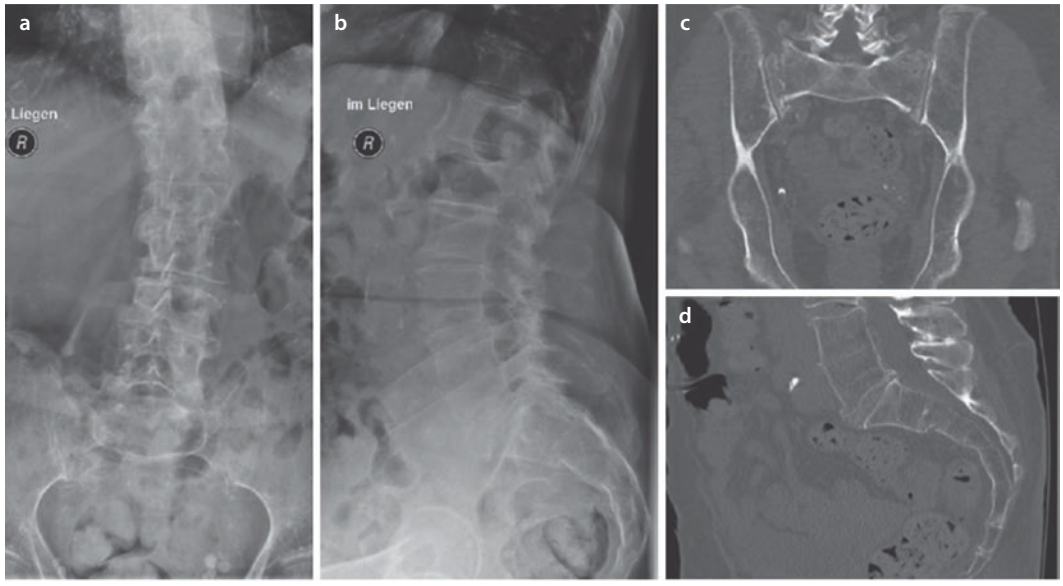


Fig. 29.4 **a**–**e** Ilioiliac internal fixator. Opposite insertion of Kirschner wires into the vertebral body of S1 **a**. Iliac screw visualized in the safe corridor by tilting the imager 30° cranially and toward the opposite side **b**. Final check of the ilioiliac internal fixator in inlet **c**, outlet **d** and a.p. image **e**

countersunk or the rod protrudes. The final check is made in inlet, outlet and a.p. projection (Fig. 29.4c–e). This method can be performed safely percutaneously, under image converter control, in 60 min and is immediately stable under load. The use of a navigation system can facilitate intraoperative orientation.

Lumbopelvic Stabilization

Lumbopelvic stabilization is certainly the most invasive of the methods presented, even when performed percutaneously or mini-open. One option for lumbopelvic stabilization is initially the percutaneous placement of pedicles of L4 and L5 with pedicle screws in the usual manner. Iliac screws are now inserted via the right and left posterior superior iliac spine as described above. Bending the titanium rod can be a bit tricky, but can be accomplished. The advantage of the technique is that it bridges the area with the weakest bone. It is debatable whether unilateral lumbopelvic suspension, as in the Jumpers fracture of the bone-healthy patient, is sufficient or whether bilateral treatment should always be performed. In my opinion, bilateral lumbopelvic stabilization is preferable to avoid overloading the opposite side. Also, bilateral stabilization significantly increases the stiffness of the construct (Song et al. 2016). This is further increased by a transverse connector. For additional stability, bilateral transiliosacral screw fixation can be performed (◘ Fig. 29.5). The means of choice is lumbopelvic stabilization with preexisting lumbar instrumentation. Combinations of SIF and degenerative changes in the lumbar spine or fractures of the lower lumbar spine can also be treated in this way. Lumbo-pelvic stabilization is always a fallback option if the other procedures described above fail.



◘ **Fig. 29.5** **a**–**f** Lumbopelvic stabilization in lumbopelvic dissociation. Radiograph a.p. and laterally for lumbopelvic dissociation and preexisting degenerative lumbar scoliosis. Note the ventral tipping in the S2 corridor **a**, **b**. Preoperative CT showing dislocation of the vertical fracture components and ventral tipping in the S2 corridor **c**, **d**. Intraoperative control a.p. **e** and strictly lateral **f**

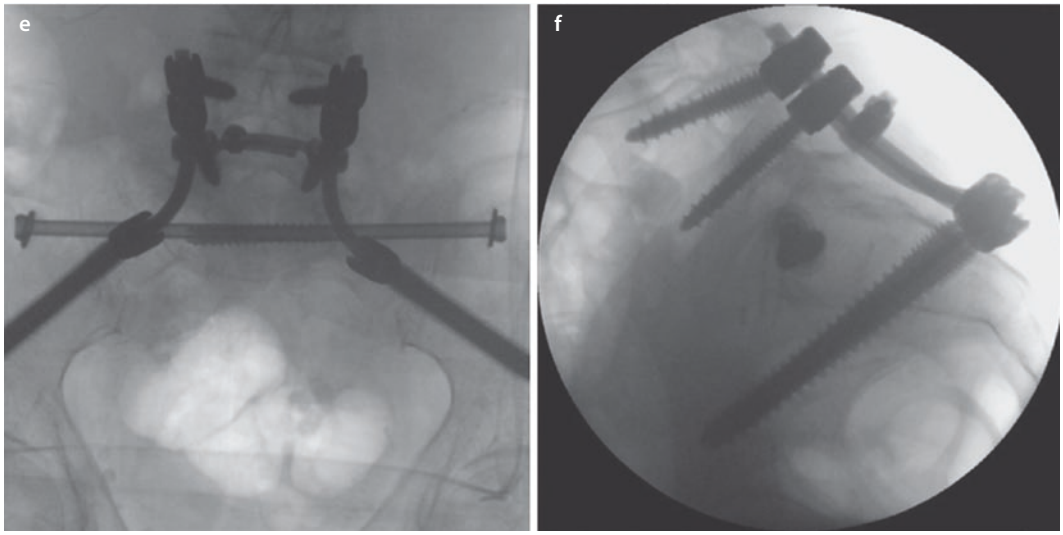


Fig. 29.5 (continued)

