Digestive Surgery

Dig Surg 1998;15:148–152

M. Schäfer
L. Krähenbühl
M.W. Büchler

Department of Visceral and Transplantation Surgery, University of Bern, Inselspital, Bern, Switzerland

Comparison of Adhesion Formation in Open and Laparoscopic Surgery

Key Words
Adhesion formation
Pathogenesis
Laparotomy
Laparoscopy
Socio-economic factors

Abstract
The development of postoperative adhesions remains an almost inevitable consequence of visceral and gynecological surgery, appearing in 50–95% of all patients. The pathogenetical sequence from peritoneal injury, with locally released cytokines and inflammatory reaction, to permanent fibrous adhesions has been elucidated in recent years. Early and late bowel obstruction, chronic abdominal pain, and infertility are the main clinical complications, and they also increase the socio-economic costs. Laparoscopic surgical procedures with their minimal access to the abdominal cavity are associated with fewer postoperative adhesions compared to open surgery, although adhesion formations cannot be entirely prevented.

Introduction

Adhesion formation is an almost unavoidable consequence of abdominal surgery. Although not all patients with intra-abdominal adhesions develop symptoms, the clinical implications, such as early and late bowel obstruction, infertility, and chronic abdominal pain, remain a common problem in general surgical and gynecological practice [1]. In addition, adhesion formation is associated with increased socio-economic costs.

The pathogenetical mechanisms of adhesion formation are now at least partly understood. Multiple factors are responsible for inducing and causing the development of adhesions, e.g. extent of the surgical trauma, local inflammatory reaction with cytokine release, and fibrinolytic activity of the peritoneum. Since its introduction, laparoscopic surgery with its minimal access to the abdominal cavity is thought to have reduced adhesion formation and its related complications.

Incidence, Clinical Symptoms and Diagnosis

The development of intra-abdominal adhesions is the consequence of visceral or gynecological surgery, pelvic inflammatory disease, appendicitis, and endometriosis. After conventional abdominal surgery, adhesion formation is very common, and appearing in 50–95% of all patients [2–4]. In a prospective trial performed by Menzies and Ellis [2], the reported rate of adhesions was 93% in 210 patients who had undergone at least one previous laparotomy. In contrast to this high rate of postoperative adhesions, only 10.4% of 115 patients without previous abdominal surgery were found to have intra-abdominal adhesions. Weibel and Maijno [3] performed a study on 752 cadavers in 1973 and found an adhesion rate of 67% in patients with previous abdominal surgery and 28% in patients without. Acute appendicitis remains the major single cause of postoperative adhesion formation and bowel obstruction since Thompson [5] reported that more

KARGER
Fax + 41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

0253–4886/98/0152–0148$15.00/0

This article is also accessible online at:
http://BioMedNet.com/karger

L. Krähenbühl, MD
Department of Visceral and Transplantation Surgery
University of Bern, Inselspital
CH–3010 Bern (Switzerland)
Tel. +41 31 632 21 11, Fax +41 31 632 97 23, E-Mail lukas.kraehenbuehl@insel.ch

than a third of all patients with bowel obstruction had previously undergone appendectomy [6]. However, Semm [7] clearly demonstrated that 84% of women who had undergone diagnostic laparoscopy after previous open abdominal surgery had adhesion formation, whereas only 40% had after previous laparoscopy. Although abdominal surgery is strongly associated with adhesion formation, only a few patients will suffer from adhesion-related clinical symptoms [8, 9]. Thus, the vast majority of patients with adhesions remain asymptomatic, which makes their clinical and epidemiological assessment difficult. Different radiological examinations, e.g. CT scan, ultrasonography and barium swallow, have been proposed to preoperatively assess the diagnosis and localization of adhesions. However, all of them, especially transabdominal ultrasonography, have a poor overall sensitivity (50–60%) and the number of false-positive and false-negative predictions make it unreliable for routine use [10]. The patient's complaint of recurrent abdominal pain with a localized and reproducible punctum maximum is still the most valuable clinical hint of symptomatic adhesions [11]. Chronic or recurrent abdominal pain with irregular bowel motions, and a history of previous abdominal surgery may be suspicious of symptomatic adhesions, causing entrapment and tension in the peritoneum. However, the exact relation of adhesions to abdominal pain is still controversial. Partial or complete mechanical bowel obstruction, if it occurs as an early or late complication of abdominal surgery is highly suspicious of intra-abdominal adhesions [12, 13]. Postoperative adhesions and fibrous scars due to endometriosis and acute appendicitis are common causes of secondary infertility in young females of child-bearing age [14]. However, the clinical relevance of these adhesions may often only be assessed by a diagnostic laparoscopy [7].

