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PAPER

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Inguinal tensile strength and pain level after Shouldice repair

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Abstract *Background:* Tension of the abdominal wall in the inguinal region induced by Shouldice repair of an inguinal hernia is said to be responsible for elevated postoperative pain levels. *Patients and methods:* In 20 patients we recorded the inguinal tensile strength during closure of the hernial gap using a wound retractor equipped with strain gauges. Postoperative pain levels were scaled using a visual analogous score, and correlated with the tensile strength of the inguinal abdominal wall together with peak flow and forced expiratory volume in 1 s (FEV1) 8, 24, and 48 h after the time of operation. *Results:* Shouldice repair caused an average increase in inguinal tensile strength of 2.9 ± 0.58 N (mean ± SEM). The pain level expressed by active patients was twice the value obtained from resting patients ($41.55 \pm 6.3\%$ vs $20.81 \pm 7.1\%$ 8 h after operation), but decreased slightly later on. Peak flow during forced expiration was depressed to about 80% of the control values, whereas the 1-s volume during forced expiration decreased only to 95% of the control value. We excluded any correlation between the recorded individual inguinal tensile strength or the changes in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament and the postoperative pain level. *Conclusion:* We failed to see any evidence for the hypothesis that higher inguinal tensile strength induced by Shouldice repair leads to an elevated level of postoperative pain. If there is any effect, it may be masked by other factors with a stronger influence.

Keywords Inguinal hernia · Shouldice repair · Tensile strength · Pain

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Introduction

Many reports deal with the favourable outcome of patients after mesh repair of their inguinal hernia [1, 8, 14, 29]. This policy, however, includes the permanent implantation of a prosthetic mesh into the inguinal region, which in the primary situation is not without controversy among inguinal hernia repair specialists [3, 11, 16, 24, 27]. Especially in young patients with a long life expectancy, this implantation of foreign material has to be viewed critically, as it induces chronic inflammatory changes, which may lead to malignancy in rare cases [13, 17].

One of the major advantages of the tension-free principle, however, is a low postoperative pain level in comparison with Shouldice repair [15, 29]. This is said to be due to the lack of tension which is induced in the abdominal wall of the inguinal region by adapting the inguinal ligament and the lateral edge of the rectus sheath during the transversal fascia plasty in Shouldice repair. This advantage is reported for all kinds of patients independent of their personal constitution and body condition. Intraoperative findings, however, indicate that some patients present strong anatomical landmarks, and others show a floppy condition of their abdominal wall. Therefore, the amount of tensile strength induced by Shouldice plasty should be strongly related to the individual constitution of the patient. Furthermore, the size of the hernial gap should also have an effect on the tensile strength in the inguinal region after closure of the defect. Following the hypothesis of obtaining better results by the omission of postoperative abdominal wall tension, the intraoperative quantification of the tensile forces induced by the

Shouldice repair should correspond to the postoperative pain level.

Materials and methods

Patients

After providing informed consent, 20 consecutive patients with a mean age of 52 years underwent intraoperative evaluation of their tensile strength in the inguinal region during original Shouldice repair of a unilateral primary inguinal hernia. All operations were carried out under local anaesthesia. Intraoperatively, the ilioinguinal nerve and the genital branch of the genitofemoral nerve were sought and preserved. Following a standardized protocol we used 5 mg diazepam for anxiolysis exclusively [20]. No other medication with relaxing side effects was given. Active cooperation of the patient was possible at all times.

Instrument

The instrument was designed based on a wound retractor. The tips of the branches contained two and three spikes, respectively, for secure fixation at fascial structures. These spikes at a distance of 1.5 cm were placed alternately such that closure of the instrument resulted in complete approximation of the fixed fascial lines. The branches of the instrument incorporated strain gauge force transducers (CEA-XX-250UW-350; Measurements Group Messtechnik, Lochham, München, Germany), protected by component cement (Fig. 1). Any force acting on the fascial level led to a bending of the force transducers, which induced an electric current. After amplification these electrical changes were recorded on a personal computer. A potentiometric distance sensor (Type 8711; Burster Präzisionsmesstechnik, Gernsbach, Germany) continuously recorded the position of the branches.

