Hernia (2021) 25:727–732
https://doi.org/10.1007/s10029-020-02168-9

ORIGINAL ARTICLE

Magnetic resonance visualization of iron-loaded meshes in patients with pain after inguinal hernia repair

E. Özveri[1] · D. E. T. Şanlı[2] · D. Yıldırım[2] · H. Gök[1] · M. Ertem[1]

Received: 8 November 2019 / Accepted: 2 March 2020 / Published online: 12 March 2020

Abstract

Purpose Chronic post-operative inguinal pain (CPIP) is defined as pain lasting more than 3 months and the incidence is less than 4% after laparoscopic hernia repair. CPIP can have several causes. In this study, we aimed to show that 3D-iron loaded mesh preparations are useful in radiological evaluation of post-operative complications, especially patients with chronic pain and the mesh status of operated inguinal hernia cases.

Methods A total of 450 cases who had been operated for inguinal hernia with 3D-iron loaded mesh and who had ongoing pain at the post-operative period were included in this study. MRI (Magnetic Resonance Imaging) was performed at the post-operative 90th day of the seven symptomatic (groin pain, limitation of movement) cases which were operated using a 3D-iron loaded mesh, 10 × 15 cm in size, (DynaMeshEndolap visible with 25% MRI-visible filaments, FEG TextiltechnikmbH, Aachen, Germany) for inguinal hernia repair to evaluate mesh status, localization, and local complications. Gradient echo sequences in the sagittal, axial, and coronal sections on MRI were discussed by two radiologists. Mesh localizations, their relationship with surrounding structures and their complications related with mesh were evaluated by two radiologists (D.Y, D.E.T.Ş).

Results No significant radiological findings related to defined anatomical structures were found in the MRI images of the study group. The dimensions measured on the sagittal, axial and coronal images were correlated with original mesh sizes and no significant shrinkage was detected.

Conclusion Mesh position and deformation as shrinkage can be the mesh-related cause of pain. The incidence of CPIP in our patients is less than 2%. 3D-iron loaded meshes were monitored with MRI in CPIP patients and there was no mesh-related changes found in our study. The use of MRI-visible meshes will most likely help us to monitor mesh preparations and show potential time-dependent changes in mesh characteristics and consequent complications. In case of doubtful clinical postoperative hernia recurrence or chronic groin pain, mesh position can be identified by MRI and unnecessary surgical intervention can be avoided.

Keywords Inguinal hernia · Laparoscopic · Hernia repair · MRI-visible mesh · Iron-loaded mesh · Chronic pain

Introduction

Inguinal hernia repair, or herniorrhaphy, is a common surgical procedure performed worldwide [1, 2]. Some of the complications that occur after herniorrhaphy include ongoing chronic pain and hernia recurrence. Chronic pain after herniorrhaphy occurs in up to 8–16% of patients, and such occurrence becomes a burden in the daily life of the individual [3, 4]. Laparoscopic hernia surgery techniques have a lower risk of chronic pain, however, it can still be the cause of chronic pain in some reported patients after surgery [5]. Pain following herniorrhaphy is common and it should subside within an expected time interval, which is approximately 3 months. If the pain lasts more than 3 months after herniorrhaphy, it is called a chronic post-operative inguinal pain (CPIP). The cause of CPIP may be multifactorial, therefore, it is sometimes not possible to diagnose the specific cause of pain. Pain may be caused by injury of the nerves due to the dissection of the nearby anatomical structures

✉ E. Özveri
emel.ozveri@acibadem.com

[1] Department of Surgery, Acıbadem Hospital, Kozyatağı, Istanbul, Turkey

[2] Department of Radiology, Acıbadem Hospital, Kozyatağı, Istanbul, Turkey

or nerves that are damaged by fixation devices. Surgeons performing laparoscopic inguinal hernia repair should be cautious of not damaging three important nerves that can cause post-operative pain, namely the lateral femoral cutaneous nerve, the femoral branch of the genitofemoral nerve, and the femoral nerve. Another way that the nerves can be trapped is by shrinking through folding or wrinkling; this process is called meshoma [6]. The inflammation process after the post-operative period is another cause of pain. Current radiological techniques are unable to determine the origin of pain during the post-operative period. Because of this, hernia recurrence and other complications of herniorrhaphy are diagnosed surgically. Using a mesh with the inclusion of 3-D iron particles has become the favor of choice since it can be visible on MRI [7–9]. As a result of this advance, changes in mesh implant and post-operative complications can be easily detected in MRI, and this will be useful for surgeons to plan for an elective surgical operation [10]. While the results of different surgical hernia procedures and mesh fixation techniques have been evaluated, the effect of mesh position and mesh deformation on chronic inguinal pain is still unknown.