Socio-Economic Factors

Rapidly increasing costs of the national health care systems in Western countries have led to studies evaluating the costs of various common diseases and clinical problems. A recently published study from Sweden revealed direct costs of USD 5,695/patient for the nonoperative and operative treatment of adhesion-related bowel obstruction [15]. Moreover, it was estimated that obstructive bowel disease may cause 2,330 hospital admissions annually, which is associated with direct costs of about USD 13 million. In the United States there were 54,100 hospital admissions in 1988 due to adhesion-related diseases, the costs were estimated about USD 1,179 million [16]. The extent of indirect costs, e.g. outpatient medical treatment, expenditure for infertility treatment and absence from work, is likely to be much higher, but cannot often be evaluated due to the limited registration in the different national health care systems. Therefore, not only exact knowledge of the pathogenesis and prevention, but also reliable diagnostic tools and therapeutic strategies are essential in order to reduce costs.

Pathogenesis of Adhesion Formation

Adhesion formation is a well-defined pathophysiological sequence of events, which has been demonstrated in many experimental series [17–20]. Initially, there is always a localized peritoneal injury, caused by different stimuli, e.g. surgical operation, bacterial infection, ischemia, irradiation or allergic tissue reaction against inserted foreign bodies. As a humoral answer for the injured tissue, various locally produced cytokines, acting individually and synergistically, are released, and thus starting, an inflammatory tissue reaction [21]. Inflammatory cytokines, predominantly interleukin-1 (IL-1), interleukin-6 (IL-6) and tumor necrosis factor-α (TNF-α), attract and activate macrophages to synthesize vascular permeability factor [21, 22]. Supported by simultaneously released kinins and histamine, vascular permeability factor increases the vascular permeability, leading to inflammatory exudation with fibrin deposition on the peritoneal surface. Additionally, IL-1 and IL-6 stimulate mesothelial and inflammatory cells to produce and release plasminogen activator inhibitor-1 and 2 in order to suppress plasminogen activation [23]. The mesothelial cells of different various body surfaces normally possess a potent fibrinolytic activity to prevent fibrous adhesion formation between tissue surfaces [24, 25]. The main fibrinolytic system is represented by the plasminogen-activating cascade [23]. Therefore, rapidly increased concentrations of plasminogen activator inhibitor-1 and 2 temporary decrease the fibrinolytic activity of the injured peritoneum allowing fibrinous depositions to transform into fibrin matrix. These organized fibrinous junctions already represent adhesions, although they are mostly absorbed within a few days of surgery. The next step in permanent adhesion formation is made by invading fibroblasts and endothelial cells forming capillaries, thus, finally replacing the fibrinous strands with collageneous tissue [20, 26]. The duration of the suppression of peritoneal fibrinolytic activity crucially determines the further course and extent of per-

Table 1. Advantages of laparoscopic procedures for preventing adhesion formation

Decreased peritoneal injury
Minimized tissue handling
Decreased immune and stress response
Prevention of air pollution in the abdominal cavity
Reduced drying of the peritoneal surface
Intact peritoneal phospholipid layer
Reduced impairment of gut motility

Table 2. Adhesion formation after laparoscopic and open Nissen fundoplication in the rat

	FL (n = 15)	FO (n = 15)
Animals without adhesions, %	33*	0
Site of adhesions		
Parietal adhesions, %	62*	15
Visceral adhesions, %	38*	85
Tenacity		
Type I + II, %	57*	18
Type III, %	43*	82

FL = Laparoscopic fundoplication; FO = open fundoplication.
* $p < 0.05$.

Table 3. Differences of adhesion formation between laparoscopic and open fundoplication in the rat

	FL (n = 15)	FO (n = 15)
Number of adhesions	1.31 ± 0.29*	2.27 ± 0.37
Site of adhesions	2.46 ± 0.47*	4.35 ± 0.26
Thickness of adhesions	1.31 ± 0.25*	2.56 ± 0.17
Tenacity	1.88 ± 0.28*	2.76 ± 0.14
Vascularization of adhesions	0.65 ± 0.12	0.76 ± 0.11
Total adhesion score	7.15 ± 1.01*	11.44 ± 0.44

FL = Laparoscopic fundoplication; FO = open fundoplication.
* $p < 0.05$.

manent adhesion formation. Indeed, there is good evidence that rapid recovery of the plasminogen-activating system, within 3–4 days, supports adhesion-free tissue healing and reduces permanent fibrous adhesion formation [25, 27].

