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EDITORIAL

Way forward: Geriatric frailty assessment as risk predictor in gastric cancer surgery

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Abstract

In gastric cancer patients chronological and biological age might vary greatly between patients. Age as well as American Society of Anaesthesiologists-physical status classifications are very non-specific and do not adequately predict adverse outcome. Improvements have been made such as the introduction of Charlson Comorbidity Index. Geriatric frailty is probably a better measure for patients resistance to stressors and physiological reserves. An increasing amount of evidence shows that geriatric frailty is a better predictor for adverse outcome after surgery, including gastric cancer surgery. Geriatric frailty can be assessed in a number of ways. Questionnaires such as the Groningen Frailty Indicator provide an ease and low cost method for gauging the presence of frailty in gastric cancer patients. This can then be used to provide a better preoperative risk assessment in these patients and improve decision making.

Key words: Gastric cancer; Surgery; Geriatric frailty

Core tip: Geriatric frailty assessment is an important way forward in order to provide a better preoperative risk assessment in gastric cancer surgical patients.

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FRAILTY ASSESSMENT AS RISK PREDICTOR

Gastric cancer constitutes a major health problem and in Western countries is predominantly a disease of the elderly with a mean age of 70 years in Western populations[1]. The ageing problem in gastric cancer is not reserved for Western countries. The proportion people over 65 years old in South Korea was 9.9% in 2007, and the proportion of ageing patients is also expected to increase[2]. Elderly patients are at an increased risk for increased complications and mortality

likely due to higher incidence comorbidities[3,4].

The American Society of Anaesthesiologists (ASA) - Physical status has been introduced in the former century and gained widespread acceptance as a scoring system for determining a patient's physical status. It has long been used to assess risks from surgery. But surgical risk assessment is complex and ASA classification is only a component of overall assessment. A major problem with ASA classification is the degree of interobserver variability, *i.e.*, different scores are ascribed to the same patient by different assessors[5]. Moreover, it is also limited as a predictive measure for adverse postoperative events; it performed moderately for prediction of postoperative mortality in a recent meta-analysis[6]. Also, it performed better in populations with lower rather than higher mortality rates[6].

The Charlson Comibidity Index (CCI) is another method for classifying comorbid conditions that determine risk of mortality[7]. This method has a much more clearly defined scoring system than the ASA classification. A study in octo- and nonogenarians who underwent surgery for gastric cancer showed that higher morbidity and mortality rates were associated with higher CCI (CCI $\geqslant$ 5)[8]. In contrast, a German study, which included 139 patients, did not find this association between CCI and adverse postoperative events. Age was an independent predictor for post-operative course[9]. So age and comorbidities are not universally found to be predictors for adverse outcome.

The fact that age is not sufficient to exclude patients from treatment is fairly widely accepted[10-12].

It is almost redundant to say that a patient's chronological age does not necessarily correspond with their biological age. Biological age is mainly determined by frailty, a state of vulnerability to stressors in older individuals, which leads to an increased risk of developing adverse health outcomes[13]. Frailty, as a predictor for adverse outcome after surgery, has gained attention in recent years[14,15]. Frailty, in this case increased scores > 7 on Edmonton frail scale, have been shown to predict increased complications after non-cardiac surgery (OR = 5.1, 95%CI: 1.55-16.25)[16]. In a larger study included patients undergoing various types of elective surgery frailty was predictive for increased postoperative complications and length-of-stay[17].

Geriatric frailty assessment is a very useful tool for preoperative risk assessment in gastric cancer patients, because gastric cancer is a disease predominantly in the elderly in Western countries and in an ageing population worldwide.

A thorough assessment of frailty can be performed with a comprehensive geriatric assessment (CGA). This employs the use of multiple questionnaires and physical tests and is usually conducted by trained professionals in an outpatient setting. In a CGA, all areas of geriatric frailty are assessed, *e.g.,* cognitive functions, mobility, Activities of Daily Living functioning, mood and nutrition. This is performed by clinical history taking as well as use of multiple questionnaires and tests (*e.g.*, timed get up and to test). Performing is a time and resource consuming effort. Therefore, questionnaires have been developed to assess or screen for presence of frailty in elderly individuals. Questionnaires offer a low-cost, low-effort, low-resource consuming way to gauge levels of frailty in patients. Examples of short questionnaires that have been used in this way in surgical populations include Hopkins Frailty score, Edmonton Frail Scale and Groningen Frailty Indicator (GFI)[14,16,18]. In gastric cancer surgery GFI $\geqslant$ 3 has been shown to be associated with increased in-hospital mortality, increased serious complications and increased length of stay[18]. In this study GFI was independently associated with in-hospital mortality.

Improved risk assessment which includes geriatric frailty assessment can be used to provide a better assessment of operative risks. This can aid the physician to better inform individual patients of their risks and improve shared decision making and informed consent. Geriatric frailty assessment does not aim to exclude patients from treatments rather improve decision making.

In conclusion age and physical status (*i.e.,* ASA classification) do not provide adequate risk assessments especially in elderly patients with gastric cancer. Frailty can provide better estimates of perioperative risks. Evidence seems to suggest that frailty questionnaires provide clinically applicable solutions for frailty assessment.

REFERENCES

1 **Dikken JL**, van Sandick JW, Allum WH, Johansson J, Jensen LS, Putter H, Coupland VH, Wouters MW, Lemmens VE, van de Velde CJ, van der Geest LG, Larsson HJ, Cats A, Verheij M. Differences in outcomes of oesophageal and gastric cancer surgery across Europe. *Br J Surg* 2013; **100**: 83-94 [PMID: 23180474 DOI: 10.1002/bjs.8966]

2 **Seo SH**, Hur H, An CW, Yi X, Kim JY, Han SU, Cho YK. Operative risk factors in gastric cancer surgery for elderly patients. *J Gastric Cancer* 2011; **11**: 116-121 [PMID: 22076212 DOI: 10.5230/jgc.2011.11.2.116]

3 **Takeshita H**, Ichikawa D, Komatsu S, Kubota T, Okamoto K, Shiozaki A, Fujiwara H, Otsuji E. Surgical outcomes of gastrectomy for elderly patients with gastric cancer. *World J Surg* 2013; **37**: 2891-2898 [PMID: 24081528 DOI: 10.1007/s00268-013-2210-7]

4 **Fujiwara Y**, Tsujie M, Hara J, Kato H, Kitani K, Isono S, Takeyama H, Yukawa M, Inoue M, Kanaizumi H. Comparison of gastric cancer surgery between patients aged >80 years and <79 years: complications and multivariate analysis of prognostic factors. *Hepatogastroenterology* 2014; **61**: 1785-1793 [PMID: 25513165]

5 **Fitz-Henry J**. The ASA classification and peri-operative risk. *Ann R Coll Surg Engl* 2011; **93**: 185-187 [PMID: 21477427 DOI: 10.1308/147870811X565070]

6 **Koo CY**, Hyder JA, Wanderer JP, Eikermann M, Ramachandran SK. A meta-analysis of the predictive accuracy of postoperative mortality using the American Society of Anesthesiologists' physical status classification system. *World J Surg* 2015; **39**: 88-103 [PMID: 25234196 DOI: 10.1007/s00268-014-2783-9]

7 **Charlson ME**, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; **40**: 373-383 [PMID: 3558716]

8 **Hsu JT**, Liu MS, Wang F, Chang CJ, Hwang TL, Jan YY, Yeh TS.