The purpose of our study was to evaluate the position and deformation of iron-loaded visible mesh implants using MRI and to correlate MRI findings in patients treated for inguinal hernias with post-surgical chronic pain.

Materials and methods

In this retrospective cohort study, 450 patients who underwent TAPP (transabdominal preperitoneal technique) and TEP (totally extraperitoneally) procedure using iron-loaded mesh for inguinal hernia between May 2013 and May 2019 were included in this study. All surgical mesh implants consisted of polyvinyidenfluoride (PVDF) monofilaments. To provide MRI visibility, tiny iron particles have been embedded into the base material, resulting in a mesh concentration of 99%PVDF and 1%Fe_3O_4.

Dynamesh Endolap Visible 15 × 10 cm was used in each case (FEG Textiltechnik mbH, Aachen, Germany) [11]. The implants were placed with a laparoscopic technique in the pre-peritoneal space, posteriorly to the abdominal approach. The implant was fixed in its correct position with glue application (LİQUİBANDFIX8® Advanced Medical Solutions Limited, Plymouth, UK) and tacker (Protack™ 5 mm Fixation Device, Covidien, Medtronic, Minneapolis, MN, USA). Mesh fixation with tacker in the first 298 patients was done in three points; pubic bone, upper medial and lateral corners while taking care of both triangles of pain and doom.

The patients were called for a check-up control in the first 3 months of post-operatively. The patients with ongoing pain at 3 months were asked to complete the Short-form Inguinal pain Questionnaire (sf-IPQ). The sf-IPQ is a reliable instrument for the assessment of groin pain [12]. This scale consists of a 12-point scale with two items (Fig. 1). The scoring system reports worst pain level from 0 points (no pain) to 6 points in Item-1; interference with daily activities in Item-2 scores one point for each activity reported to limited by groin pain.

MRI was performed in seven patients having chronic pain 3 months after the operation with a sf-IPQ scale above 5. The MRI examinations were performed on a clinical 1.5-T scanner (Achieve;Philips Heathcare, the Netherlands) with a multichannel torso coil to acquire the signal (Sense XL Torso Coil; Philips Heathcare) in the prone position. The MRI sequence protocol included a conventional gradient echo sequences (GRE) (repetition time: 868 ms, echo time: 18 ms, flip angle: 25 deg, field of view: 240 mm, bandwidth: 230 Hz/Px, slice thickness: 3 mm, scan duration: 5 min) and T2-weighted turbo spinecho (T2W TSE) sequences (repetition time: 900 ms, echo time: 94 ms, flip angle: 140 deg, field of view: 300 mm, bandwidth: 650 Hz/Px, slice thickness: 5 mm, scan duration: 3 min), each in coronal, sagittal and axial orientation (Fig. 2). Two experienced radiologists (D.Y, D.E.T.Ş) independently evaluated mesh status-localization-migration, mean size, and complication findings due to mesh or operation in coronal, sagittal, and axial orientations. Mesh deformation and coverage of the hernia were evaluated with MRI. The mesh area measurements for shrinkage evaluation were also quantitatively obtained from the multiplanar reformat and reconstructed T2W images using thin Maximum Intensity Projection (MIP) slices with Syngo-via (Via-TM, VB10A, Siemens Heathcare, Germany) software on MRI examination. The curved planar cross-sections used to measure mesh areas and folded interfaces were also opened. In addition, the presence of fluid, abscess, and collection secondary to mesh or operation was also evaluated with MRI.

Results

Among the 450 patients in this study who were operated for inguinal hernia with iron-loaded mesh implants, 93% ($n = 418$) were men and 7% ($n = 32$) were women. The median age of the patients was 49 and the median age was 52 (31–80) for women and 49 (21–83) for men. Conversion from laparoscopic to open technique did not occur. All surgical cases were performed under general anesthesia. When the anatomical aspect of the hernias was taken into consideration, 57% ($n = 256$) of the cases were indirect inguinal hernias while 24% ($n = 108$) were direct inguinal hernias. Only 17% ($n = 76$) included both direct with indirect hernias and only 2% ($n = 10$) were femoral hernia cases. TEP was performed in 85% ($n = 382$) of the patients and TAPP was

1. Estimate the worst pain you felt in the operated groin during the past week

No pain	□
Pain present but can easily be ignored	□
Pain present, cannot be ignored, but thus not interfere with daily activities	□
Pain present, cannot be ignored, interferes with most activities	□
Pain present, cannot be ignored, necessitates bed rest	□
Pain present, cannot be ignored, prompt medical advice sought	□

2. If you have experienced groin pain, to what extent has it limited your ability to perform following activities? More thanone option may be selected.