Less Adhesion Formation after Laparoscopy compared to Laparotomy

The introduction of laparoscopic surgery into the armament of general surgery and gynecology was associated with the expectation of markedly reduced adhesion formation. Therefore, a large number of experimental and clinical studies have been performed in order to evaluate the possible advantages of laparoscopy, which are shown in table 1 [7, 28–35]. Most of the clinical studies retrospectively determined the number, the anatomical localization and the tenacity of the adhesions, which had been developed after previous open or laparoscopic surgery. Experimental studies using different animal models tried furthermore to examine the microscopic and humoral changes of adhesion formation during laparoscopic operations. Summarizing the results, laparoscopy indeed reduces postoperative adhesion formation experimentally and in humans. First of all, the minimal access to the abdominal cavity reduces the magnitude of peritoneal trauma, which is the chief trigger of adhesion formation. Avoiding incisions through well-vascularized anatomical structures, e.g. muscle layers, and minimizing their extent are two confirmed basic principles for reducing postoperative adhesions [36]. Minimal access also prevents the abdominal cavity from exposure to air. Therefore, drying of the peritoneum with loss of the phospholipid layer as well as contamination of the peritoneal surface with different endotoxins can be avoided [37, 38]. Gut motility is less impaired by laparoscopy, therefore earlier recovery of peristalsis may tear fibrinous adhesions and reduce permanent adhesion formation [39].

In our own experimental study, we compared adhesion formation after laparoscopic and open Nissen fundoplication in rats [40]. Postoperative determination of adhesion formation was performed after 3 weeks using the score system of Moreno et al. [41]. Animals with open fundoplication developed significantly more adhesions, which were in addition also thicker and of a higher tenacity grade in comparison to laparoscopic fundoplication (table 2, 3). Moreover, open surgery mainly caused adhesions between the intra-abdominal organs themselves ('visceral adhesions'), whereas after laparoscopic operations there were predominantly parietal adhesions between the abdominal wall and the intestine. The exact clinical impact of these observations remains unclear. Nevertheless, it can be assumed that bowel obstruction is more likely to be due to visceral adhesion, whereas parietal adhesions represent a potential danger for iatrogenic bowel perforation while reoperating on these patients.

The data concerning the immune and stress response induced by laparoscopy are still controversial. Whereas some studies demonstrated a decreased immune response, others revealed equal or even higher plasma concentrations of catecholamines, and higher amounts of white blood cells and cytokines [22, 42–46]. Nevertheless, at least some pathophysiological facts have been accepted. Whereas the systemic immune response after open and laparoscopic surgery may remain unchanged, the local cytokine release is decreased after laparoscopic surgery. Some authors demonstrated a direct correlation between the cytokine levels, mainly TNF-α and IL-6, and the extent of adhesion formation [47, 48]. Inflammatory cytokines are therefore mainly produced and released in the peritoneal cavity, and then partly absorbed into the systemic blood circulation [40, 42].

Conclusions

The formation of adhesions remains a common complication of general and gynecological surgery, and is responsible for a high clinical workload as well as increasing costs. Chronic abdominal pain, early and late bowel obstruction and infertility are the main clinical features related to adhesions. The pathogenetical cascade from peritoneal injury to permanent fibrous adhesion formation has partly been elucidated. This better understanding has essentially been influenced by the successfully introduction of minimally invasive surgical procedures in recent years. However, meticulous surgical technique with careful tissue handling, hemostasis, and liberal irrigation remain the major clinical precautions for preventing adhesion formation after surgical operations. Laparoscopic operations are associated with less adhesion formation, although it cannot completely be avoided. Medical prophylaxis and intra-abdominally placed chemical barriers have not yet achieved clinical importance.

