Coll. Antropol. **35** (2011) 3: 911–914
Original scientific paper

Formation of Adhesions at Surgical Meshes in a Rat Experimental Model

Zdravko Perko[1], Zenon Pogorelić[2], Nikica Družijanić[1], Kanito Bilan[1] and Katarina Vilović[3]

[1] University of Split, Split University Hospital Center, Department of Surgery, Split, Croatia
[2] University of Split, Split University Hospital Center, Department of Pediatric Surgery, Split, Croatia
[3] University of Split, Split University Hospital Center, Department of Pathology, Split, Croatia

A B S T R A C T

Abdominal wall hernias are surgical problem that are easily solved with laparoscopic surgery. The determining factor for the success of the operation is the right choice and use of surgical mesh as the support material. The most common complication of surgical mesh placement is the formation of adhesions. Aim of this paper is to determine whether there is a statistic difference in formation of adhesions between different surgical meshes in lab environment. Wistar rats were used as the experimental model. After the anaesthesia a 1x1 cm defect of the abdominal wall was made, but the skin was left intact. The mesh was placed directly on the internal organs. The experiment considered four different mesh types. After set time periods of one, two or four weeks the animals were sacrificed and the amount of formed adhesions were evaluated based on the modified Diamond scale. Immediately after the first week we found a statistically significant difference in the adhesion occurrence rate between compared materials. The smallest amount of adhesions was caused by polypropylen + polydoksanon mesh, and the most by polypropilen mesh. Polypropylen + polyglactin mesh showed significant reduction of adhesion formation between the tested weeks. We can conclude that polypropylen + polydoxanon meshes are superior for ventral hernia operation, because those defects are in close contact with the internal organs and it is very important to have the smallest amount of adhesions.

Key words: *abdominal adhesions, adhesion prevention, surgical mesh, rats, abdominal wall hernia*

Introduction

Abdominal hernia represents an abnormal bulging or protrusion of tissue or an organ thru defects on the abdominal wall and supportive structures. Hernia incidence is 2–3%, and the ratio between men and women is 4:1[1]. Hernias are one of the surgical problems that are easily solved with laparoscopic surgery. The determining factor for success of the operation in both, laparoscopic and open surgery is right choice and use of surgical mesh as support material. Inguinal hernia reconstruction requires surgical meshes that will induce fibroblast proliferation and connective tissue growth.

Almost any defect in the abdominal wall can result in herniation, especially if the risk factors are present like infection, obesity, pregnancy, aging, previous surgical procedures etc. It was realized that durable ventral hernia management, because of large number of recidives, require synthetic material. For this hernia type a non-resorptive mesh is required, that will stimulate connective tissue growth with smallest amount of adhesions on abdominal organs. Satisfactory results were obtained using mesh in ventral hernias care with recurrent rate of less than 3%[1].

There is no ideal mesh for every assignment, but the right mesh choice can make adequate mesh ideal for individual operation. Mesh usage can also result with postoperative complications. Formation of adhesions is one of potential complications, which can lead to serious morbidity and mortality, because of obstruction, perforation or fistula formation[2,3]. Adhesions formation can be reduced by maintain the parietal peritoneum intact, which is in ventral hernia operations very hard to achieve[4,5].

Animal experiments have natural limitations and these results can not be directly replicated in human population. Aim of this study is to compare in vivo function and tissue reaction on embedded meshes in standardized experimental conditions.

Received for publication January 20, 2009

Materials and Methods

We used 200-g Wistar rats as the experimental model. Animals were randomised in 4 experimental groups, each experimental group consisted of 30 animals and each group was assigned for one type of surgical mesh. Inside each group animals were divided in 3 subsets according to planned sacrificed time.

The animals were etherized and anesthetized with ketamin hydrochloride (Ketanest 10%, Parke-Davis, Berlin, Germany), in the dosage of 10 mg *per* animal. After the anaesthesia, the animals underwent a procedure in which a 1×1 cm complete defect of the abdominal wall was made, but the skin was left intact. The mesh was placed directly on the internal organs.

Four different meshes were used in the experiment. We used surgical meshes polypropylen (Prolene), polypropylen + polyglactin I and II (Vypro I and II) and polypropylen + polydoxanon (Proceed); (Ethicon Endo-Surgery, Cincinnati, USA). Meshes were cut to 2,5×2,5 cm pieces and fixed with polyglactin suture 6/0 (Vicryl, Ethicon Endo-Surgery, Cincinnati, USA).