Standard radical gastrectomy in octogenarians and nonagenarians with gastric cancer: are short-term surgical results and long-term survival substantial? *J Gastrointest Surg* 2012; **16**: 728-737 [PMID: 22350724 DOI: 10.1007/s11605-012-1835-4]

9 **Lübke T**, Mönig SP, Schneider PM, Hölscher AH, Bollschweiler E. [Does Charlson-comorbidity index correlate with short-term outcome in patients with gastric cancer?]. *Zentralbl Chir* 2003; **128**: 970-976 [PMID: 14669119 DOI: 10.1055/s-2003-44805]

10 **Saif MW**, Makrilia N, Zalonis A, Merikas M, Syrigos K. Gastric cancer in the elderly: an overview. *Eur J Surg Oncol* 2010; **36**: 709-717 [PMID: 20542657 DOI: 10.1016/j.ejso.2010.05.023]

11 **Bi YM**, Chen XZ, Jing CK, Zhou RB, Gao YF, Yang LB, Chen XL, Yang K, Zhang B, Chen ZX, Chen JP, Zhou ZG, Hu JK. Safety and survival benefit of surgical management for elderly gastric cancer patients. *Hepatogastroenterology* 2014; **61**: 1801-1805 [PMID: 25436382]

12 **Leo S**, Accettura C, Gnoni A, Licchetta A, Giampaglia M, Mauro A, Saracino V, Carr BI. Systemic treatment of gastrointestinal cancer in elderly patients. *J Gastrointest Cancer* 2013; **44**: 22-32 [PMID: 23150086 DOI: 10.1007/s12029-012-9447-5]

13 **Fried LP**, Hadley EC, Walston JD, Newman AB, Guralnik JM, Studenski S, Harris TB, Ershler WB, Ferrucci L. From bedside to bench: research agenda for frailty. *Sci Aging Knowledge Environ* 2005; **2005**: pe24 [PMID: 16079413 DOI: 10.1126/sageke.2005.31.pe24]

14 **Robinson TN**, Eiseman B, Wallace JI, Church SD, McFann KK, Pfister SM, Sharp TJ, Moss M. Redefining geriatric preoperative assessment using frailty, disability and co-morbidity. *Ann Surg* 2009; **250**: 449-455 [PMID: 19730176 DOI: 10.1097/SLA.0b013e3181b45598]

15 **Oresanya LB**, Lyons WL, Finlayson E. Preoperative assessment of the older patient: a narrative review. *JAMA* 2014; **311**: 2110-2120 [PMID: 24867014 DOI: 10.1001/jama.2014.4573]

16 **Dasgupta M**, Rolfson DB, Stolee P, Borrie MJ, Speechley M. Frailty is associated with postoperative complications in older adults with medical problems. *Arch Gerontol Geriatr* 2009; **48**: 78-83 [PMID: 18068828 DOI: 10.1016/j.archger.2007.10.007]

17 **Makary MA**, Segev DL, Pronovost PJ, Syin D, Bandeen-Roche K, Patel P, Takenaga R, Devgan L, Holzmueller CG, Tian J, Fried LP. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg* 2010; **210**: 901-908 [PMID: 20510798 DOI: 10.1016/j.jamcollsurg.2010.01.028]

18 **Tegels JJ**, de Maat MF, Hulsewé KW, Hoofwijk AG, Stoot JH. Value of geriatric frailty and nutritional status assessment in predicting postoperative mortality in gastric cancer surgery. *J Gastrointest Surg* 2014; **18**: 439-445; discussion 445-446 [PMID: 24420730 DOI: 10.1007/s11605-013-2443-7]

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EDITORIAL

Mesh implants: An overview of crucial mesh parameters

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Abstract

Hernia repair is one of the most frequently performed surgical interventions that use mesh implants. This article evaluates crucial mesh parameters to facilitate selection of the most appropriate mesh implant, considering raw materials, mesh composition, structure parameters and mechanical parameters. A literature review was performed using the PubMed database. The most important mesh parameters in the selection of a mesh implant are the raw material, structural parameters and mechanical parameters, which should match the physiological conditions. The structural parameters, especially the porosity, are the most important predictors of the biocompatibility performance of synthetic meshes. Meshes with large pores exhibit less inflammatory infiltrate, connective tissue and scar bridging, which allows increased soft tissue ingrowth. The raw material and combination of raw materials of the used mesh, including potential coatings and textile design, strongly impact the inflammatory reaction to the mesh. Synthetic meshes made from innovative polymers combined with surface coating have been demonstrated to exhibit advantageous behavior in specialized fields. Monofilament, large-pore synthetic meshes exhibit advantages. The value of mesh classification based on mesh weight seems to be overestimated. Mechanical properties of meshes, such as anisotropy/isotropy, elasticity and tensile strength, are crucial parameters for predicting mesh performance after implantation.

Key words: Hernia repair; Hernia mesh; Incontinence mesh implant; Synthetic mesh; Mesh properties; Textile structure; Structure parameters; Mechanical parameters; Mesh weight; Synthetic raw materials

Core tip: Hernia repair is one of the most frequently performed surgical interventions that use mesh implants. This article evaluates crucial mesh parameters to facilitate selection of the most appropriate mesh implant based

on raw material, mesh composition, and structural and mechanical parameters. The structural parameters of the mesh, especially the porosity, are the most important predictors of the biocompatibility performance of synthetic meshes. Monofilament large-pore meshes exhibit less inflammatory infiltrate, connective tissue and scar bridging, which allows increased soft tissue ingrowth. The value of mesh classification based on the mesh weight seems to be overestimated. Other properties, such as the isotropy, elasticity and tensile strength, are crucial parameters for predicting the performance of meshes after implantation.

Zhu LM, Schuster P, Klinge U. Mesh implants: An overview of crucial mesh parameters. *World J Gastrointest Surg* 2015; 7(10): 226-236 Available from: URL: http://www.wjgnet.com/1948-9366/full/v7/i10/226.htm DOI: http://dx.doi.org/10.4240/wjgs.v7.i10.226

INTRODUCTION

Synthetic mesh implants are frequently used in many surgical interventions, especially in hernia repair. Mesh implants are composed of polypropylene (PP), polyethylene terephthalate (PET), expanded polytetrafluoroethylene (ePTFE), polyvinylidenefluoride (PVDF), and absorbable materials, such as polylactide (PLA), polyglycolic acid (PGA), polycaprolactone (PCL) and polydioxanone (PDO). Potential mesh-related complications include chronic infections, chronic pain and mesh rupture[1-3]. The reasons for chronic pain and the impact of mesh fixation in this context are controversial[4,5]. Chronic infections are favored by concomitant inflammatory and fibrotic reactions to the foreign body, hindering the local clearance from bacterial which leads to a chronic inflammatory wound with marked scarring, loss of compliance, mesh contraction, migration, physiochemical changes, seroma, infection, and in some cases, eventual mesh removal to resolve the problem[6]. A basic understanding of the physicochemical properties of meshes is essential for rational selection of the most appropriate device. This article evaluates the following crucial mesh parameters to facilitate selection of the most appropriate mesh implant: raw material, mesh composition, and structural and mechanical parameters (Figure 1).