References

1 Scott-Coombes DM, Vipond MN, Thompson JN: General surgeons' attitudes to the treatment and prevention of abdominal adhesions. Ann R Coll Surg Engl 1993;75:123–128.
2 Menzies D, Ellis H: Intestinal obstruction from adhesions: How big is the problem? Ann R Coll Surg Engl 1990;72:60–63.
3 Weibel M, Maijno G: Peritoneal adhesions and their relation to abdominal surgery. Am J Surg 1973;126:345–353.
4 Ellis H: The cause and prevention of intestinal adhesions. Br J Surg 1982;69:241–243.
5 Thompson J: The pathogenesis and prevention of adhesion formation. Dig Surg 1998, in press.
6 DeWild RL: Goodbye to late bowel obstruction after appendectomy. Lancet 1991;338:1012.
7 Semm K. Pelviscopic surgery: A key for conserving fertility. Ann NY Acad Sci 1991;626: 372–398.
8 Reich H: Laparoscopic surgery for adhesiolysis; in Arregui ME, Fitzgibbons RJ Jr, Kathkouda N, McKernan JB, Reich H (eds): Principles of Laperoscopic Surgery. Basic and Advanced Techniques. New York, 1995, pp 283–298.
9 Schwemmle K: Ursachen von Verwachsungen im Abdomen. Langenbecks Arch Chir 1990; (suppl II):1017–1021.
10 Uberoi R, D'Costa H, Brown C, Dubbins P. Visceral slide for intraperitoneal adhesions? A prospective study in 48 patients with surgical correlation. J Clin Ultrasound 1995;25:363–366.
11 Freys SM, Fuchs KH, Heimbucher J, Thiede A: Laparoscopic adhesiolysis. Surg Endosc 1994;8:1202–1207.
12 Mucha P: Small intestinal obstruction. Surg Clin North Am 1987;67:597–620.
13 Steward RM, Page CP, Brender J, Schwesinger W, Eisenhut D: The incidence and risk of early postoperative bowel obstruction. Am J Surg 1987;154:643–647.
14 Lehmann-Willenbrock E, Mecke H, Riedel HH: Sequelae of appendectomy, with special reference to intra-abdominal adhesions, chronic abdominal pain, and infertility. Gynecol Obstet Invest 1990;29:241–245.
15 Ivarsson ML, Homdahl L, Franzen G, Risberg B: Costs of bowel obstruction from adhesions. Eur J Surg 1997;163:679–684.
16 Ray NF, Larsen JW, Stillman RJ: Economic impact of hospitalizations for lower abdominal adhesiolysis in the United States in 1988. Surg Gynecol Obstet 1993;176:271–276.
17 Milligan DW, Raftery AT: Observation on the pathogenesis of peritoneal adhesions: A light and electron microscopyical study. Br J Surg 1974;61:274–280.
18 Johnson FR, Whiting HW: Repair of parietal peritoneum. Br J Surg 1962;49:653–660.
19 Renvall SY: Peritoneal metabolism and intra-abdominal adhesion formation. Acta Chir Scand Suppl 1980;508:4–48.
20 Elkins TE, Stovall TG, Warren J, Ling F, Meyer NL: A histological evaluation of peritoneal injury and repair: Implications for adhesion formation. Obstet Gynecol 1987;70:225–228.
21 Reber P, Andrén-Sandberg A, Schmied B, Büchler MW: Cytokines in surgical trauma: Cholecystectomy as an example. Dig Surg 1998, in press.
22 Badia JM, Whawell SA, Scott-Coombes DM, Abel PD, Williamson RCN, Thompson JN: Peritoneal and systemic cytokine response to laparotomy. Br J Surg 1996;83:347–348.
23 Whawell SA, Wang Y, Fleming KA, Thompson EM, Thompson JN: Localization of plasminogen activator inhibitor-1 production in inflamed appendix by in situ mRNA hybridization. J Pathol 1993;169:67–71.
24 Raftery AT: Regeneration of peritoneum: A fibrinolytic study. J Anat 1979;129:659–664.
25 Vipond MN, Whawell SA, Thompson JN, Dudley HAF: Peritoneal fibrinolytic activity and intra-abdominal adhesions. Lancet 1990; 335:1120–1122.
26 Thompson JN, Whawell SA: Pathogenesis and prevention of adhesion formation. Br J Surg 1995;82:3–5.
27 Vipond MN, Whawell SA, Thompson JN, Dudley HAF: Effect of experimental peritonitis and ischemia on peritoneal fibrinolytic activity. Eur J Surg 1994;160:471–477.
28 Tulandi T: How can we avoid adhesions after laparoscopic surgery? Curr Opin Obstet Gynecol 1997;9:239–243.
29 Diamond MP, Daniell JF, Johns DA: Postoperative adhesion development after operative laparoscopy: Evaluation at early second-look procedures. Fertil Steril 1991;55:700–704.