Data collection

After division of the transversal fascia the base of the inguinal ligament and the lateral edge of the rectus sheath were prepared. Then the branches of the instrument were fixed to the structures mentioned. Closure of the wound retractor approximated the lateral edge of the rectus sheath to the basis of the inguinal ligament thereby closing the hernial gap. This manoeuvre simulated Shouldice repair. A continuous increase in the tensile strength was recorded simultaneously with decreasing distance between the branches of the wound retractor (Fig. 2). A remaining distance of 3 mm was left following the conditions during Shouldice repair.

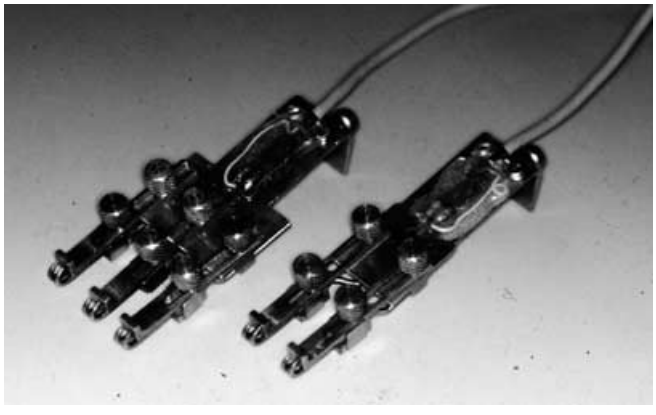

Fig. 1 Branches of the wound retractor designed for recording the tensile strength induced by Shouldice repair

Data were collected at a frequency of 10 Hz from channel bridge amplifiers (type 301; Hugo Sachs Elektronik, March-Hugstetten, Germany) using a high-speed analogue and digital I/O board (DAS 1202, MetraByte Corporation, Taunton, Mass.), and stored in a personal computer.

Pain analysis

Pain analysis was carried out using the 100-mm visual analogue scale score described by Huskisson [12]. The patient was asked to mark his current pain level between the two end points "no pain" and "worst imaginable pain". From the back of the instrument the investigator read the corresponding percentage pain level. This instrument has been found to be appropriate for measuring acute pain intensity [4] and has been successfully tested against different pain assessment tools [9]. The pain level was evaluated 8, 24, and 48 h postoperatively, and was recorded at rest and during normal activities such as coughing and walking. The pain-related ventilatory parameters peak flow and forced expiratory volume in 1 s (FEV1) were also determined as objective factors [10] using a mobile analyser (Spirotron; Dräger, Lübeck, Germany).

After giving detailed instructions to the patient and following a minimum rest of 30 min, we chose the best of three tests. The spirometric value achieved before operation was regarded 100%, and the postoperative decrease in the ventilatory function recorded as a percentage of the preoperative function. The relationships between the individual tensile strength and the postoperative pain level or the change in the ventilatory parameters were also analysed, For this purpose the patients were classified according to their amount of inguinal tensile strength: low (0–1.4 N, $n=7$), moderate (1.5–3.9 N, $n=7$), and high (4–10 N, $n=6$). Finally, the degree of correlation between the change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament and the postoperative pain level was determined. Therefore, the patients had to be classified according to the amount of change in distance: small (0–0.5 cm, $n=9$), moderate (0.51–1.1 cm, $n=6$), and large (>1.1 cm, $n=5$).

Statistical analysis was carried out using the two-tailed unpaired t-test. Statistical significance of differences was assumed for P-values less than 0.05. All data are presented as mean ± SEM.