The impact of mesh implants on clinical results is the current subject of much litigation in the field of stress urinary incontinence and pelvic prolapse, and some manufacturers were sued because of allegedly defective implants. However, many other factors besides mesh parameters must be considered in evaluations of the overall outcome of an intervention, including the patient's constitution, the selection of a proper operation technique and the operation performance, which are essential for the success or failure of a therapy.

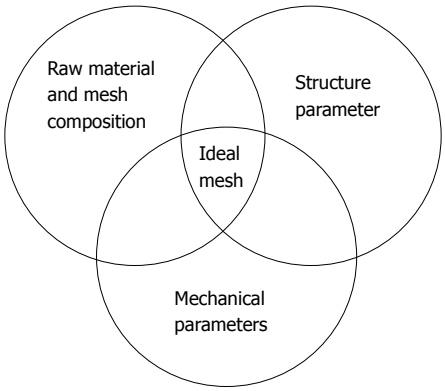

Figure 1 Crucial mesh parameters for selection of an ideal mesh.

BIOCHEMICAL FUNDAMENTALS

Implantation of a mesh triggers a foreign-body reaction, which plays a crucial role in the incorporation of the mesh into the host tissue. Incorporation of mesh into tissues is a complicated biochemical healing process. Implantation initiates an acute inflammatory cellular response that is initiated by protein absorption at the surface and attracts local inflammatory cells, such as macrophages, that converge to foreign body giant cells and eventually create a chronic wound around the mesh fibers. New blood vessels and collagen form around the mesh[7]. A relatively high level of macrophage invasion is detectable 20 min after mesh implantation, and these levels increase slightly and then decrease within 24 mo[8]. More than 80% of the cells in the mesh infiltrate positively express CD68, CD8, CD45R0 and vimentin, which indicates a mixture of cells of various origins and confirms the existence of multiple transition forms that are involved in the inflammatory response[9]. Complement and mast cell activation may also be involved in the mediation of local tissue responses to synthetic hernia meshes[10,11]. Cell migration is followed by collagen deposition, with an increase in the type Ⅰ to type Ⅲ collagen ratio over time[12]. The majority of tissue ingrowth and strength may be completed 2 wk after mesh implantation, but the final remodeling process is a very significant challenge[13]. Mesh-induced foreign body responses must be balanced to result in normal wound healing. Swift and adequate tissue ingrowth into the mesh results in superior biocompatibility and likely improved clinical performance. Intense or prolonged inflammation, bad infiltration, and immature collagen deposition result in scar plate formation, which can be accompanied by increased stiffness of the abdominal wall, shrinkage or deformation of the biomaterial, recurrence, adhesion, fistula or erosion of nearby tissue[14].

TEXTILE FUNDAMENTALS

Textile structures consist of mono- or multifilament fibers. Figure 2 shows the schematic appearance of

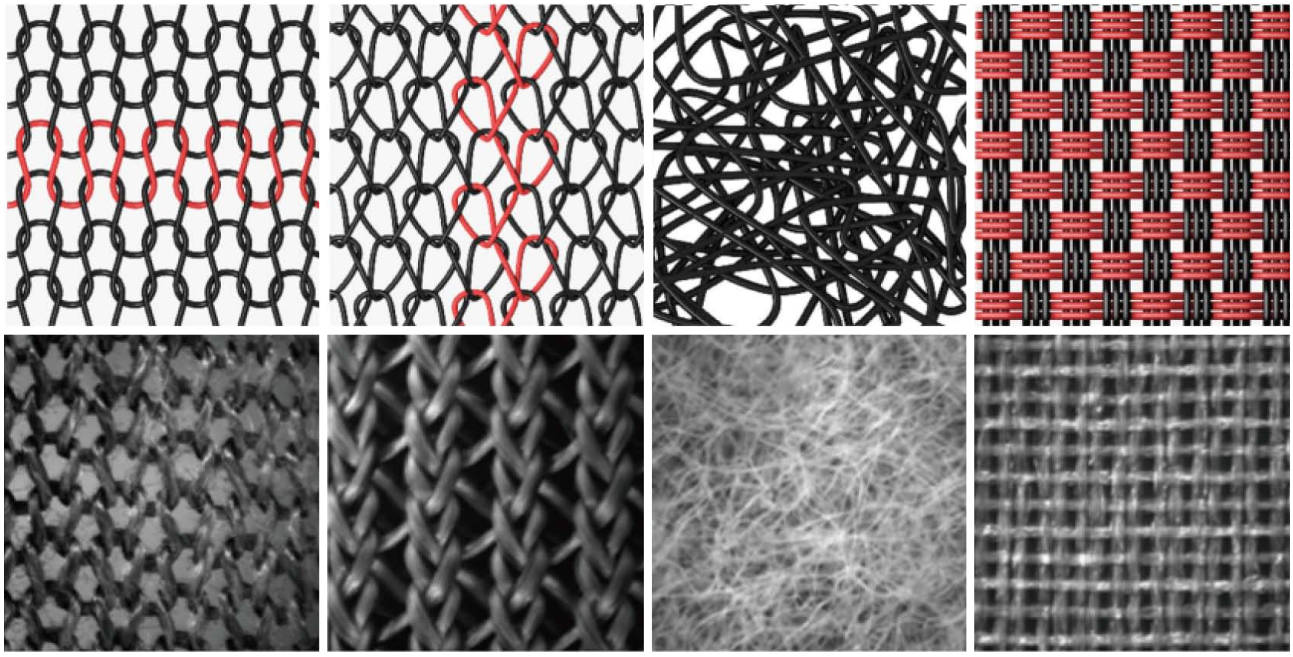

Figure 2 Textile structures from left to right: Knitted structure, warp-knitted structure, nonwoven structure, and woven structure.

Table 1 Definitions of the knit, warp-knit, nonwoven and woven textile structures

Textile structure	Definition
Knitted fabric	Knitted fabric consists of a number of consecutive rows of loops, called stitches. Knitted structures are manufactures from single yarn systems. Thus, knitted structures can be ribbed off. Trimming of knitted structures often leads to a complete falling apart
Warp-knitted fabric	Warp-knitted fabric consists of a number of consecutive courses of loops, called stitches. Warp-knitted structures are manufactures from multi yarn systems whereby the number of separate strands of yarn equals the number of stitches in a row. In contrast to knitted structures warp-knitted structures can be trimmed and sewed
Nonwoven fabric	Nonwoven fabric consists of non orientated or to a certain degree orientated staple or endless fibers. After the nonwoven formation the structure needs to be bonded which either is realised by mechanical, thermal or chemical bonding
Woven fabric	Woven structures consist of two distinct sets of yarns or threads which are interlaced at right angles to form a fabric

Table 2 Essential properties of the knit, warp-knit, nonwoven and woven textile structures

Textile structure	Porosity (macropores)	Elasticity	Mechanical behaviour	Trim-ability
Knitted fabric	++	++	Anisotropic	--
Warp-knitted fabric	++	++	Isotropic, anisotropic	++
Nonwoven fabric	-	-	Isotropic	++
Woven fabric	-	--	Isotropic	++

knitted, warp-knitted, nonwoven and woven structures. Table 1 provides definitions of these different textile structures.