30 Gurgan T, Urman B, Yarali H: Adhesion formation and reformation after laparoscopic removal of ovarian endometriosis. J Am Assoc Gynecol Laparosc 1996;3:389–392.
31 Levrant SG, Bieber EJ, Barnes RB: Anterior abdominal wall adhesions after laparotomy or laparoscopy. J Am Assoc Gynecol Laparosc 1997;4:353–356.
32 Bulletti C, Polli V, Negrini V, Giacomucci E, Flamigni C: Adhesion formation after laparoscopic myomectomy. J Am Assoc Gynecol Laparosc 1996;3:533–536.
33 Moore RG, Partin AW, Adams JB, Kavoussi LR: Adhesion formation after transperitoneal nephrectomy: laparoscopic vs. open approach. J Endourol 1995;9:277–280.
34 Tittel A, Schippers E, Treutner KH, Anuroff M, Poliveda M, Ottinger A, Schumpelick V: Laparoskopie versus Laparotomie. Eine tierexperimentelle Studie zum Vergleich der Adhäsionsbildung im Hund. Langenbecks Arch Chir 1994;379:95–98.
35 Lundorff P, Thorburn J, Hahlin M, Linblom B, Kallfelt B: Adhesion formation after laparoscopic surgery in tubal pregnancy: a randomized trial versus laparotomy. Fertil Steril 1991; 55:911–915.
36 Moreno A, Aguayo JL, Zambudio G, Ramirez P, Canteras M, Parilla P: Influence of abdominal incision on the formation of postoperative peritoneal adhesions: An experimental study in rats. Eur J Surg 1996;162:181–185.
37 Snoj M, Ar'Rajab A, Ahren B, Bengmark S: Effect of phosphatidylcholine on postoperative adhesions after small bowel anastomosis in the rat. Br J Surg 1992;79:427–429.
38 Watson RW, Redmond HP, McCarthy J, Burke PE, Bouchier-Hayes D: Exposure of the peritoneal cavity to air regulates early inflammatory response to surgery in a murine model. Br J Surg 1995;82:1060–1065.
39 Menzies D, Ellis H: The role of plasminogen activator in adhesion prevention. Surg Gynecol Obstet 1991;172:362–366.
40 Krähenbühl L, Schäfer M, Kuzinkovas V, Renzulli P, Baer HU, Büchler MW: An experimental study of adhesion formation in open and laparoscopic fundoplication. Br J Surg 1998, in press.
41 Moreno EA, Aguayo AJL, Zambudio CA, Parilla PP: Adhesion response to different forms of treating a peritoneal lesion: An experimental study in rats. Dig Surg 1995;12:334–337.
42 Sakamoto K, Arakawa H, Mita S, Ishiko T, Ikei S, Egami H, Hisano S, Ogawa M: Elevation of circulating interleukin 6 after surgery: Factors influencing the serum level. Cytokine 1994;6: 181–186.
43 McMahon AJ, O'Dwyer PJ, Cruikshank AM: Comparison of metabolic response to laparoscopic and minilaparotomy cholecystectomy. Br J Surg 1993;80:1255–1258.
44 Bessler M, Whelan RL, Halverson A, Treat MR, Nowygrod R: Is immune function better preserved after laparoscopic versus open colon resection? Surg Endosc 1994;8:881–883.
45 Nguyen N, Shurin MR, Shatz S, Tran Q, Ravid J, Edwards J, Schauer PR: The effect of open and laparoscopic surgery on cellular immunity (abstract). Surg Endosc 1997;11:208.
46 Redmond HP, Watson RWG, Houghton T, Condron C, Watson RGK, Bouchier-Hayes D: Immune function in patients undergoing open versus laparoscopic cholecystectomy. Surg Laparosc Endosc 1996;6:136–139.
47 Kaidi AA, Gurchumelidze T, Nazzal M, Figert P, Vanterpool C, Silva Y: Tumor necrosis factor-α: A marker for peritoneal adhesion formation. J Surg Res 1995;58:516–518.
48 Buyalos RP, Funari VA, Azziz R, Watson JM, Martinez-Maza O: Elevated interleukin-6 levels in peritoneal fluid of patients with pelvic pathology. Fertil Steril 1992;58:302–306.