Getting up from a low chair	□
Sitting down (more than 30 minutes)	□
Standing up (more than 30 minutes)	□
Going up or down stairs	□
Driving a car	□
Exercising or performing sports	□

Fig. 1 The short-form IPQ (sf-IPQ) consisting of two items with a total score ranging between 0 and 12. Question 1 contributes 0–6 points (higher points for more intense pain) and question 2 adds one point for each reported activity limited by pain (6 in all)

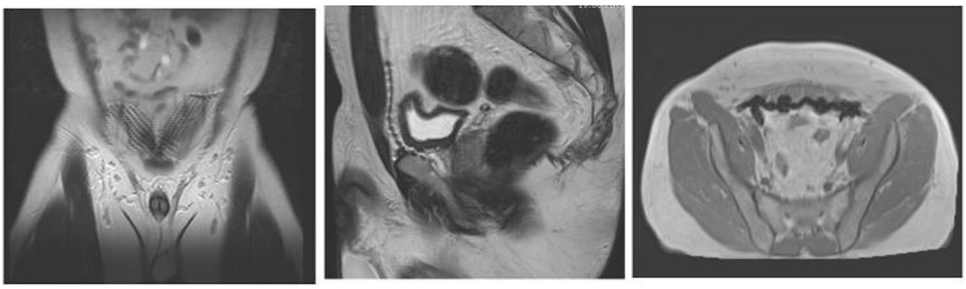

Fig. 2 **a** Coronal, **b** sagittal, **c** axial orientated GRE sequences of the case underwent bilateral inguinal hernia repair using iron-loaded mesh (DynaMeshEndolap visible with 25% MRI-visible filaments, FEG TextiltechnikmbH, Aachen, Germany). Mesh implant can be delineated as hypointense (dark) susceptibility artifacts against the hyperintense (bright) surrounding fatty tissue

performed in 15% ($n=68$) of the patients. Bilateral inguinal hernia was detected in 38% ($n=171$) of the patients; 42% ($n=189$) only included rightside, 20% ($n=90$) only included leftside. Tacker was used in the first 298 patients and glue application was used in the last 152 patients (Table 1).

Seven patients had persistant pain lasting more than 3 months and CPIP incidence in our patients were about 2%. The median age of the seven patients with pain was 39. Most of the operations included the TEP technique and tacker was the only fixation method in patients with pain. All of the patients had indirect hernia and two patients had bilateral. The patients rated their pain with the sf-IPQ scale. Pain scores were higher than 5 in all of the cases (Table 2).

Bilateral herniorrhaphy was performed in two patients, therefore, a total of nine meshes were evaluated with MRI. In the initial MRI examinations, all nine meshes used for hernia repair exhibited a typical mesh configuration along the inner abdominal wall down to the symphisis pubis with convex lateral folding and a change of direction towards the psoas muscle. During the consequent follow-up MRI images, there was not a significant change in terms of mesh localization or mesh configuration. All of the seven cases and

Table 1 Characteristics of patients who were operated with dynamesh

	N = 450
Age, median (range)	49 (21–83)
Gender	
Female	32
Male	418
Surgical approach	
TEP	382
TAPP	68
Uni-bilateral	
Unilateral repair	279
Bilateral repair	171

nine meshes exhibited complete coverage of hernia defects and no relation was found with pain and mesh localization. There was no more than 30% shrinkage between the mesh sizes and the values obtained in the calculation of the mesh area using free hand technique in axial sections (Table 3). Of the seven patients who had pain, only one had linear effusion around the mesh. In other cases, no significant signs of inflammation, such as abscess and collection, were differentiated. According to MRI findings, there was a poor correlation between hernia coverage and mesh configuration with clinical symptoms.

