Synthetic mesh in laparoscopic treatment of abdominal hernia was first used in 1993. Since that time this technique has been constantly developed and enabled to reduce in the percentage of recurrences and infections of postoperative wounds. Berger et al. reported 4 recurrences without mesh infection in 150 patients that were operated with this method, whereas Carbajo et al. showed recurrences at the level of 4.4% after a 4-year follow-up. Recent studies by Gillian et al. on 100 patients who underwent laparoscopic surgery of abdominal incisional hernia showed recurrence in only 1 patient, who was also reoperated with laparoscopic method. Laparoscopic repair reduces the risk of intraoperative complications, shorten hospitalization period and give better insight into the operated site, allowing for easier adhesion release and application of a bigger mesh than in open operations. Nevertheless, these techniques require surgeons who are experienced in laparoscopic surgeries. Moreover, in such surgeries seromas are common. It is not surprising then that hernia treatment techniques have been constantly developed to reduce the number of complications, including postoperative pain and to reduce the high costs, which result from the expensive instruments and the material used (1).

The aim of this article is to present the results of studies on treating abdominal and inguinal hernia using non-invasive methods with sutureless meshes that are used in different systems.

Intensity of pain after repair of inguinal hernias with Lichtenstein technique

Using synthetic mesh is a routine surgical procedure in case of both inguinal and abdominal hernias. It allowed to reduce significantly the possibility of recurrence. But the biggest problem while fixing mesh with sutures is the postoperative pain that sometimes can have features of a chronic pain. The European Hernia Society defines pain complex syndrome as presence of at least one of the following symptoms with duration over 1 year after a conducted surgery:
1) the sensation of burning and numbness – the frequency after open surgeries 10 – 23%,
2) discomfort in inguinal region at frequency from 11 to 27%,
3) neuralgia with pain radiating to scrotum skin/labia minora on the operated side and to Scarpa’s triangle (anatomical region surrounded by medial border of a sartorius muscle, anterior border of a thigh long adductor muscle and inguinal ligament) that may last to one year after the operation.

This phenomenon may be observed in 25% of patients who underwent inguinal hernia surgery.

The etiopathogenesis of pain is thought to be non-neuropathic, neuropathic or the combination of both. The first group includes mechanical irritation caused by folded mesh and pulling by the forming scar tissue (2). In some patients, the pain may be caused by the infec-
tion of the spermatic chord induced by the mesh or vein thrombosis of the spermatic chord (3). Neuropathic pain may result from perioperative nerve damage, drawing nerve endings into the scar and adjuvant compression or from suturing the nerves into the mesh structure while placing it in the right location using sutures, clamps, anchors (2). It is related to 3 basic nerves: nervus ilioinguinalis, nervus iliohypogastricus and genital branch of genitofemoral nerve (3). Limiting or completely eliminating mechanical fixing of mesh should decrease the number of such complications. The above reasoning led Campanelli et al. to study the use of fibrin tissue glue to secure meshes in patients with inguinal hernia.

The authors, basing on their own studies and literature, have estimated that the pain would sustain in 25% of patients who were operated on by the Lichtenstein technique in a classical way. The studies done in a group of 113 patients (101 men (89.4%) – the average age 58, 12 women (10.6%) – the average age 55) were to determine whether tissue glue in the amount of 4 ml (1 ml per pubic bone, the remaining 3 ml in a spray for the whole mesh surface) used to fix the mesh instead of sutures will decrease the number of patients suffering from chronic pain after hernioplasty. The control group consisted of 328 adult men who underwent repair of inguinal hernia with the Lichtenstein technique. An eighteen-month follow-up showed no complications in a form of hematoma or seroma or hernias recurrence. The postoperative pain was assessed during a phone conversation within 1 week to 18 months after the surgery using a five-level scale (1 – no pain, 5 – the worst imaginable pain). Among 113 patients, 92 (81.5%) reported complete lack of pain – 82 men (M) and 10 women (W), 18 patients (15.8) reported pain with the intensity of 2/5 – 16 M and 2 W, and 3 M reported pain with the intensity of 3/5 (tab. 1). It is worth mentioning that none of the patients who underwent the treatment reported pain above 3/5. Conducted multicentre studies showed that, that the use of fibrin tissue glue in inguinal hernioplasty is a convenient tool in an open tension-free inguinal hernia repair.