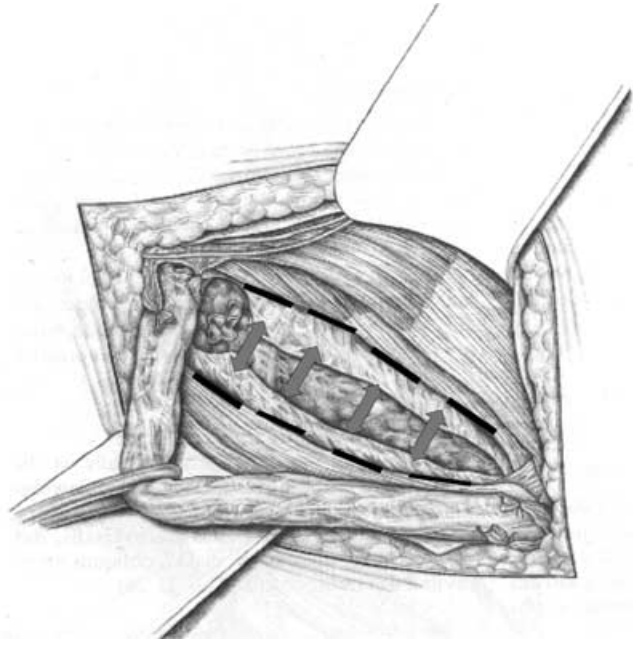

Fig. 2 Direction of the tensile forces acting on the branches of the wound retractor during closure of the hernial gap

Results

Closure of the hernial gap by approaching the lateral edge of the rectus sheath to the base of the inguinal ligament to a remaining distance of 3 mm increased the tensile strength of the abdominal wall in the inguinal region (Fig. 3). In 20 patients we found a mean tensile strength increase of 2.92 ± 0.58 N (range 0.15–9.92 N). More than 50% of our patients showed an increase in tensile strength level of 2 N or less (Fig. 4).

The postoperative pain levels as evaluated by the visual analogous score showed mean values in active patients twice those in resting patients (Table 1). However, the mean pain level decreased distinctly during the postoperative period of 48 h. We looked for a correlation between the extent of tensile strength resulting from closure of the hernial gap and the pain level occurring in the following 8, 24, and 48 h. In resting patients, 8 h after operation the highest pain level of 26.6 ± 6.8% was observed in the group with moderate tensile strength (1.5–3.9 N), while the groups with high (4–10 N) and low tensile strength (0–1.4 N) showed only moderate pain levels (17.6 ± 7.1% and 17.8 ± 7.5%, respectively). After 48 hours the lowest pain level was observed in the group with high tensile strength (8.3 ± 3.9%), and similar pain levels in the other groups (17.4 ± 8.2% and 16.5 ± 7.1%, respectively; Fig. 5). These differences were not statistically significant ($P > 0.05$).

Among active patients, there were no differences in pain levels regardless of the amount of inguinal tensile strength during the first 24 h. After 48 h the low tensile strength group showed the highest pain levels (42.0 ± 9.8% vs 28.8 ± 5.2% and 30.0 ± 6.0%, respectively), but this was also without statistical significance (Fig. 5).

The mean value of the peak flow during forced expiration determined 8 h after the time of operation was distinctly depressed to 80.81% of the control value (Table 1), but improved subsequently. The greatest depression to about 62.3% of the control value

Table 1 The postoperative pain level in resting and active patients as well as the reduction in the pain-related parameters peak flow and 1-s volume after forced expiration (FEV1) collected from 20 patients 8, 24, and 48 h after Shouldice repair. The values are means ± SEM

	Time after operation (h)		
	8	24	48
Pain level (%)			
Resting patient	20.81 ± 7.1	17.63 ± 6.9	14.36 ± 6.4
Active patient	41.55 ± 6.3	37.47 ± 6.9	33.78 ± 7.0
Reduction in peak flow (% of control)	80.81 ± 6.5	82.51 ± 4.1	86.35 ± 2.8
Reduction in FEV1 (% of control)	97.13 ± 1.3	94.61 ± 2.7	96.66 ± 2.1