Table 2 presents the general essential properties of these textile structures. These properties are adjustable in a wide range through the selection of production technology and through the specific settings of the production process parameters. Most textile mesh implants are warp-knitted because of the ability of these implants to provide large pores and elasticity under load. Warp-knitted meshes also do not lose material or structural strength at margins when trimmed to the size of the surgical need. Nonwoven meshes are used as mesh implants in exceptional cases.

RAW MATERIAL AND MESH COMPOSITION

Raw material

The polymer and fiber surface affect the inflammatory response within the granuloma. Most synthetic meshes use one of following raw materials: nonabsorbable materials, such as PP, PET, PVDF and ePTFE, or absorbable materials, such as PLA, PGA, PCL, PDO

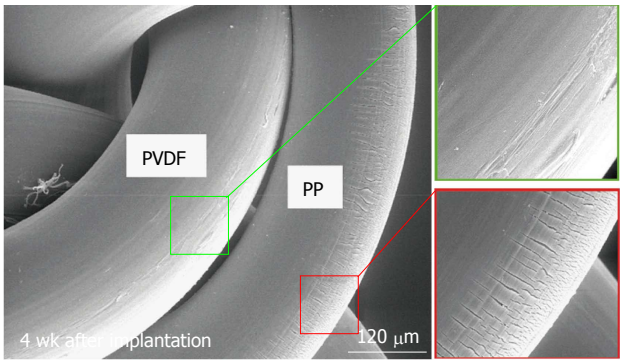

Figure 3 Comparison of the *in vivo* stability of the surface of polypropylene and polyvinylidenefluoride 4 wk after implantation[18]. PP: Polypropylene; PVDF: Polyvinylidenefluoride.

and PHB. These materials may also be used in combination with each other or a range of additional materials, such as titanium and hyaluronate. The foreign body reaction is fairly uniform regardless of the type of mesh implanted, but the different raw materials affect the extent of the reaction. PP meshes result in an intensified inflammatory reaction with deposition of more collagen fibers and significantly higher collagen type Ⅰ/Ⅲ ratios within the resulting scar neotissue compared with ePTFE meshes[15]. PET meshes induce the greatest foreign body reaction and longest-lasting chronic inflammatory response, which may be enhanced by the construction of PET fibers as a multifilament. Marked fibrosis and encapsulation surround ePTFE films[16]. PTFE is a more reactogenic material than PP, and it primarily stimulates the local production of pro-inflammatory cytokines. Therefore, the local anti-inflammatory effect of PP is less pronounced in comparison, but the inflammation persists for a longer time[17]. PVDF meshes produce a significantly reduced foreign body granuloma size compared with PP. PP is less stable than PVDF *in vivo*. Clear cracks in the surface of PP filaments have been detected 4 wk after implantation (Figure 3)[18]. These findings suggest that the raw material strongly influences the inflammatory and fibrotic responses.

Mesh composition

The primary aspects of mesh compositions are the use of different raw materials with or without surface coating in various textile designs.

Coatings may influence the degree of the inflammatory response. Nonabsorbable and absorbable materials are used for coatings. Absorbable materials are preferred if the coating provides a drug-eluting function. However, the degradation products may also influence the inflammatory response. A comparison of PP meshes, PP + polyglactin (PP + PG) meshes and PP + titanium (PP + TI) meshes demonstrated a reduced inflammatory reaction in the PP mesh group and increased reaction in the PP + PG mesh group. The PP mesh induced large early elevations in vascular endothelial growth factor, cyclooxygenase-2 and collagen levels, whereas the PP + PG mesh caused only small elevations in the levels of these factors. PP + TI meshes induced inflammatory response levels in between those of the other 2 meshes[19]. Human fibroblasts colonized on the macroporous PP side of a composite mesh made of two PP layers, but no cell growth occurred on the film PP side[20]. The suppressive effect of the mesh on the transforming growth factor β1 was more pronounced for partially absorbable materials compared with pure PP meshes, which suggests that a change in raw material composition and type affects the early biological reaction of connective tissue cells to the mesh[21]. Woven and nonwoven meshes have received less attention. Raptis *et al*[22] demonstrated that woven PP meshes became fully peritonealized intraperitoneally but generated thicker and more plentiful adhesions than nonwoven PP. PP nonwoven prosthesis are comparable to conventional warp-knitted meshes[23].

The textile design markedly influences the inflammatory reaction to the mesh. Using the best polymer in a poor textile design may lead to pronounced inflammation and scar formation. In contrast, an adequate tissue reaction may be achieved with a suboptimal polymer if the essential parameters of the textile design (*e.g.*, the filament structure and pore size) are considered. The particular type of mesh used in hernia repair may affect the wound healing response and clinical outcome[24].

STRUCTURE PARAMETERS

Pore characteristics

The characteristics of the mesh used - primarily the pore characteristics especially the collapse of pores under strain, amount of mesh material, prosthesis weight, and mechanical properties - crucially influence the dynamic incorporation. In 1997, Amid[25] identified mesh porosity as the decisive factor for risk of infection. Amid defined pores larger than 75 μm as macropores before large-pore meshes (3-5 mm) were developed. Klinge *et al*[26] evaluated a remarkable number of explanted meshes and found that the mesh porosity was the most important determinant of the tissue reaction and risk of scar entrapment. The pore size must be much larger than 75 μm to preserve tissue integration without filling the pores with scar tissue. A pore size > 1 mm is required for PP, and the pore size should be > 3 mm in cases of mechanical strain. Meshes with large pores exhibit less inflammatory infiltrate, connective tissue, fistula formation, calcification, and bridging (*i.e.*, the pores are filled by scar tissue) than meshes with small pores[27,28]. Granulomas normally form around individual mesh fibers as part of the foreign body reaction, but the term "bridging" describes the process whereby individual granulomas become confluent with each

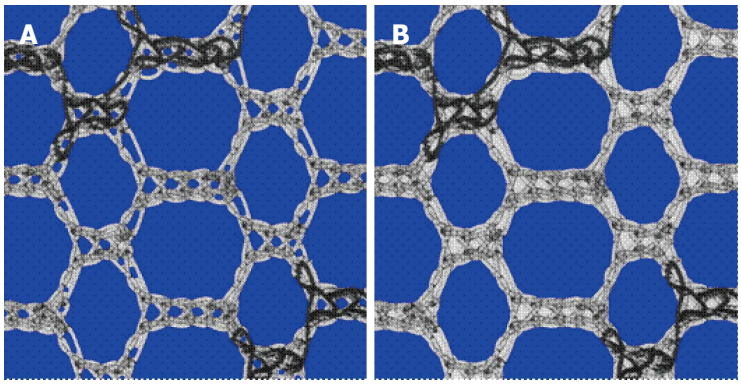

Figure 4 Comparison of the textile porosity (A) and the effective porosity (B).

other and encapsulate the entire mesh, which leads to a stiff scar plate and reduced flexibility[29]. A pore that is not completely filled by scar tissue is considered "effective" according to Mühl *et al*[30]. Therefore, large pore sizes preserve the "effective porosity" and thus avoid formation of scar bridges (Figure 4).