In the 18-month follow-up those authors did not observe any complications that could result from the used technique (2). However, the authors did not report the results of pain intensity in patients in the control group. In multicentre studies described by Kingsnorth et al. it was compared, in a group of 302 patients, self-fixating Parietex™ ProGrip™ mesh (149 patients with or without mechanical fixation – P group) with traditional Lichtenstien technique, where the mesh was fixed with sutures (153 patients – group L). The postoperative pain was assessed on the discharge day (-10% in group P vs +39%? I can only guess what the matter is in group L) and 7 days after the surgery (-13% in group P vs +21% in group L). It is worth mentioning that the pain in patients in group P, where the mesh was fixed with a single suture, was assessed by the patients as more intensified in comparison to the patients from the same group for which the sutures were not used at all (1 month: -20.9% vs -6.15%, 3 months: -24.3% vs -7.7%). Moreover, the percentage of infections was significantly lower in group P than in group L at a 3-month follow-up (2% vs 7.2%). The operative time was significantly statistically shorter in group P (32.4 vs 39.1 min; p<0.001) which does not clinical significance. In both groups the authors did not observe recurrence incidents in 3 months. The use of sutures for mesh fixing resulted in occurrence of stronger incidents in the early postoperative period accounts for the efficacy of Parietex™ ProGrip™ mesh fixed also with the sutureless technique (4).

Kim-Fuchs et al. also found that the cause of chronic pain in patients who underwent surgery by the Lichtenstien technique may be the fact that sutures used to fix the mesh irritate or compress nerves. The studies were done among 264 men, who were divided into

<table>
<thead>
<tr>
<th>Pain intensity (1-5 points)</th>
<th>1 point</th>
<th>2 points</th>
<th>3 points</th>
<th>4 points</th>
<th>5 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Men</td>
<td>82</td>
<td>16</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>0</td>
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</table>
Modern techniques of fixing of meshes in surgical repair of inguinal and abdominal hernias

2 groups: I – 133 patients, in which slowly-absorbable sutures were used (PDS 2.0), II – 131 patients, in which tissue glue (Histoacryl) was used. This study had as long as 5-year follow-up. In final control there were 59% of patients. In group I 10/85 (11.7%) patients suffered from chronic pain in inguinal area, whereas in group II – 3/70 (4.2%). Operative time was shorter in group II (79 min. vs 73 min., p=0.01). The percentage of recurrences was 5.9% (5/85) and 10% (7/70) in groups I and II respectively (tab. 2). The use of both techniques of fixing the mesh resulted in a similar percentage of chronic pain in the inguinal area, and the use of tissue glue allowed for slight decrease in the operative time. This means that sutureless mesh fixation with The use of Histoacryl is an alternative which should be taken into consideration especially in patients prone to pain (5).

In studies conducted by Lionetti et al., apart from the assessment of chronic pain also the return to normal everyday activity after hernioplasty was assessed. 148 patients were divided randomly into two groups: A – used partly absorbable mesh and a cork fixed with 1 ml tissue glue, B – non-absorbable mesh and a cork fixed with polypropylene suture. The studies showed that, apart from smaller number of chronic pain incidents (0% vs 7.8%), patients in which fixing of prostheses with glue was used returned to work and normal everyday life more quickly than patients from group B (6).

Canonico et al. assessed – from the point of view of operating surgeons – the results of hernioplasty where Lichtenstien technique with human fibrin glue (Tissucol ™) was used in 80 patients with one-sided inguinal hernia. The authors assessed the surgery level of difficulty as easy (average 31/100 points), and satisfaction level as high (84/100 points). The average operation time was 36 minutes and all the patients were discharged home after 5 to 6 hours from the surgery. No complications were reported at 12-month follow-up (7).