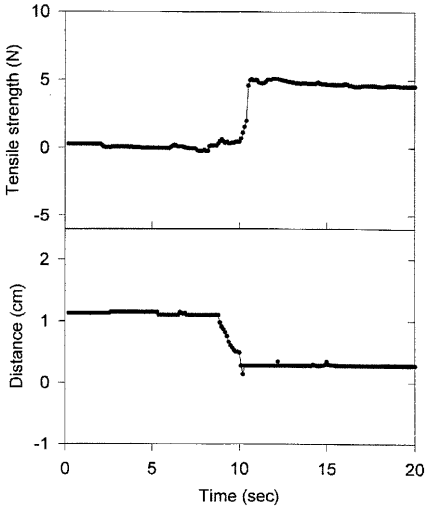

Fig. 3 Increasing tensile strength of the abdominal wall in the inguinal region during closure of the hernial gap in a representative patient

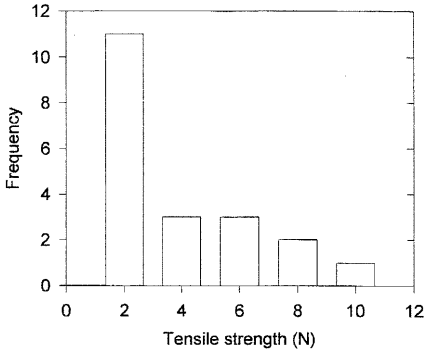

Fig. 4 Tensile strength of the abdominal wall induced by Shouldice repair in 20 patients

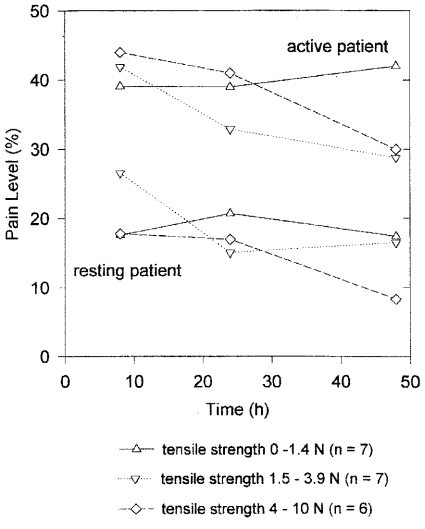

Fig. 5 Mean postoperative pain level at rest and during activity (coughing and walking) 8, 24, and 48 h after Shouldice repair ($n = 20$). The data were grouped in three categories of tensile strength obtained during the repair

occurred in the moderate tensile strength group (Fig. 6), but in both the low and high tensile strength groups distinctly smaller depressions of the peak flow ($85.8 \pm 6.7\%$ and $87.6 \pm 5.8\%$ after 8 h, and $92.6 \pm 4.0\%$ and $94.3 \pm 3.0\%$ after 24 hours, respectively) were observed. The 1-s volume during forced expiration decreased only slightly to about 95% during the postoperative period of 48 h (Table 1). The patient groups with the lowest and the highest inguinal tensile strength showed no depression (Fig. 7), but the patients with moderate tensile strength showed a significant depression of their 1-s forced expiratory volume to $85.9 \pm 6.9\%$ as measured 24 h after the end of the operation ($P < 0.05$).

Correlating the change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament and the postoperative pain levels, the highest pain levels and the largest depression in pain-related ventilation parameters were observed in the group with the smallest change in distance (Figs. 8, 9, 10, 11).

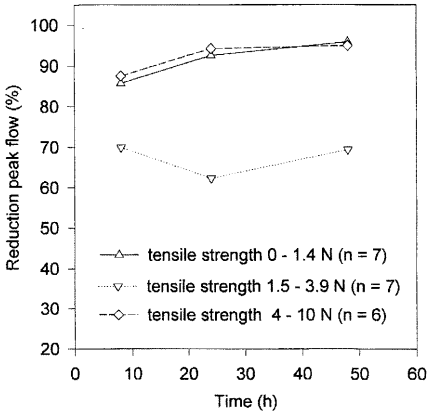

Fig. 6 Mean peak flow during forced expiration 8, 24, and 48 h after Shouldice repair (n = 20). The data were grouped in three categories of tensile strength obtained during Shouldice repair