It is difficult to define a best pore size a priori because different raw materials result in different "effective porosities". Bridging of granuloma and encapsulation of the entire mesh is more likely for PP meshes with small pores (< 800 μm)[31]. In contrast, PVDF meshes do not exhibit bridging even for pore sizes of < 650 μm[32,33]. Klinge *et al*[26] characterized large-pore meshes using a textile porosity > 60% or an effective porosity > 0%. Pore shape may also determine integration. Lake *et al*[34] found that hexagonal pores resulted in the strongest tissue ingrowth, followed by square pores and diamond pores.

Mesh weight

Synthetic meshes may be classified as heavyweight or lightweight. The mesh weight depends on the polymer weight (raw material) and the amount of material used.

Coda *et al*[35] proposed a classification system based on the mesh weight that includes simple, composite and combined meshes. Meshes with weight per unit area of greater than 140 g/m² are defined as heavyweight meshes, meshes with weight per unit area in the range 35-70 g/m^2 are defined as lightweight meshes and meshes with weight per unit area in the range of 70-140 g/m^2 are defined as standard-weight meshes. Lightweight meshes generally contain less material and induce a less-pronounced foreign body reaction and decreased inflammatory response, which results in better tissue incorporation, increased prosthesis compliance, and decreased patient discomfort and pain. In an animal study, restriction of the abdominal wall mobility was significantly reduced and the inflammatory reaction and connective tissue formation were markedly diminished with lightweight meshes compared with heavyweight meshes[36]. Randomized prospective trials compared lightweight and heavyweight meshes for ventral hernia repair and found that they had equal outcomes in terms of ventral hernia recurrence[37]. Patients with lightweight mesh hernia repair exhibited better outcomes in terms of pain and seroma and an earlier return to activity[38].

Most current lightweight meshes have larger pores than heavyweight small-pore constructions[39]. However, mesh classification only in terms of weight disregards fiber and pore characteristics. Weyhe *et al*[40] considered the textile mesh construction, which they characterized in terms of the pore size and filament structure, as a more important determinant of foreign body reactions after implantation than absolute material reduction. This result attenuates the importance of mesh weight for the prediction of biocompatibility[41]. The advantages of lightweight meshes may be primarily related to their tendency to utilize a large pore size and/or monofilament.

However, an excessive reduction of mesh weight may also decrease the tensile strength. Lightweight meshes are sufficiently strong to resist abdominal wall pressure, but these meshes lose some burst strength compared with heavyweight meshes[32,42]. Experiments using small animals suggest that heavyweight small-pore meshes may withstand greater forces of scar contraction than large-pore lightweight meshes and may exhibit less shrinkage. Zogbi *et al*[43] found that lightweight PP mesh exhibited greater median shrinkage than heavyweight PP mesh in rats 7, 28 and 90 d after implantation.

MECHANICAL PARAMETERS

Mechanical properties are important parameters to consider when determining the suitability of a particular mesh for a specific clinical situation. However, surgeons typically implant meshes to provide maximum overlap over the defect with little regard for the mechanical properties of the mesh. Each synthetic mesh is composed of a unique combination of the material properties of the polymer and the textile design. The textile properties depend on the manufacturing process and the manufacturing process parameters.

The choice of raw materials determines a material's properties, which in many cases implies a combination of the properties of more than one raw material. These features ultimately determine the mechanical properties

Table 3 Definitions of mechanical mesh properties based on the definitions given by the American Society for Testing and Materials[44]

Property	Definition
Tensile strength	Tensile strength is the maximum force that can be applied to a mesh without tearing or breaking of the mesh. The tensile strength is measured in Newton (N) and is usually given in relation to the clamping width as Newton per centimeter (N/cm)
Burst strength	The burst strength is the maximum uniformly distributed pressure applied at right angle to its surface that a material will withstand under standardized conditions. The burst strength is given in pressure per unit area (Pa/cm²)
Elasticity (elastic elongation)	Elasticity (elastic elongation) is the property of a material whereby it changes its shape and size under the action of opposing forces (%), but recovers its original configuration when the forces are removed. In contrast, to the elastic elongation the plastic elongation indicates the elongation ratio which does not recover after unloading the structure
Stiffness	Stiffness can be expressed as ratio of steadily increasing or decreasing force acting on a deformable elastic material to the resulting displacement or deformation. Stiffness is a crucial aspect that reflects the drapablity of a textile structure, means the ability of a textile structure to be adapted to a 3-dimensional geometry

of the resulting mesh. An important consequence of the manufacturing process is the anisotropy of the tensile strength, elasticity, burst strength and stiffness. The American Society for Testing and Materials (ASTM) specification (D 4850 Terminology of textile structures) provides definitions of these properties (Table 3)[44].

The actual load on the abdominal wall is of major relevance for the selection of the suitability of meshes for use in ventral hernia repair. Different groups often perform simple tensile tests (N/cm), measurements of the inner abdominal pressure (Pa = N/mm²) or calculations of the abdominal wall tension (N/cm) using the Young-Laplace equation to characterize the native abdominal wall properties. The different measuring methods and different units should be considered when comparing these measurement results. Conversion of the inner abdominal wall pressure (Pa = N/mm²) (using the Young-Laplace equation) to the abdominal wall tension (N/cm) is only possible if the circumference of the patient is also provided. Use of the Young-Laplace equation requires a distinction between the sphere-like anatomy of the groin and the cylinder-like anatomy of the abdominal wall.

Hollinsky *et al*[45] measured the tensile load of the linea alba, the anterior and posterior rectus sheath, and scar tissue following median laparotomy in fresh cadavers and found that the tissue in the epigastric region ruptured at a mean horizontal load of 10 N/mm^2 in the linea alba and 6.9 N/mm^2 in scar tissue and at a mean vertical load of 4.5 N/mm^2 in the linea alba and 3.3 N/mm^2 in scar tissue. In earlier research, Williams *et al*[46] estimated the maximum force applied to the abdominal wall after hernia repair surgery as 22 N/cm in the cranial/caudal direction and 32 N/cm in the lateral direction. Cobb *et al*[47] investigated the intra-abdominal pressure using a transurethral bladder (Foley) catheter under different physical situations, including standing, sitting, bending at the waist, bending at the knees, performing abdominal crunches, jumping, climbing stairs, bench-pressing 25 pounds, arm curling 10 pounds, and performing a valsalva and coughing while sitting and standing, and identified a pressure of 22.7 kPa (171 mmHg) as the maximum pressure during coughing. Deeken *et al*[48] argued that stress in the transverse direction can reach levels of 47.8 N/cm in obese males with a large abdominal circumference. The true peak pressure in situations such as expectoration or sternutation in the abdominal wall was not fully addressed, but it is accepted that 22 N/cm in the cranial/caudal and 32 N/cm in the lateral direction are the maximum forces applied to the abdominal wall after hernia repair surgery[49]. A load of 16 N/cm is accepted as the maximum load in the groin because of the more sphere-like anatomy of the groin[50].