The studies conducted by Chastan’s among 52 patients (69 inguinal hernias) assessed the pain intensity in operated persons at the discharge moment day and one month after the surgery. He used self-fixating Sofradim mesh. It is made of lightweight polypropylene, and contains in its structure micro PLA hooks from polyactic acid (PLA), which undergo resorption within about a year from the surgery, was used, On the day of discharge (Day 1) 23 patients (44.2%) were taking Paracetamol and the average pain intensity using VAS/10 was 1.1 (± 1.2) on the left side and 1.4 (± 1.4) on the right side. On control done 1 month after 3 patients (5.7%) were taking Paracetamol, the pain intensity in accordance with VAS/10 was 0.3 (± 0.6) on the left side and 0.1 (± 0.4) on the right. They returned to everyday activities on 5.5 day on average (± 3.6) and to work on the 20th day (± 11). There was one incident of skin infection, which healed within 30 days. No recurrences or pain radiating to the core were observed. The author highlights short operative time with the used technique – average 19 min (from skin incision to stitching). The time needed for mesh implantation was below 1 min, which in the author’s opinion may reduce the number of infectious complications connected with short period of mesh exposition to external conditions. According to this author, an equally important aspect of using Sofradim mesh is that the mesh undergoes adherence on the whole surface, which may reduce the risk for moving the hernia sac between the mesh and transversalis fascia, and the fascia protecting ilioinguinal nerve is not penetrated by the fixing hooks (8).

### Table 2

<table>
<thead>
<tr>
<th>Presence of chronic pain</th>
<th>Surgery time</th>
<th>Recurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>11.7%</td>
<td>79 min</td>
</tr>
<tr>
<td>Group II</td>
<td>4.2%</td>
<td>73 min</td>
</tr>
</tbody>
</table>

Advantages of a self-fixating meshes in laparoscopic repair surgeries of inguinal hernias

Studies, where a similar self-fixating mesh was used, were conducted by Kosai et al.; however, they used a product called The Parietene ProGrip™ (TYCO Healthcare) with the size of 15x9 cm which also contains in its structure microhooks with PLA (polyactic acid) on one side. The surgery was conducted with laparoscopic (TAPP – transabdominal preperitoneal repair) technique. 29 patients participated in the research, in which 43 inguinal hernias
were operated on. 3 ports (one 10 mm and two 5 mm) were used in the surgeries. The mesh was implemented by the 10 mm port by grabbing it in the middle on the hook-free side with a tool, and then fixed in the defect site in the peritoneal envelope. The peritoneum was sutured with 3/0 vicryl thread. The follow-up took 6 months. The average surgery time was 47.6 min. 15 patients were discharged on the day of the surgery, 13 on the next day and 1 patient on the third day. The average time of returning to everyday activities was 24.5 days. There was also significant improvement in the pain intensity on the VAS scale. The average pre-operative result was 14, whereas after 6 months it was 0 (p<0.01 Wilcoxon test). No recurrences were observed, only 1 patient developed hematoma. All the patients were happy with the surgery results.

The authors highlight economical aspect of using self-fixating mesh. They have estimated that mesh at a price of £91.65 (US$144.96) is much cheaper than a standard Protack™ device for automatic sewing used in TAPP that costs £228.40 (US$361.25). It allowed for reducing surgery costs by £136.75 (US$216.37) per one case and therefore the authors saved £3965.75 (US$6274.58) in total (9).

Champault et al experimental study confirms positive results of fixating meshes with tissue glue. In the study the mesh integration with tissues was assessed on both macroscopic and histologic level. The researchers used, polypropylene meshes with a low mass (40 mg/m²) which were covered with glue on the one side to promote adhesion. The control group consisted of the same meshes fixed with clamps and not covered with glue. The study was done on pigs implanting meshes in the preperitoneal space using laparoscope. The operation time was significantly shorter when meshes with glue were used in comparison to fixing meshes with clamps [23 min (15-32) vs. 31 min (21-40) p=0.01]. The first hematoma development was observed after 3 minutes on average (2-4). In the control group mesh manipulation time was 8.3 min (5-14) (p = 0.01). During implantation of mesh with tissue glue its adhesive properties and manipulation possibilities during implantation were evaluated. Then, implantation site was assessed on the day after the surgery, 1 week and 1 month after implantation. In 90-100% of cases where meshes with glue were used, the results were good or very good. Good integration with muscle was observed, which was confirmed in histological tests. No mesh shrinking, moving or mobilization from implantation site were observed. In the evaluation 1 month after the surgery the thickness of sclerosis in the self-fixating mesh area was much bigger (p=0.02). In the same study, the authors highlight the possibility of reducing hernia repair costs by shortening operative time and eliminating clamps (10).