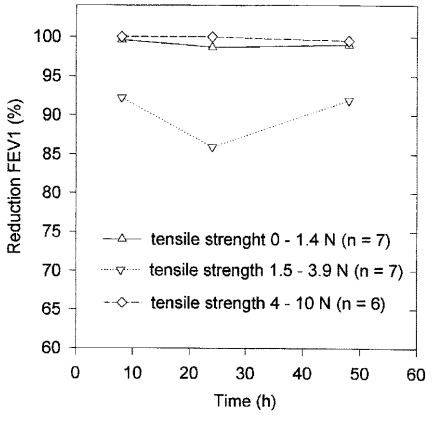

Fig. 7 Mean forced expiratory volume in the first second (FEV1) 8, 24, and 48 h after Shouldice repair ($n = 20$). The data were grouped in three categories of tensile strength obtained during Shouldice repair

Discussion

Several reports already deal with the attempt to quantify the tensile forces during inguinal hernia repair. In 1981 Read and McLeod recorded tensile forces to investigate the necessity for relaxing incisions of the rectus sheath

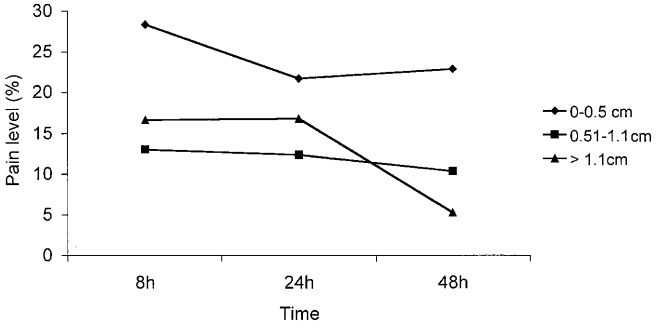

Fig. 8 Mean postoperative pain level at rest 8, 24, and 48 h after Shouldice repair ($n = 20$). The data were grouped in three categories of change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament obtained during Shouldice repair

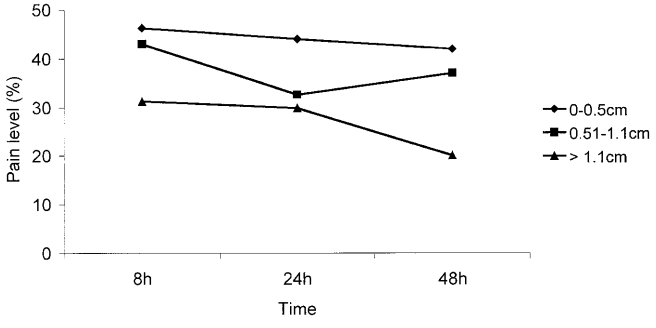

Fig. 9 Mean postoperative pain level during activity (coughing and walking) 8, 24, and 48 h after the Shouldice repair ($n = 20$). The data were grouped in three categories of change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament obtained during Shouldice repair

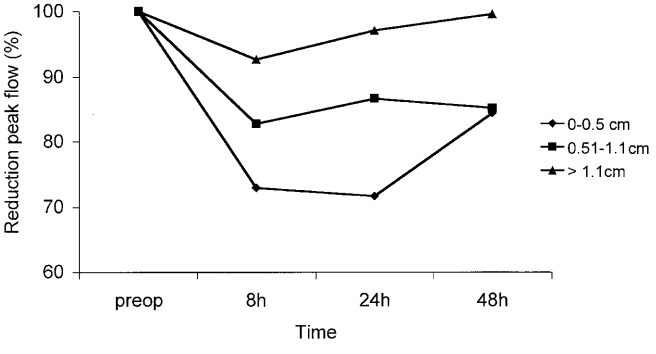

Fig. 10 Mean peak flow during forced expiration 8, 24, and 48 h after Shouldice repair ($n = 20$). The data were grouped in three categories of change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament obtained during Shouldice repair