Discussion

After undergoing herniorrhaphy, pain after physical activity is a common finding in individuals. It has been shown that recurrence of a hernia can be reduced with the use of a prosthetic mesh; however, improving the quality and success rate of inguinal hernia surgery is still necessary to reduce the occurrence of groin pain after surgery [13, 14]. When the weight of the mesh and groin pain was taken into consideration, there was no advantage of light meshes over heavy meshes and a correlation was not shown [15]. When the fixation method and pain was evaluated in the previous studies, no advantage of glue application was found [5]. Placement of a wide mesh covering the entire myopectineal orifice and the use of atraumatic or carefully placed traumatic fixation away from the triangle of pain and doom can help minimize the risk of recurrence and chronic pain. Even though the guidelines mostly recommend atraumatic or no fixation in the majority of the cases, mesh fixation is still the option to go in patients with large direct hernias to prevent recurrence [16]. It is important to exclude a possible hernia recurrence in a person presenting with pain that has already undergone herniorrhaphy. It should also be kept in mind that pain in the inguinal region can also be due to the variety of diseases of the musculoskeletal system of the localized area. Patients having risk factors such as younger age, pain

Table 2 Characteristics of patients with pain

	Age	Gender	Surgical approach	Uni/bilateral	Fixation	sf-IPQ scores
Patient 1	36	Male	TEP	Right indirect	Protack	8/12
Patient 2	56	Female	TEP	Left indirect	Protack	8/12
Patient 3	39	Male	TEP	Right indirect	Protack	5/12
Patient 4	34	Male	TEP	Bilateral indirect	Protack	6/12
Patient 5	61	Male	TAPP	Bilateral indirect	Protack	8/12
Patient 6	35	Female	TEP	Left indirect	Protack	7/12
Patient 7	45	Male	TEP	Right direct	Protack	7/12
Mean	39 ± 10.82					6.91 ± 1.15

Table 3 The mesh area measurements of the cases obtained by MRI

	Right					Left				
	Sagittal	Coronal	Axial	Mesh area in MRI (mm^2)	Shrinkage (%)	Sagittal	Coronal	Axial	Mesh area in MRI (mm^2)	Shrinkage (%)
Patient 1	1.1	13.3	8.5	113.05	24.7					
Patient 2						1.1	13.1	8.9	116.59	22.3
Patient 3	1.1	14	8.8	123.2	18					
Patient 4	1.3	14.2	8.3	117.86	21.5	1.2	13	8.7	75.4	24.6
Patient 5	1.2	12.6	8.5	107.1	28.6	1.3	12	9	108	28
Patient 6	1.3	13	9	117	22					
Patient 7	1.2	12.1	8.9	107.69	28.3					

prior to surgery, severe early post-operative pain, female gender, and post-operative complications are more likely to develop persistent pain following hernia repair [17–19]. When chronic pain after open hernia surgery was taken into consideration, age was found to be the single most important risk factor involved [20]. Higher level of acute post-operative pain predicts persistent pain after surgery. Complications such as recurrent hernia, post-operative hematoma, and infection may also play a role [21, 22]. Acute pain after surgery is most likely due to an inflammatory process of the localized region and it's severity decreases over a period of 6–8 weeks [23]. When pain persists more than 8 weeks, chronic neuropathic pain has to come to mind due to abnormal neural activity; this is the result of a nerve injury of the involved region [6]. Primary nerve injuries can be caused by nerve transections, nerve damage during manipulation, and entrapment of nerves with fixation. Nerve entrapment can also be caused by a process called meshoma. The median age of our patients with pain was low and severe early post-operative pain was also present in our patients, similar with other studies in the literature.

When chronic pain after hernia surgery lasts more than 3 months, imaging modalities such as the MRI can be performed to look for other causes of pain of the involved region (i.e., mesh infection, recurrent hernia, osteitis pubis). Up to this day, visualization of the mesh patch was not radiographically possible. It was the introduction of ferroxide particles on the mesh patch that led to contrast modulation, as a result, separation of the patch from the surrounding anatomical structures was possible, leading to it's visualization on MRI. Iron-loaded implants have also been shown to be visualized on MRI in the animal studies; deformation and other mesh complication were evaluated in detail. Therefore, the application of this new device in groin hernia repair has started to become widespread [24, 25]. With the use of mesh in hernia surgery in daily practice, 30% of the patients undergoing such surgery had post-operative complications. When the mesh material and surgical technique was taken into consideration, mesh shrinkage ranging from 3.6% up to 57% was observed [26–29]. Shrinkage of a mesh patch is probably one of the most feared complications since it is a common cause of hernia recurrence as well as chronic pain. [30]. It is, therefore, necessary to look for non-invasive tools to visualize the status of the mesh patch once it is inserted into the body [31].