Treatment of abdominal hernias in the light of analysis by Cochrane Collaboration

Abdominal hernia in a postoperative scar is a frequent complication after open operations in the abdominal area. The frequency of their occurrence is estimated at 10%. High frequency of occurrences and lack of standardized preparation of this type of hernia leads to multiple studies that aim at proving that one of the available techniques is better than others (11).

In a big analysis by Cochrane Collaboration including 10 clinical trials, the effects of using laparoscopy and classical methods in hernia repair were compared. In the study 880 patients that underwent operations because of primary hernia, incisional hernia or both in the abdominal area were under observation. Laparoscopic access was gained with the use of 3 or 4 trocars. In each case non-absorbable mesh was used, which was fixed by sutures, clamps or both, retaining at least 3-cm margin from the defect’s edge.

With classical methods in most cases sublay technique was used, but in two onlay technique was applied in control group and in 1 case intraperitoneal onlay mesh repair was used. The follow-up ranged from less than 1 year in two clinical trials, from 1 to 2 years in 4 clinical trials to more than 2 years in 5 clinical trials.

Hernia recurrence was the main parameter in these studies. It was reported that there was no statistical difference between both operation techniques (laparoscopic and open) (RR 1.22; 95% CI 0.62 to 2.38) where recurrence is taken into consideration. This may result from short follow-up.

The percentage of observed complications was also evaluated. As a result of various out-
comes, it was not possible to determine the frequency of their occurrence. In one case it was highlighted that although in the group where laparoscopic method was used complications were rarer they were more serious. Theoretically, using laparoscopy is connected with higher risk of endoabdominal complications because it is necessary to release all adhesions from the site where mesh is implanted. These studies did not show the difference in the number of intestinal perforations. Nevertheless, intestinal perforation did not include accidental incision of the very serosa what would increase the frequency of perforation.

Major discrepancy was observed in case of seromas. According to one author the frequency of their occurrence was two times higher more frequently when laparoscopic method was used. Another trial showed that their frequency was higher after open surgeries. In this case also explicit results were not possible to obtain because of significantly varying outcomes. Nevertheless, it was highlighted that seromas and especially their puncture, were accompanied by possible later wound infection. Hematomas occurred at similar frequency in laparoscopic and open surgeries. It was reported that in laparoscopic operations the risk of infection in the wound area is significantly lower than in open operations (RR= 0.26; 95% CI 0.15 to 0.46). Two studies also reported the necessity to remove implemented meshes in patients operated on by the traditional technique: in the first study these included 4 cases out of 23-person group (17%) and in the second one – 3 cases out of 30 (10%). These results are not representative because the number of people in each group was too small. The percentage of necessary reoperations, on the basis of result analysis from 4 different clinical trials, was not statistically different for control and examined group but in patients operated on by the traditional technique there was a higher risk of mesh removal.

The lower risk of infection in the wound area while using laparoscopic method was proved in other operations, such as laparoscopic cholecystectomy or appendectomy. It is so, because the total length of skin incision is shorter in case of laparoscopy and this prevents bacteria from entering the wound. Taking into consideration direct implantation of mesh in the incision area in the open method, wound infection may become a really serious clinical problem that may lead to removal of the infected mesh.

On the basis of four trials assessing postoperative pain intensity, no differences between laparoscopic and open methods were found what differentiates these results from the results observed in other laparoscopic operations such as cholecystectomy or fundoplication. It is worth noting that in both laparoscopic and open method of hernia repair, mesh was fixed in a similar way – by sutures, clamps or both. Only in one case chronic pain was more intense after laparoscopic surgery (4/85 vs 8/85). However, in the same case 2 patients, who underwent laparoscopic hernia repair, had clamps fixing the mesh removed.