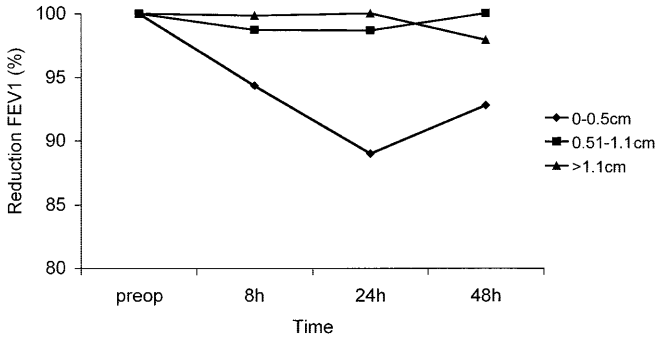

Fig. 11 Mean forced expiratory volume in the first second (FEV1) 8, 24, and 48 h after Shouldice repair ($n=20$). The data were grouped in three categories of change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament obtained during Shouldice repair

[23]. Their tensiometer recorded the force necessary for tying a knot in an interrupted suture line. Elevated tensile forces were found with the McVay repair compared to Bassini's procedure. Altogether the recorded forces were between 0.5 and 2.2 N, which are in the same order as found in our experiments (Fig. 4). In 1981 Wantz also reported a method to quantify the tensile forces during Shouldice repair using a spring scale fixed to a needle holder [28]. He found a tensile strength in the first approximating bite of 1 N, which declined in the last bites to 0.25 N. A mean force of 0.29 ± 0.16 N in the first Shouldice suture line has also been found using the same device [5].

Our equipment enabled us also to quantify the tensile strength in the inguinal abdominal wall during Shouldice repair. In our view, however, it is of great importance to record the acting tensile forces over the whole distance of the repair instead of measurement at one point, as mentioned above. We could achieve this by the use of a regular wound retractor with modified branches for the fixation of the tissue and for force measurement. Closure of the instrument approximates the lateral edge of the rectus sheath and the basis of the inguinal ligament over the whole distance used during the repair. Thereby Shouldice plasty could be simulated in a very realistic way, and the forces resulting from this manoeuvre would be analysed exactly. One additional aspect is the direction of the force vectors. Their measurement has to be carried out exactly in the acting level and direction. This was guaranteed by the design of our instrument. The branches always pointed at an angle of 90º to the transversal fascia and could record the forces acting on them exactly. Several clinical investigations [21] and animal experimental studies [22] have shown the reliability and reproducibility of the resulting data.

The amount of postoperative pain after inguinal hernia repair and the superior outcome after tension-free hernia repair in comparison to Shouldice plasty has been the subject of many reports [15, 16, 29]. The tension-free principle covers the hernial gap with a prosthetic mesh and neglects the approximation of two distant structures such as the lateral edge of the rectus sheath and the inguinal ligament. This is said to be the underlying reason for the superior outcome in these patients with regard to postoperative pain levels [18]. However, none of these studies analysed the relationships between the amount of elevated tensile strength in the inguinal region resulting from the hernia repair and the postoperative course, particularly the pain level.

We quantified the postoperative pain level by two different and appropriate means – the visual analogous score and the recording of the pain-related ventilatory parameters peak flow and FEV1. If there was any correlation between tensile strength of the abdominal wall and the postoperative pain level, a low level of tensile strength should be associated with moderate levels of postoperative pain, while high tensile strength should be associated with elevated postoperative pain levels. From this hypothesis, it was our objective to determine during the operative procedure whether the patient suffered much pain postoperatively and therefore needed a type of tension-free repair, or whether the expected small amount of pain would make an implantation of a prosthetic mesh unnecessary.