The natural elasticity of the abdominal wall at 32 N/cm is approximately 38%, with higher resilience in the horizontal direction than the longitudinal direction[45,46]. DuBay *et al*[51] indicate that the use of meshes in ventral hernia repair increases abdominal wall elasticity, which results in lower recurrence rates. Lightweight meshes exhibit an elasticity of approximately 20%-35% at 16 N/cm, but heavyweight meshes exhibit half of this elasticity (4%-15% at 16 N/cm), which may restrict abdominal distension[39]. An inappropriate mesh tensile strength, which results in an inappropriate ability of the mesh material to stretch, may potentially lead to poor functional results, with pain, hernia recurrence or prolapse. Elongation rates of greater than 30% indicate that these materials may stretch more than the native human abdominal wall. These meshes may not maintain functional repair, which could result in bulging or recurrence[48].

Tensile strengths of greater than 100 N/cm of conventional heavyweight meshes (*e.g.*, Prolene) are disproportionate and not necessary for effective repair[39]. Most synthetic meshes, even the lightest meshes, reach a tensile strength of at least 32 N/cm and are sufficiently strong. The mean burst strength and stiffness of lightweight meshes 5 mo after implantation in a pig was significantly less than those of heavyweight and middleweight meshes, but the burst strength for all meshes tested was much greater than the strengths measured for the abdominal wall fascia alone[32]. Bellón *et al*[52] demonstrated that the tensile strengths of lightweight and heavyweight meshes were comparable 90 d after implantation. However, Petro *et al*[53] recently reported 7 cases of mechanical failure or fracturing of lightweight monofilament polyester meshes after open incisional

Table 4 Essential properties of hernia meshes used for groin and abdominal wall hernia repair

Property	Recommendation
Tensile strength (abdominal wall)	22 N/cm (cranial/caudal) 32 N/cm (lateral)
Tensile strength (groin)	16 N/cm
Elongation	20%-40%
Orientation	No specific orientation for meshes with isotropic properties For meshes with anisotropic properties: orientation in the appropriate direction to match the physiological stretchability
Pore size	Depending on the used raw material and the foreign body reaction, respectively. To achieve a high effective porosity: for PP meshes a pore size ≥ 1000 μm should be used; for PVDF meshes a pore size ≥ 600 μm should be used

PP: Polypropylene; PVDF: Polyvinylidenefluoride.

hernia repair. Zuvela *et al*[3] and Lintin *et al*[54] reported central ruptures of low-weight PP meshes after initial sublay incisional hernia repair. These isolated case reports are insufficient to question the use of lightweight meshes in ventral hernia repair, but one should consider that the maximum initial tensile strength of synthetic meshes did not predict long-term strength after implantation[55]. Eliason *et al*[56] demonstrated that BardMesh, Dualmesh, and Prolene exhibited significantly reduced tensile strength, and BardMesh, Proceed, Prolene, ProLite, ProLite Ultra, and Ultrapro exhibited significantly increased permanent elongation after exposure to 1000 cycles of repetitive loading sequences that simulated changes in the intra-abdominal pressure. Mesh elongation also led to the loss of effective porosity in most meshes, which is an important aspect for scar formation and foreign body reaction[57]. Stiffness and breaking strength also vary widely among available meshes for hernia repair, and most meshes exhibit significant anisotropy in terms of their mechanical behavior. Pott *et al*[49] compared six meshes composed of different raw materials and different textile structures. All six mesh types exhibited differences in maximum tensile strength (11.1 ± 6.4 to 100.9 ± 9.4 N/cm), stiffness (0.3 ± 0.1 to 4.6 ± 0.5 N/mm), and elongation at break (150% ± 6% to 340% ± 20%) based on the load direction: the warp direction, or "longitudinal direction", *vs* the weft direction, or "orthogonal direction". Deeken *et al*[58] recently evaluated 13 mesh types that exhibited a wide range of mechanical properties. Some meshes were nearly isotropic, with nearly similar properties in the vertical and horizontal strain directions [C-QUR™, DUALMESH(®), PHYSIOMESH™, and PROCEED(®)], but other meshes were highly anisotropic (Ventralight™ ST, Bard™ Mesh, and Bard™ Soft Mesh). Some meshes exhibited a nearly linear behavior (Bard™ Mesh), but other meshes were non-linear, with a long toe region followed by a sharp rise in tension.

Meshes with different mechanical properties are treated as uniform and interchangeable, but it is important to understand the characteristics of the meshes to identify an appropriate mesh for each patient and place the mesh in an appropriate position to avoid mechanical mismatch, which may impair graft fixation, and enable optimized integration into the host tissue[59,60]. Therefore, surgeons may use meshes with isotropic properties regardless of the mesh orientation, but surgeons should pay attention to the orientation of meshes with anisotropic properties, which should be placed with their major elasticity in the appropriate direction to match the physiological stretch abilities (Table 4).

NEW DEVELOPMENTS

The evolution of meshes is not complete. New synthetic meshes are continuously developed, and new polymers and innovative coatings are continuously introduced. Ulrich *et al*[61] examined 3 new warp-knitted synthetic meshes composed of different polymers with different tensile properties, polyetheretherketone, polyamide (PA) and a composite, gelatin-coated PA (PA + G), in a rat model. All new materials exhibited better tissue integration, new collagen deposition and sustained neovascularization compared with PP meshes. Therefore, these new materials provide a promising alternative for future mesh developments. Meshes manufactured from native spider dragline revealed rapid cell migration, complete degradation, formation of a stable scar with constant tensile strength values and the highest relative elongation among standard biological and synthetic meshes[62].

Biosynthetic meshes are a possible cost-effective alternative to synthetic and biological meshes. Bio-degradable polymers, instead of animal or cadaver tissue, provide a temporary scaffold for deposition of proteins and cells that are necessary for tissue ingrowths, neovascularization, and host integration[63]. Powell *et al*[64] reported good results in the early phase for "synthetic remodeling meshes" made from PGA/trimethylene carbonate in a study of 70 patients who underwent hiatal hernia repair. However, Symeonidis *et al*[65] used the same "synthetic remodeling mesh" in a pilot study of inguinal hernia repair and reported discouraging results, with a 38% recurrence rate after a mean follow-up of 2 years, which questions the general suitability of this mesh. Another fully absorbable

mesh composed of knitted poly-4-hydroxybutyrate monofilament fibers, named the Phasix mesh, exhibited a strength that was 80%, 65%, 58%, 37% and 18% greater than the native abdominal wall at 8, 16, 32, and 48 wk post-implantation, respectively. The significant reduction of the polymers' molecular weight over time demonstrated successful transfer of load-bearing from the mesh to the repaired abdominal wall[66].

Configurations that include a metal component may also add new properties to standard synthetic meshes. Mesh shrinkage, migration, and configuration changes in the host tissue cause severe complications and discomfort after mesh implantation. There is no way to revise an implanted mesh postoperatively except for access to samples that have been explanted because of severe infection, chronic pain and recurrence. However, incorporation of small iron particles into the polymer provides an effective option for noninvasive revision using magnetic resonance imaging[67]. Another promising metal to improve mesh performance is nitinol. Nitinol-containing memory frame mesh is a valuable tool to achieve complete deployment in transinguinal preperitoneal repair for inguinal hernias that offers an acceptable morbidity and a low recurrence rate[68].