The quality of life measured in the early postoperative period was also comparable in both groups. The analysis of 6 clinical trials including hospitalization time showed that laparoscopic technique is better but only when standard postoperative hospitalization time after open method surgery is relatively longer. Hospitalization in intensive care departments was not mentioned. One of the trials indicates lack of differences in returning to everyday life activities, whereas in another trial laparoscopic method proved to have bit better results. These data could not have been verified with the use of meta analysis because the author provided only median values (23 vs 28.5 day). Only in one case the patient’s satisfaction with the appearance of the scar after the operation was assessed but no statistically significant differences were found.

The cost analysis of laparoscopic operations in one of the trials indicates much higher costs of laparoscopic procedures (1900 euro) than in open operations (300 euro), which results from the fact that more expensive meshes have to be used. Even though this analysis is only theoretical, a different economical analysis found in other studies shows that laparoscopic method is 9 times more expensive than traditional method. None of the studies conducted so far have shown whether shorter hospitalization connected with laparoscopic method may cover the difference in the incurred costs.

For patients with hernia the most important thing is to remove it and prevent recurring. The studies available are characterized by short
observation period and therefore it cannot be explicitly stated that laparoscopic method is more effective. Further research is necessary with at least 3-year follow-up to show superiority of one of these methods also on the basis of chronic pain occurrence, which is quite frequent after hernia repair surgeries (12).

Modern intraperitoneal meshes

An interesting study was conducted in Wielkopolskie Centrum Onkologii (Greater Poland Cancer Centre) where bilateral Parietex composite mesh made of multi-fiber polyester with absorbable layer preventing adhesions was used in patients with abdominal hernia. The mesh is implanted intraperitoneally. 4 patients, who earlier underwent operations because of oncological problems with adjuvant chemotherapy, underwent repair surgeries. What is more, those patients suffered from internal diseases (4 – circulatory failure, 3 – arterial hypertension, 2 – Insulin Dependent Diabetes Mellitus). Hernias were located in the midline and hernia rings were the size from 5x7 cm to 18x21 cm. Meshes were fixed with prolene sutures placed in 4 corners and additionally with absorbable clamps of Protack type. Authors did not observe significant postoperative complications. Only in the patient with the biggest hernia sarcoma occurred (in the 2nd week after operation) that did not require aspiration. At 13-month follow-up no hernia recurrence and only in one case there was the so called burst. This patient was later reoperated but as a result of cancer recurrence. Intraoperatively the absence of hernia sac was stated and the burst resulted from mesh elasticity. What is more, single soft adhesions to the mesh were found (13). Because trials were conducted on small number of patients it can be treated only as a report that needs to be verified in larger population.

Akkary et al. conducted studies on a group of 12 obese patients (the average BMI was 44.2 kg/m²) who underwent laparoscopic abdominal hernioplasty, where similarly to Greater Poland Cancer Centre Oarietex composite mesh was used (Covidien, Norwalk, CT) placed intraperitoneally. The mesh was fixed to the fascia only by clamps without application of trans-facial sutures leaving free cuff of at least 4 cm. The average hernia size in this group was 5.3 cm². The average operative time was 42 minutes. The aim of this study was the assessment of effectiveness of the used technique on the basis of recurrence. At 7-month follow-up no recurrences were reported. Moreover, 11 patients were discharged home on the day of operation after 2-6 hour observation in postoperative room. One patient required long analgesic therapy and 8 patients (67%) developed palpable seromas, which resorbed spontaneously. The researchers showed that the technique without TFS (trans-fascial sutures) may be applied also with obese patients, providing that hernia size is limited. Nevertheless, longer observation is required that will allow for verification of the obtained results and trials conducted on bigger number of patients (11).

Multicentre research conducted in the USA on 111 patients, in whom mesh position was retromuscular-preperitoneal, showed that sublay technique is safe and effective in treating abdominal hernia of small and medium size in particular.

Small percentage of recurrences (3%), average postoperative pain on VAS level of 4 (1-8) encourage to quit using sutures to fix mesh (14, 15).

Canziani et al. from University of Insubria, Varese (VA) between 2002 – 2007 subjected 40 patients with incisional hernia to repair consisting of positioning retromuscular-preperitoneal polypropylene mesh fixed with 2ml of human fibre glue. Postoperative pain developed in 2 (5%) patients and chronic pain in one (2.5%). Other complications included: wound infection (4 patients, 10%) and hematoma (3 patients 7.5%) (16).