It is of great interest that our investigations did not lead to the expected result. Moreover, we were able to exclude any correlation between the tensile strength of the abdominal wall during Shouldice repair and the postoperative pain level. Patients with high tensile strength after closing the hernial gap showed only moderate postoperative pain, while some patients with low tensile forces induced by the hernia repair suffered from marked postoperative pain. The only detectable statistically significant difference between the groups pointed in the opposite direction. Patients with moderate tensile strength (1.5–3.9 N) showed a higher depression in their postoperative peak flow test (37.7%) than those with a low tensile strength (0–1.4 N; 14.2%), but also than those with high tensile strength (4–10 N; 12.4%). Analysis of the postoperative changes in the FEV1 pointed in the same direction. Furthermore, the postoperative pain level was also not related to the amount of change in distance between the lateral edge of the rectus sheath and the base of the inguinal ligament during Shouldice simulation.

In conclusion, from these results we found no evidence for the hypothesis that high levels of tensile strength in the inguinal region induced by Shouldice repair lead to an elevated level of postoperative pain. The amount of postoperative pain may depend on many different factors. One is the kind of anaesthesia. It is well known that the use of local anaesthesia leads to a positive postoperative course, including the amount of postoperative pain. Even after the effect of the medication ceases, patients operated on under local anaesthesia have fewer pain sensations [20]. Two days after the operation negligible pain levels have been recorded. Therefore we stopped the pain analysis after 48 h in our current study. Exclusively, we used local anaesthesia for all 20 patients.

Another factor leading to less postoperative pain is early mobilization. Patients receiving a Shouldice repair may walk away from the operating table, while the use of peridural or general anaesthesia requires a certain time of bed rest. This mobilization and the stretching of the involved muscles under the protection of local anaesthesia may prevent painful muscular cramping afterwards. Furthermore, there are substantial differences in subjective pain sensations among individuals. Pain analyses in patients undergoing extracorporeal gallstone lithotripsy have shown a range of subjective pain sensation from "no pain" (45% of patients) to "pain worse than 50%" (20%). This pain intensity is inversely correlated with an elevated level of β-endorphin, which shows peak values between 4.5 and 6.6 pmol/l [19]. This variation seems to be responsible for differences in pain perception. Another cause is age: younger patients show higher postoperative pain scores than older patients [6].

All these factors may have an influence on the postoperative pain level, which together may be more pronounced than just the effect associated with different operation principles. This may be the reason why some have failed to find the above-described superior results of tension-free methods concerning postoperative pain levels [2, 7, 25, 26]. Our results do not support the advantages of tension-free repair over the gold standard of Shouldice repair, as other operation-related and independent factors may influence postoperative pain levels and pain perception to a greater degree. Therefore, we continue to use Shouldice repair routinely in primary inguinal hernias.