Coatings are another effective method to modify the properties of synthetic meshes. A titanium-coated PP mesh was associated with less postoperative pain in the short term, lower analgesic consumption and shorter convalescence compared with the Parietex composite mesh[69]. Intraperitoneal implantation of PP meshes is not recommended because of the likeliness of inducing intense adhesion and intestinal fistula. A PP mesh coated with poly(L-lactic acid) exhibited an additional property of anti-adhesion in a rat model[70]. Extracellular matrix-coated PP meshes attenuated the pro-inflammatory response with reduced cell accumulation, fewer foreign body giant cells and decreased collagen density without changes in the mechanical properties of the mesh[71,72]. Chitosan-coated PP meshes elicited preferential attachment of myoblasts over fibroblast attachment *in vitro*, which was associated with the restoration of functional skeletal muscle with histomorphological characteristics that resembled native muscle *in vivo*[73]. Degradable drug delivery coatings with incorporated antibiotics provide a specific approach to reduce post-surgical infections[74]. These promising laboratory and animal trial results may be incorporated in clinical practice in the future.

The use of electro-spun nanofibers of various polymers as tissue scaffolds in hernia repair has been an active research topic in recent years. Electro-spun materials feature three-dimensional nanofibrous structure with high surface-to-volume ratios and high porosity with high pore-interconnectivity that are similar to the native extracellular matrix. Drugs and growth factors for the prevention of incisional hernia formation have also been incorporated into electro-spun nanofibers[75]. Recent research revealed that PET and PET/chitosan electro-spun meshes performed well during incisional hernia surgery. However, the formation of foreign body granuloma in response to electro-spun structures was greater than when conventional meshes were used[76]. Further studies are required to elucidate the mechanisms that underlie the interactions between cells/tissues and nanofibrous materials.

CONCLUSION

Large-pore, monofilament, lightweight synthetic meshes are the current standard of practice. However, the risk of infection and other complications associated with the use of meshes are inevitable. An ideal synthetic mesh should consist of a monofilamentous large-pore structure with anisotropic mechanical properties that are similar to the native properties of the healthy host tissue and composed of a highly biocompatible raw material with long-term stability. An optimal mesh for intraperitoneal use must resist visceral adhesions to limit the risk of bowel obstruction and intestinal fistula. The use of innovative raw materials or coatings of currently available raw materials are promising approaches to realize these ideals. The individual response of the patient influences the local response after mesh implantation. Therefore, a thorough understanding of the biological processes of tissue formation and remodeling in the context of wound-healing processes after hernia repair is needed.

REFERENCES

1 **Scott NW**, McCormack K, Graham P, Go PM, Ross SJ, Grant AM. Open mesh versus non-mesh for repair of femoral and inguinal hernia. *Cochrane Database Syst Rev* 2002; **(4)**: CD002197 [PMID: 12519568]

2 **den Hartog D**, Dur AH, Tuinebreijer WE, Kreis RW. Open surgical procedures for incisional hernias. *Cochrane Database Syst Rev* 2008; **(3)**: CD006438 [PMID: 18646155 DOI: 10.1002/14651858.CD006438.pub2]

3 **Zuvela M**, Galun D, Djurić-Stefanović A, Palibrk I, Petrović M, Milićević M. Central rupture and bulging of low-weight polypropylene mesh following recurrent incisional sublay hernioplasty. *Hernia* 2014; **18**: 135-140 [PMID: 24309998 DOI: 10.1007/s10029-013-1197-1]

4 **Sanders DL**, Waydia S. A systematic review of randomised control trials assessing mesh fixation in open inguinal hernia repair. *Hernia* 2014; **18**: 165-176 [PMID: 23649403 DOI: 10.1007/s10029-013-1093-8]

5 **Gutlic N**, Rogmark P, Nordin P, Petersson U, Montgomery A. Impact of Mesh Fixation on Chronic Pain in Total Extraperitoneal Inguinal Hernia Repair (TEP): A Nationwide Register-based Study. *Ann Surg* 2015 Jul 1; Epub ahead of print [PMID: 26135697 DOI: 10.1097/SLA.0000000000001306]

6 **Deligiannidis N**, Papavasiliou I, Sapalidis K, Kesisoglou I, Papavramidis S, Gamvros O. The use of three different mesh materials in the treatment of abdominal wall defects. *Hernia* 2002; **6**: 51-55 [PMID: 12152638 DOI: 10.1007/s10029-002-0054-4]

7 **Klink CD**, Binnebösel M, Kaemmer D, Schachtrupp A, Fiebeler A, Anurov M, Schumpelick V, Klinge U. Comet-tail-like inflammatory infiltrate to polymer filaments develops in tension-free conditions. *Eur Surg Res* 2011; **46**: 73-81 [PMID: 21196740 DOI: 10.1159/000322250]

8 **Gerullis H**, Georgas E, Borós M, Klosterhalfen B, Eimer C, Arndt C, Otto S, Barski D, Ysebaert D, Ramon A, Otto T. Inflammatory reaction as determinant of foreign body reaction is an early and susceptible event after mesh implantation. *Biomed Res Int* 2014; **2014**: 510807 [PMID: 24783209 DOI: 10.1155/2014/510807]

9 **Klinge U**, Dietz U, Fet N, Klosterhalfen B. Characterisation of the cellular infiltrate in the foreign body granuloma of textile meshes with its impact on collagen deposition. *Hernia* 2014; **18**: 571-578 [PMID: 24500375 DOI: 10.1007/s10029-014-1220-1]

10 **Kourtzelis I**, Rafail S, DeAngelis RA, Foukas PG, Ricklin D, Lambris JD. Inhibition of biomaterial-induced complement activation attenuates the inflammatory host response to implantation. *FASEB J* 2013; **27**: 2768-2776 [PMID: 23558338 DOI: 10.1096/fj.12-225888]

11 **Orenstein SB**, Saberski ER, Klueh U, Kreutzer DL, Novitsky YW. Effects of mast cell modulation on early host response to implanted synthetic meshes. *Hernia* 2010; **14**: 511-516 [PMID: 20526725 DOI: 10.1007/s10029-010-0680-1]

12 **Vaz M**, Krebs RK, Trindade EN, Trindade MR. Fibroplasia after polypropylene mesh implantation for abdominal wall hernia repair in rats. *Acta Cir Bras* 2009; **24**: 19-25 [PMID: 19169537 DOI: 10.1590/s0102-86502009000100005]

13 **Majercik S**, Tsikitis V, Iannitti DA. Strength of tissue attachment to mesh after ventral hernia repair with synthetic composite mesh in a porcine model. *Surg Endosc* 2006; **20**: 1671-1674 [PMID: 17001442 DOI: 10.1007/s00464-005-0660-1]

14 **Wood AJ**, Cozad MJ, Grant DA, Ostdiek AM, Bachman SL, Grant SA. Materials characterization and histological analysis of explanted polypropylene, PTFE, and PET hernia meshes from an individual patient. *J Mater Sci Mater Med* 2013; **24**: 1113-1122 [PMID: 23371769 DOI: 10.1007/s10856-013-4872-y]