Ciritsis et al. found 21% of PVDF mesh shrinkage in TAPP treated patients [10]. True 3D volumetric sizes of the meshes were not measured in our study due to the lack of an appropriate CAD program for the measurement. On the other hand, we measured the 3-dimensional length of the meshes with free-hand by opening folded interfaces and there was no reduction of more than 30% of the mesh area used. Ciritsis et al. found that the mean mesh dislocation was 0.23 (0.03) cm, and the mean (SD) length of the vector indicating the centroid shift between the 1st and 90th day points measured 1.17 (0.47) cm with regard to the implemented iliac bone reference system [10].

In our study group, patients with pain had meshes located in the correct position on the MRI examination. Implanted meshes were found in the exact defined anatomical boundaries in which they were placed during the operation. As a result, we did not find a correlation between clinical symptoms and mesh location. These findings gave us a strong reason to believe that the cause of pain is not relevant to the location of mesh. The weaknesses of this study were the retrospective nature of the study and the lack of a suitable CAD program for shrinkage assessment. In this study, we examined only cases where herniorrhaphy was performed with iron-loaded mesh. Complications and imaging findings can be evaluated by comparing traditional meshes and iron loadad meshes in different and larger patient groups in the future.

Future studies on the etiology of symptomatic patients with pain could be done in a larger patient group. In patients with shrinkage, the relationship between the degree of shrinkage and symptomatology, whether there is compression of small nerve branches by mesh dislocation and the relationship of mesh with other soft tissues can be evaluated.

In conclusion, the results of our study showed that MRI studies of iron-loaded meshes give satisfactory visualisation. The use of MRI-visible meshes will most likely help us to monitor implants and give answers to important questions in potential changes in mesh characteristics and consequent complications to evaluate the need for a revision surgery. Other possible reasons for chronic pain deserve attention and might be a subject to another study. Post-herniorrhaphy neuralgia as a cause of persistent post-operative pain should be taken into consideration and properly managed in every case. Imaging studies such as MRI are used primarily to exclude non-neuropathic hernia-related pathologies or other non-hernia related diseases in the differential diagnosis, preventing unnecessary explorative surgery.

Compliance with ethical standards

Conflict of ınterest Author Özveri E., Author Şanlı D.E.T., Author Yıldırm D., Author Gök H and Author Ertem M. declare that they have no conflict of interest.

Ethical approval This study did not need approval from an ethic committee.

Human and animal rights This article does not contain any studies with animals performed by any of the authors.

Informed consent In this retrospective study, all patients with pain provided written informed concent.