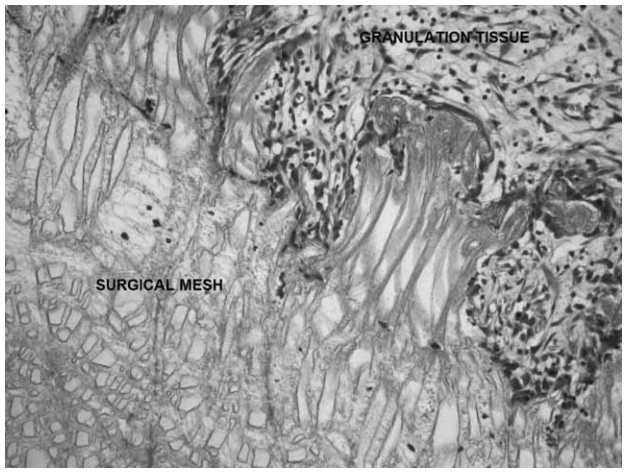

Fig. 2. Granulation tissue formation around surgical mesh. Granulation tissue showing numerous new small blood vessels, edema, fibroblasts, and occasional inflammatory cells (HEx20).

TABLE 1
EVALUATION OF ADHESIONS AMOUNT BY MODIFIED DIAMOND'S CLASSIFICATION

Score of adhesions amount	Percent of mesh area in adhesions
0	No adhesions
1	≤25
2	≤50
3	≤75
4	>75

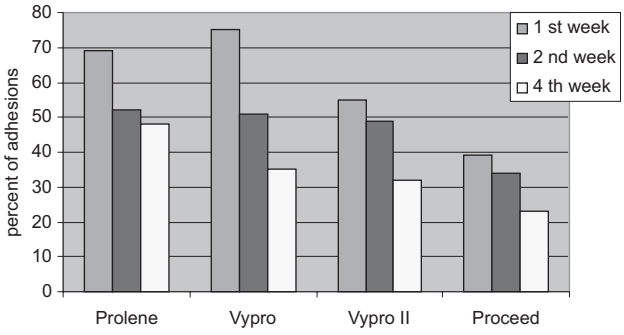

Fig. 1. Percent of adhesions at each mesh by weeks.

After the set time period of one, two or four weeks, the animals were sacrificed and the amount of formed adhesions was evaluated macroscopically based on the modified Diamond scale from 0 to 4 considering percentage of mesh struck with adhesions (Table 1, Figure 1).

To perform this experiment, we obtained the approval of the Ethical Committee of Split University Hospital Center.

Statistics

Kruskal–Wallis and χ^2-tests were used in statistical analysis, employing SPSS for Windows, version 11,0 (Statistical Package for Social Sciences, Copyright (c) SPSS Inc., 1989–2003). The level of significance was set at $p<0.05$.

Results

Highest number of adhesions was found using Prolene mesh (medium score 3.21; SD±0.27). The smallest

TABLE 2
MEAN SCORE BY WEEKS FOR ALL MESHES USING DIAMOND' S CLASSIFICATION

Mean score by weeks for all meshes				
	After 1st week	After 2nd week	After 4th week	Total score±SD
Prolene	3.50	3.20	2.95	3.21±0.27
Vypro I	3.65	2.90	2.40	2.98±0.63
Vypro II	3.00	3.20	2.40	2.86±0.41
Proceed	1.60	1.60	1.25	1.48±0.20

amount of adhesions was caused by Proceed mesh (medium score 1.48; SD±0.20) (Table 2).

Immediately after the first week we found a statistically significant difference in the adhesion occurrence rate between tested materials (p=0.026). That means that differences between adhesions formatting using different meshes can be seen the first week after operation (Figure 1).

When we tested particular materials inside each experimental animal group, we found statistically significant difference inside observed weeks only for Vypro I mesh (p=0.022). In that mesh type there was significantly less adhesions in second and fourth weeks, although in the first week that mesh had the biggest amount of adhesions.

When we tested results between different materials, there is statistically significant difference (p=0.002). Proceed mesh had the smallest amount of adhesions which is statistically significant, and Prolene mesh had the biggest amount of adhesions which is statistically significant too (Table 2, Figure 2).