References

Andresen R et al (2017) Comparison of the 18-month outcome after the treatment of osteoporotic insufficiency fractures by means of balloon sacroplasty (BSP) and radiofrequency sacroplasty (RFS) in comparison: a prospective randomised study. Eur Spine J 26(12):3235–3240

Cabarrus MC et al (2008) MRI and CT of insufficiency fractures of the pelvis and the proximal femur. AJR Am J Roentgenol 191(4):995–1001

Cheng JS, Song JK (2005) Anatomy of the sacrum. Neurosurg Focus 15(2):E3

Fujii M et al (2005) Honda sign and variants in patients suspected of having a sacral insufficiency fracture. Clin Nucl Med 30(3):165–169

Gotis-Graham I et al (1994) Sacral insufficiency fractures in the elderly. J Bone Joint Surg Br 76(6):882–886

Grasland A et al (1996) Sacral insufficiency fractures: an easily overlooked cause of back pain in elderly women. Arch Intern Med 156(6):668–674

Gruneweller N et al (2017) Biomechanical comparison of augmented versus non-augmented sacroiliac screws in a novel hemi-pelvis test model. J Orthop Res 35(7):1485–1493

Höch A et al (2017) Biomechanical analysis of stiffness and fracture displacement after using PMMA-augmented sacroiliac screw fixation for sacrum fractures. Biomed Tech (Berl) 62(4):421–428

Hohenberger G (2017) Teriparatide as a therapy approach in sacral insufficiency fractures. Unfallchirurg 120(11):1000–1003

Kannus P et al (2000) Epidemiology of osteoporotic pelvic fractures in elderly people in Finland: sharp increase in 1970-1997 and alarming projections for the new millennium. Osteoporos Int 11(5):443–448

Kortman K et al (2013) Multicenter study to assess the efficacy and safety of sacroplasty in patients with osteoporotic sacral insufficiency fractures or pathologic sacral lesions. J Neurointerv Surg 5(5):461–466

Lourie H (1982) Spontaneous osteoporotic fracture of the sacrum. An unrecognized syndrome of the elderly. JAMA 248(6):715–717

Lyders EM et al (2010) Imaging and treatment of sacral insufficiency fractures. AJNR Am J Neuroradiol 31(2):201–210

Matta JM, Saucedo T (1989) Internal fixation of pelvic ring fractures. Clin Orthop Relat Res 242:83–97

Mendel T et al (2013) The influence of sacral morphology on the existence of secure S1 and S2 transverse bone corridors for iliosacroiliac screw fixation. Injury 44(12):1773–1779

Osterhoff G et al (2016) Cement augmentation in sacroiliac screw fixation offers modest biomechanical advantages in a cadaver model. Clin Orthop Relat Res 474(11):2522–2530

Peretz AM, Hipp JA, Heggeness MH (1998) The internal bony architecture of the sacrum. Spine (Phila Pa 1976) 23(9):971–974

Prokop A, Andresen R, Chmielnicki M (2016) Balloonsacroplasty: C-arm or CT controlled application? Experience with 46 patients. Unfallchirurg 119(11):929–935

Richards AM et al (2010) Bone density and cortical thickness in normal, osteopenic, and osteoporotic

sacra. J Osteoporos 2010:504078. https://doi.org/10.4061/2010/504078
Song W, Zhou D, He Y (2016) The biomechanical advantages of bilateral lumbo-iliac fixation in unilateral comminuted sacral fractures without sacroiliac screw safe channel: a finite element analysis. Medicine (Baltimore) 95(40):e5026
Taillandier J et al (2003) Mortality and functional outcomes of pelvic insufficiency fractures in older patients. Joint Bone Spine 70(4):287–289
Talmadge J et al (2014) Clinical impact of sacroplasty on patient mobility. J Vasc Interv Radiol 25(6):911–915
Thakkar SC et al (2017) 2D versus 3D fluoroscopy-based navigation in posterior pelvic fixation: review of the literature on current technology. Int J Comput Assist Radiol Surg 12(1):69–76
Wagner D et al (2017) Critical dimensions of transsacral corridors assessed by 3D CT models: relevance for implant positioning in fractures of the sacrum. J Orthop Res 35(11):2577–2584
Weber M, Hasler P, Gerber H (1993) Insufficiency fractures of the sacrum. Twenty cases and review of the literature. Spine (Phila Pa 1976) 18(16):2507–2512
West SG et al (1994) Sacral insufficiency fractures in rheumatoid arthritis. Spine (Phila Pa 1976) 19(18):2117–2121
Yoo JI et al (2017) Teriparatide treatment in elderly patients with sacral insufficiency fracture. J Clin Endocrinol Metab 102(2):560–565