References

1. Primatesta P, Goldacre MJ (1996) Inguinal hernia repair: incidence of elective and emergency surgery, readmission and mortality. Int J Epidemiol 25:835–839
2. Kingsnorth AN, LeBlanc KA (2003) Management of abdominal hernias, 3rd edn. Edward Arnold, London, pp 40–47
3. Aasvang EK, Gmaehle E, Hansen JB et al (2010) Predictive risk factors for persistent postherniotomy pain. Anesthesiology 112(4):957–969
4. Andresen K, Burcharht J, Fonnes S et al (2017) Chronic pain after inguinal hernia repair with the ONSTEP versus the Lichtenstein technique, results of a double-blinded multicenter randomized clinical trial. Langenbecks Arch Surg 402(2):213–218
5. Andersen K, Fenger AQ, Burchharth J, Pommergaard HC, Rosenberg J (2017) Mesh fixation methods and chronic pain after transabdominal preperitoneal (TAPP) inguinal hernia surgery: a comparison between fibrin sealant and tacks. SurgEndosc 31(10):4077–4084
6. Amid PK (2004) Radiologic images of meshoma a new phenomenon causing chronic pain after prosthetic repair of abdominal wall hernias. JAMA Surg 139(12):1297–1298
7. Kraemer NA, Donker HC, Otto J et al (2010) A concept formagnetic resonance visualisation of surgical textile implants. Invest Radiol 45:477–483
8. Donker HC, Kraemer NA, Otto J et al (2012) Mapping of proton relaxation near superparamagnetic iron oxide particle-loaded polymer threads for magnetic susceptibility difference quantification. Invest Radiol 47:359–367
9. Slabu I, Guentheradt G, Schmitz-Rode T et al (2012) Investigation of superparamagnetic iron oxide nanoparticles for MR-visualization of surgical implants. Curr Pharm Biotechnol 13:545–551
10. Ciritsis A, Hansen NL, Barabasch A et al (2014) Time-dependent changes of magnetic resonance imaging-visible mesh implants in patients. Invest Radiol 49:439–444
11. Kraemer NA, Donker HC, Kuehnert N, Otto J, Schrading S, Krombach GA et al (2013) In vivo visualization of polmer-based mesh implants using conventional magnetic resonance imaging and positive contrast susceptibility imaging. Invest Radiol 48:200–205
12. Olsson A, Sandblom G, Franneby U, Sonden A, Gunnarsson U, Dahlstrand U (2019) The short-form inguinal pain questionnaire (sf-IPQ): An instrument for rating groin pain after inguinal hernia surgery in daily clinical practice. World J Surg 43(3):806–881
13. EU Hernia Trialists Collaboration (2000) Mesh compared with non-mesh methods of open groin hernia repair: systematic review of randomized controlled trails. Br J Surg 87:854–859
14. Page B, Paterson C, Young D et al (2002) Pain from primary inguinal hernia and the effect of repair on pain. Br J Surg 89:1315–1318
15. Burgmans JP, Voorbrood CE, Simmermacher RK et al (2016) Long term results of a randomized double-blinded prospective trial of a lightweight (Ultrapro) versus a heavyweight mesh (prolene) in laparoscopic total extraperitoneal inguinal hernia repair (TULP-trial). Ann Surg 263(5):862–866
16. HerniaSurge Group (2018) International guidelines for groin hernia management. Hernia 22(1):1–165
17. Wermer MU, Kongsgaard UEI (2014) Defining persistent postsurgical pain:is an update required. Br J Anaesth 113(1):1–4
18. Franneby U, Sandblom G, Nordin P, Nyren O, Gunnarsson U (2006) Risk factors for long term pain after hernia surgery. Ann Surg 244:212–219
19. Olsson A, Sandblom G, Franneby U, Sonden A, Gunnarsson U, Dahlstrand U (2017) Impact of postoperative complications on the risk of chronic groin pain after open inguinal hernia repair. Surgery 161:509–516
20. Poobalan AS, Bruce J, King PM et al (2001) Chronic pain and quality of life following open inguinal hernia repair. Br J Surg 88:1122
21. Aasvang EK, Mohl B, Bay-Nielsen M, Kehlet H (2006) Pain related sexual dysfunction after inguinal herniorrhaphy. Pain 122:258
22. Hawn MT, Itani KM, Giobbie-Hurder A et al (2006) Patient-reported outcomes after inguinal herniorrhaphy. Surgery 140:198
23. Hakeem A, Shanmugam V (2011) Current trends in the diagnosis and management of post-herniorraphy chronic groin pain. World J Gastrointest Surg 3:73
24. Köhler G, Pallwein-Prettner L, Koch OO, Luketina RR, Lechner M, Emmanuel K (2015) Magnetic resonance-visible meshes for laparoscopic ventral hernia repair. JSLS 19(1):00175
25. Otto J, Kuehnert N, Busch D, Lambertz A, Klink C, Hansen NL, Ciritsis A, Kuhl C, Klinge U, Neumann UP, Conze J, Kraemer NA (2014) MR-visualization of surgical textile implants. BioNanomaterials 15(1–2):3–8
26. Hansen NL, Barabasch A, Distelmaier M et al (2013) First in human magnetic resonance visualization of surgical mesh implants for inguinal hernia treatment. Invest Radiol 48:770–778
27. Novitsky Y, Harel AG, Cristiano JA et al (2007) Comparative evaluation of adhesion formation, strength of ingrowth, and textile properties of prostetic meshes after lon-term intra-abdominal implantation in a rabbit. Surg Res 140:6–11
28. McGinty JJ, Hogle NJ, McCarty H et al (2005) A comparative study of adhesion formation and abdominal wall ingrowth after laparoscopic ventral hernia repair in a pocine model using multiple types of mesh. Surg Endosc 19:786–790
29. Burger JW, Halm JA, Wijsmuller AR et al (2006) Evaluation of new prosthetic meshes for ventral hernia repair. Surg Endosc 20:1320–1325
30. Schoenmaeckers EJP, van der Valk SBA, van den Hout HW, Raymakers JFTJ, Rakic S (2009) Computed tomographic measurements of mesh shrinkage after laparoscopic ventral incisional hernia repair with an expanded polytetrafluoroethylene mesh. Surg Endosc 23:1620–1623
31. Kirchhoff S, Ladurner R, Kirchhoff C, Mussack T, Reiser MF, Lienemann A (2009) Detection of recurrent hernia and intraabdominal adhesions following incisional hernia repair: a functional cine MRI-study. Abdom Imaging 35:224–231