References

1. Amid PK, Shulman AG, Lichtenstein IL (1996) Open "tension-free" repair of inguinal hernias: the Lichtenstein technique. Eur J Surg 162:447–453
2. Barth RJ, Burchard KW, Tosteson A, Sutton JE Jr, Colacchio TA, Henriques HF, Howard R, Steadman S (1998) Short-term outcome after mesh or Shouldice herniorrhaphy: a randomized, prospective study. Surgery 123:121–126
3. Bendavid R (1997) The Shouldice technique: a canon in hernia repair. Can J Surg 40:199–205
4. Bertier F, Potel G, Leconte P, Touze MD, Baron D (1998) Comparative study of methods of measuring acute pain intensity in an ED. Am J Emerg Med 16:132–136
5. Calcagno D, Wantz GE (1985) Suture tension and the Shouldice repair. Lancet 1:1446
6. Callesen T, Bech K, Nielsen R, Andersen J, Hesselfeldt P, Roikjaer O, Kehlet H (1998) Pain after groin hernia repair. Br J Surg 85:1412–1414
7. Danielsson P, Isacson S, Hansen MV (1999) Randomized study of Lichtenstein compared with Shouldice inguinal hernia repair by surgeons in training. Eur J Surg 165:49–53
8. Friis E, Lindahl F (1996) The tension-free hernioplasty in a randomized trial. Am J Surg 172:315–319
9. Gaston-Johansson F (1996) Measurement of pain: the psychometric properties of the Pain-O-Meter, a simple, inexpensive pain assessment tool that could change health care practices. J Pain Symptom Manage 12:172–181
10. Godfrey PJ, Greenan J, Ranasinghe DD, Shabestary SM, Pollock AV (1981) Ventilatory capacity after three methods of anaesthesia for inguinal hernia repair: a randomized controlled trial. Br J Surg 68:587–589
11. Heise CP, Starling JR (1998) Mesh inguinodynia: a new clinical syndrome after inguinal herniorrhaphy? J Am Coll Surg 187:514–518
12. Huskisson EC (1974) Measurement of pain. Lancet 2(7889):1127–1131
13. Jennings TA, Peterson L, Axiotis CA, Friedländer GE, Cooke RA, Rosai J (1988) Angiosarcoma associated with foreign body material. A report of three cases. Cancer 62:2436–2444
14. Köninger JS, Oster M, Butters M (1998) Inguinal hernia: a comparison of common techniques. Chirurg 69:1340–1344
15. Kozol R, Lange PM, Kosir M, Beleski K, Mason K, Tennenberg S, Kubinec SM, Wilson RF (1997) A prospective, randomized study of open vs. laparoscopic inguinal hernia repair. An assessment of postoperative pain. Arch Surg 132:292–295
16. Kux M (1995) Preperitoneal repair of groin hernias without mesh. In: Schumpelick V, Wantz GE (eds) Inguinal hernia repair. Karger, Basel, pp 149–151
17. Leinhardt DJ, Smart PJ, Howat JM (1988) Jejunal carcinoma associated with non-absorbable suture material. Postgrad Med J 64:716–717
18. Lichtenstein IL (1987) Herniorrhaphy, a personal experience with 6,321 cases. Am J Surg 169:553–559
19. Negri M, Lomanto D, Tonnarini G, Bernardinis GB, d'Alessandro M, Mariani P, Speranza V (1993) Plasma opioid levels during extracorporeal gallstone lithotripsy. Am J Gastroenterol 88:1093–1096
20. Peiper Ch, Töns Ch, Schippers E, Busch F, Schumpelick V (1994) Local versus general anesthesia for Shouldice Repair of the inguinal hernia. World J Surg 18:912–915
21. Peiper Ch, Junge K, Füting A, Conze J, Bassalay P, Schumpelick V (1998) Intraoperative measurement of the suture forces during Shouldice repair of the primary inguinal hernia. Chirurg 69:1077–1081
22. Peiper Ch, Junge K, Bühner A, Schumpelick V (1999) Stress of the inguinal region after Shouldice repair under standardised conditions. Hernia 3[Suppl 2]:66
23. Read RC, McLeod PC (1981) Influence of a relaxing incision on suture tension in Bassini's and McVay's repairs. Arch Surg 116:440–445
24. Rulli F, Percudani M, Muzi M, Tucci G, Sianesi M (1998) From Bassini to tension-free mesh hernia repair. Review of 1409 consecutive cases. G Chir 19:285–289
25. Schmitz R, Treckmann J, Shah S, Schneider K (1997) "Tension-free technique" in open inguinal hernia repair. A prospective, randomized study of postoperative pain perception ("tension-free reconstruction" vs. Shouldice technique). Chirurg 68:259–263
26. Schrenk P, Woisetschlager R, Rieger R, Wayand W (1996) Prospective randomized trial comparing postoperative pain and return to physical activity after transabdominal preperitoneal, total preperitoneal or Shouldice technique for inguinal hernia repair. Br J Surg 83:1563–1566
27. Schumpelick V, Treutner KH, Arlt G (1994) Inguinal hernia repair in adults. Lancet 344:375–379
28. Wantz GE (1981) Suture tension in Shouldice's hernioplasty. Arch Surg 116:1238–1239
29. Zieren J, Zieren HU, Jacobi CA, Wenger FA, Müller JM (1998) Prospective randomized study comparing laparoscopic and open tension-free inguinal hernia repair with Shouldice's operation. Am J Surg 175:330–333