Discussion

Intra-abdominal adhesions are found in up to 93% of patients who have undergone intra-abdominal surgery[6]. Normally, most adhesions are asymptomatic, but will, however, cause problems in about 5% of the patients. These postsurgical, adhesion-related problems include small bowel obstruction, female infertility, pelvic pain and abdominal pain. The formation of adhesions also causes secondary problems like prolongation and endangering future intra-abdominal operations. Many types of peritoneal injury have been described that lead to adhesion formation. Mechanical trauma, foreign bodies, bacterial infection, termal injury, chemical injury, irradiation, allergic reactions and ischemic injury can lead to injury and subsequent adhesion formation[7–11].

The most important factor to reduce adhesions is the introduction of minimal surgical trauma and the absence of powdered gloves[12].

In hernia treatment particular interest exists in ventral hernias treatment. Umbilical, epigastric and postoperative incision hernias belongs to that group. It was realized that durable ventral hernias care with low recidive risk requires synthetic material. The aim was that proliferated connective tissue and embedded mesh function like žcicatricle mesh', not like cicatricle board. This type of hernias requires mesh with prolong thickness, non resorptive, which will stimulate connective tissue growth, and on the other side not form adhesions with abdominal organs. Using mesh, satisfactory results are reached in ventral hernias management with recidive rate of less than 3%[1].

There are many different types of meshes, such as: mono or multifilament, resorptive, semi resorptive or non resorptive; braided or weaved; combined with different materials or a slim layer which prevents adhesion formation.

After surgery there is no tissue which will separate synthetic mesh from direct contact with abdominal organs, so bowel and omentum adhesions can occur[1].

Adhesions arise on the first postoperative day, the rate increases till seventh postoperative day but after that there are no more adhesions arising. Regions covered with mesothelial cells did not form adhesions[1]. The fibrinolytic activity in the peritoneum normally degrades fibrin and peritoneal regeneration can take place. The injured area is invaded by inflammatory cells, initially neutrophils but after 24 h mostly macrophages. Chemotactic messengers released by platelets, prostaglandins and leukotrienes are hence produced and recruit leukocytes to the site of injury[12]. This attracts mesothelial cells and at 24 h the reperitonealization starts from multiple foci, cell islands, and is finished after 5–7 days[12,13]. This time range is regardless of the size of the peritoneal wound. The process continues to healing and/or fibrosis and the subsequent deposition of extracellular matrix. After the first week and up to a month, the matrix is remodeled and replaced by persistent proteins, such as collagen, and revascularization occurs. The fibrinous adhesions are lysed if the fibrinolytic activity is adequate, otherwise connective tissue forms and adhesions are developed[14]. Several studies point at the imbalance between fibrin formation and fibrinolysis in the early phase of peritoneal repair as the main determinant in adhesion formation, as demonstrated by studies where decreased fibrinolytic activity increased adhesions[12].

Formation of adhesions is proved to be connected with reduced ability of fibrin in peritoneal cavity. Fibrinolytic ability is decreasing by the operation time. Formation of adhesions between the meshes and surrounding internal organs is completely eliminated in presence of parietal peritoneum.

Postoperative formation of adhesions can be burdened with serious postoperative morbidity and mortality[3]. Serious complications like perforation and fistula formation are rare but, local changes like seroma and lower abdominal wall agility can be notified in almost half of the patients.

The three main principle pathways to decrease adhesions of today are: decreasing the trauma to the peritoneum; medical interventions in the fibrin formation/degradation balance, and barriers preventing organs from bridging over to other structures in the abdomen and thereby forming adhesions[12].

Four meshes with different characteristics were considered. The intent was to compare the formation of adhesions on different types of meshes in lab conditions. According to our results there are differences in formation of adhesions using different mesh types, and our results confirms manufactor guides. Prolene i Vypro meshes are intended for inguinal hernia operations and could not be used for ventral hernias operations, because these meshes produces highest number of adhesions.

Our results also show that in hernia operations these meshes have to be covered with peritoneum. On the other side, Proceed meshes could be used for ventral hernia operations, though, considering our results, these meshes produce the smallest number of adhesions. In future, manufactors have to tend to produce better meshes, which would not produce any adhesions.

We can conclude that most adhesions were formed by Prolene mesh and the least by Proceed mesh. According to those results Proceed mesh is recommended for ventral hernia repair. Prolene, Vypro I and Vypro II meshes should be covered with peritoneum in order to reduce adhesion formatting and post operating complications.