Casuistic research done by Hermann et al. on using coated mesh in 2 patients shows positive effects. The operations were done on patients with big incisional hernias with accompanying symptoms qualifying for surgery (in one patient cholecystectomy was conducted and in the other partial resection of small intestine). In one case polyester mesh coated with compounds of polyethylene glycol with glycerol and oxidized collagen, and in the latter polypropylene single-fibre mesh coated with silicon was used. Even though the operations were conducted in infected operating field, authors did not report any complications in both patients (17).
Experiments done by Hermann et al. on good tolerance of coated meshes seem to be proved by those conducted by Lukasiewicz et al. where it was assessed whether collagen patch implanted in abdominal wall defects in rats induces adhesion formation. Liquid collagen was obtained during rat tail ligament extraction in acetic acid. As a result of further processes two thin collagen sheets were obtained that were used later. After 3 months authors made macroscopic evaluation of abdominal cavity and microscopic evaluation of preparations of collagen membrane. There were no adhesions in all instances between collagen patch and intestines. In one rat there was adhesion between the web and polypropylene suture that was used to fix the patch. Microscopically in all instances internal surface of the membrane was wholly covered with mesothelium, and in its area there were new blood vessels. Authors highlight however that because of small number of rats (10 rats) in the group it is necessary to confirm obtained results on a larger number of animals (18).

CONCLUSIONS

Commonly used tension-free techniques of treating inguinal and abdominal hernia are effective. With careful implantation, following all aseptic and antiseptic rules they ensure small percentage of recurrences and infectious complications. Laparoscopic techniques used in hernia repair made it less invasive reducing the number of complications including pain. This problem seemed to be very difficult to eliminate because of the very operative technique that requires sutures to fix mesh. Numerous modifications of commonly used techniques presented in this article give chance to eliminate postoperative chronic pain as a complication of hernia repair surgeries. Moreover, other advantages were also reported including shorter operative time, shorter time of returning to normal activities and professional life. The lower percentage of infectious complications reported in laparoscopic techniques also influences a decrease the costs of treating a patient with hernia.

Techniques of treating inguinal hernia with the use of sutureless mesh have to be popularized among surgeons. The one-time cost of purchasing modern self-fixating or intraperitoneal meshes and the way of settling accounts with the payer are still the most important problem.

Classical meshes used in abdominal hernioplasty may cause infections, which lead to adhesions, enterostenosis, lacerations and fistulas. This is the main reason why the use of such meshes is limited in laparoscopic method. Introducing new materials used to coat meshes from the side of the contact with viscera reduced the risk of reactions with abdominal cavity organs and limited the formation of massive adhesions. There are lots of intraperitoneal meshes made of polypropylene (PP), polyester (PES) or polytetrafluoroethylene coated with silicon or collagen (e.g. Parietex composite, Supramesh, Tutomesh, Dulamesh, Ultrapro, Tmesh, Proceed, Prolene) available now on the market, which vary according to incorporation method, elasticity, adhesion formation surface (13, 15).

It is significant progress in popularizing laparoscopic method of abdominal hernia repair. Biological materials, such as SIS (small intestine submucose) are also used. This is a cell-less structure consisting of collagen. Unlike polymers it is able to stimulate tissue regeneration rather than scarring. Bioplasts also include Permacol (made of porcine skin collagen) and AlloDerm (made of human skin) whose use significantly reduces the number of infectious complications but is connected with frequent recurrence (to 20%) (15).

In the light of presented publications it seems reasonable to implement in abdominal hernia operations meshes that would not cause infections in abdominal cavity or allergic reactions. Meshes that would be chemically neutral and non-cancerogenic, resistant to infections, quickly integrating with the environment, and whose fixing would be easy and without the necessity of using sutures which requires a lot of proficiency from a surgeon. Further development in hernia repair should be based on simplifying treatment procedures with possibility to use intraperitoneal self-fixating meshes coated with anti-adhesive layer characterized with properties mentioned above on the side of contact with viscera.
REFERENCES


Received: 8.05.2014 r.
Adress correspondence: 50-326 Wrocław, ul. Poniatowskiego 2
e-mail: zrybak@poczta.onet.pl