REFERENCES

1. BAPTISTA M, BONSACK M, J am Coll Surg, 3 (2000) 190. — 2. IVAARSON M, FALK P, HOLMDAHL L, British Journal of Surgery, 88 (2001) 151. — 3. KLOSTERHALFEN B, KILNGE U, SCHUMPELICK V, Biomaterials, 19 (1998) 2235. — 4. BELLON J, CONTRERAS L, BIJAN J, 19 (1998) 669. — 5. BOLAND GM, WEIGEL RJ, J Surg Res, 132 (2006) 3. — 6. PARKER M, WILSON M, MENZIES D, SUNDERLAND G, THOMPSON J, CLARK D, KNIGHT A, CROWE A, Colorectal Dis, 6 (2004) 505. — 7. BINDA MM, MOLINAS CR, HANSEN P, KONINCKX PR, Fertil Steril, 86 (2006) 166. — 8. PERKO Z, BILAN K, POGORELIĆ Z, DRUŽIJANIĆ N, SRŠEN D, KRALJEVIĆ D, JURIČIĆ J, KRNIĆ D, Coll Anthropol, 32 (2008) 307. — 9. PERKO Z, POGORELIĆ Z, BILAN K, TOMIĆ S, VILOVIĆ K, KRNIĆ D, DRUŽIJANIĆ N, KRALJEVIĆ D, JURIČIĆ J, Surg Endosc, 20 (2006) 322. — 10. POGORELIĆ Z, PERKO Z, DRUŽIJANIĆ N, TOMIĆ S, MRKLIĆ I, Eur Surg Res, 43 (2009) 235. — 11. PERKO Z, DRUŽIJANIĆ N, BILAN K, POGORELIĆ Z, KRALJEVIĆ D, JURIČIĆ J, SRŠEN D, KRNIĆ D, Coll Anthropol, 32 (2008) 187. — 12. TINGSTEDT B, ISAKSSON K, ANDERSSON E, ANDERSSON R, Eur Surg Res, 39 (2007) 259. — 13. RENDU F, BROHARD-BOHN B, Platelets, 12 (2001) 261. — 14. GOVRY DA, HERRICK SE, SHAH M, FERGUSON MW, Am J Pathol, 167 (2005) 1005.

Z. Pogorelić

University of Split, Split University Hospital Center, Department of Pediatric Surgery, Spinčićeva 1, 21000 Split, Croatia
e-mail: zenon@vip.hr

STVARANJE PRIRASLICA NA KIRURŠKIM MREŽICAMA KOD ŠTAKORA

SAŽETAK

Kile su jedan od kirurških problema koji se danas uspješno rješava laparoskopskim operacijama. Za uspjeh operacije presudan je pravilan odabir i uporaba sintetskih mrežica kao rasterećujućeg stredstva. Razna su svojstva i namjene kirurških mrežica i pravilan izbor je ključan za smanjenje poslijeoperacijskih komplikacija. Jedna od najčešćih komplikacija je stvaranje priraslica. Naš cilj je bio ispitati postoji li statistički značajna razlika u stvaranju priraslica između različitih kirurških mrežica u laboratorijskim uvjetima. Korišteni su albino štakori soja Wistar. Nakon anestezije, životinjama je napravljen potpuni defekt trbušne stijenke veličine 1x1 cm, s time da je koža ostavljena intaktna. Mrežica je postavljena izravno na unutrašnje organe. Istraživanje je učinjeno na četiri različite vrste mrežica. Nakon određenog vremenskog perioda, od jedan, dva ili četiri tjedna, životinje su žrtvovane a količina stvorenih priraslica je procjenjena prema modificiranoj Diamondovoj skali. Već nakon prvog tjedna dobivena je statistički značajna razlika u stvaranju priraslica između uspoređivanih materijala. Najmanje priraslica je izazvala mrežica sastava polipropilen i polidoksanon, a najviše polipropilenska. Mrežice sastava polipropilen i poliglaktin su pokazale značajno smanjenje stvaranja priraslica između uspoređivanih tjedana. Prema gore navedenom može se zaključiti da je preporučljivo rabiti mrežicu sastava polipropilen i polidoksanon za operacije ventralnih kila, jer su to baš oni defekti kod kojih sintetska mrežica dolazi u bliski kontakt s unutrašnjim organima i poželjno je što manje stvaranje priraslica.