15 **Baktir A**, Dogru O, Girgin M, Aygen E, Kanat BH, Dabak DO, Kuloglu T. The effects of different prosthetic materials on the formation of collagen types in incisional hernia. *Hernia* 2013; **17**: 249-253 [PMID: 22907153 DOI: 10.1007/s10029-012-0979-1]

16 **Orenstein SB**, Saberski ER, Kreutzer DL, Novitsky YW. Comparative analysis of histopathologic effects of synthetic meshes based on material, weight, and pore size in mice. *J Surg Res* 2012; **176**: 423-429 [PMID: 22099590 DOI: 10.1016/j.jss.2011.09.031]

17 **Grigoryuk AA**, Turmova EP. Effects of polypropylene and polytetrafluoroethylene prostheses for abdominal plasty on local and systemic cytokine production. *Bull Exp Biol Med* 2014; **156**: 530-534 [PMID: 24771444 DOI: 10.1007/s10517-014-2391-6]

18 **Klink CD**, Junge K, Binnebösel M, Alizai HP, Otto J, Neumann UP, Klinge U. Comparison of long-term biocompability of PVDF and PP meshes. *J Invest Surg* 2011; **24**: 292-299 [PMID: 22047202 DOI: 10.3109/08941939.2011.589883]

19 **Pereira-lucena CG**, Artigiani Neto R, de Rezende DT, Lopes-Filho Gde J, Matos D, Linhares MM. Early and late postoperative inflammatory and collagen deposition responses in three different meshes: an experimental study in rats. *Hernia* 2014; **18**: 563-570 [PMID: 24370605 DOI: 10.1007/s10029-013-1206-4]

20 **Canuto RA**, Saracino S, Oraldi M, Festa V, Festa F, Muzio G, Chiaravalloti A. Colonization by human fibroblasts of polypropylene prosthesis in a composite form for hernia repair. *Hernia* 2013; **17**: 241-248 [PMID: 22996952 DOI: 10.1007/s10029-012-0996-0]

21 **Weyhe D**, Hoffmann P, Belyaev O, Mros K, Muller C, Uhl W, Schmitz F. The role of TGF-beta1 as a determinant of foreign body reaction to alloplastic materials in rat fibroblast cultures: comparison of different commercially available polypropylene meshes for hernia repair. *Regul Pept* 2007; **138**: 10-14 [PMID: 16973225 DOI: 10.1016/j.regpep.2006.07.010]

22 **Raptis DA**, Vichova B, Breza J, Skipworth J, Barker S. A comparison of woven versus nonwoven polypropylene (PP) and expanded versus condensed polytetrafluoroethylene (PTFE) on their intraperitoneal incorporation and adhesion formation. *J Surg Res* 2011; **169**: 1-6 [PMID: 20400113 DOI: 10.1016/j.jss.2009.12.014]

23 **Reis Pdos S**, Chagas VL, Silva JM, Silva PC, Jamel N, Schanaider A. Nonwoven polypropylene prosthesis in large abdominal wall defects in rats. *Acta Cir Bras* 2012; **27**: 671-680 [PMID: 23033127 DOI: 10.1590/s0102-86502012001000002]

24 **Asarias JR**, Nguyen PT, Mings JR, Gehrich AP, Pierce LM. Influence of mesh materials on the expression of mediators involved in wound healing. *J Invest Surg* 2011; **24**: 87-98 [PMID: 21345009 DOI: 10.3109/08941939.2010.548904]

25 **Amid PK**. Classification of biomaterials and their related complications in abdominal wall hernia surgery. *Hernia* 1997; **1**: 15-21 [DOI: 10.1007/BF02426382]

26 **Klinge U**, Klosterhalfen B. Modified classification of surgical meshes for hernia repair based on the analyses of 1,000 explanted meshes. *Hernia* 2012; **16**: 251-258 [PMID: 22562353 DOI: 10.1007/s10029-012-0913-6]

27 **Klosterhalfen B**, Klinge U. Retrieval study at 623 human mesh explants made of polypropylene--impact of mesh class and indication for mesh removal on tissue reaction. *J Biomed Mater Res B Appl Biomater* 2013; **101**: 1393-1399 [PMID: 24591221 DOI: 10.1002/jbmb.32958]

28 **Greca FH**, Souza-Filho ZA, Giovanini A, Rubin MR, Kuenzer RF, Reese FB, Araujo LM. The influence of porosity on the integration histology of two polypropylene meshes for the treatment of abdominal wall defects in dogs. *Hernia* 2008; **12**: 45-49 [PMID: 17823771 DOI: 10.1007/s10029-007-0276-6]

29 **Jerabek J**, Novotny T, Vesely K, Cagas J, Jedlicka V, Vlcek P, Capov I. Evaluation of three purely polypropylene meshes of different pore sizes in an onlay position in a New Zealand white rabbit model. *Hernia* 2014; **18**: 855-864 [PMID: 25033941 DOI: 10.1007/s10029-014-1278-9]

30 **Mühl T**, Binnebösel M, Klinge U, Goedderz T. New objective measurement to characterize the porosity of textile implants. *J Biomed Mater Res B Appl Biomater* 2008; **84**: 176-183 [PMID: 17497684 DOI: 10.1002/jbm.b.30859]

31 **Brown CN**, Finch JG. Which mesh for hernia repair? *Ann R Coll Surg Engl* 2010; **92**: 272-278 [PMID: 20501011 DOI: 10.1308/003588410X12664192076296]

32 **Cobb WS**, Burns JM, Peindl RD, Carbonell AM, Matthews BD, Kercher KW, Heniford BT. Textile analysis of heavy weight, mid-weight, and light weight polypropylene mesh in a porcine ventral hernia model. *J Surg Res* 2006; **136**: 1-7 [PMID: 16996087 DOI: 10.1016/j.jss.2006.05.022]

33 **Conze J**, Junge K, Weiss C, Anurov M, Oettinger A, Klinge U, Schumpelick V. New polymer for intra-abdominal meshes--PVDF copolymer. *J Biomed Mater Res B Appl Biomater* 2008; **87**: 321-328 [PMID: 18435400 DOI: 10.1002/jbm.b.31106]

34 **Lake SP**, Ray S, Zihni AM, Thompson DM, Gluckstein J, Deeken CR. Pore size and pore shape--but not mesh density--alter the mechanical strength of tissue ingrowth and host tissue response to synthetic mesh materials in a porcine model of ventral hernia repair. *J Mech Behav Biomed Mater* 2015; **42**: 186-197 [PMID: 25486631 DOI: 10.1016/j.jmbbm.2014.11.011]

35 **Coda A**, Lamberti R, Martorana S. Classification of prosthetics used in hernia repair based on weight and biomaterial. *Hernia* 2012; **16**: 9-20 [PMID: 21837484 DOI: 10.1007/s10029-011-0868-z]

36 **Novitsky YW**, Cristiano JA, Harrell AG, Newcomb W, Norton JH, Kercher KW, Heniford BT. Immunohistochemical analysis of host reaction to heavyweight-, reduced-weight-, and expanded polytetrafluoroethylene (ePTFE)-based meshes after short- and long-term intraabdominal implantations. *Surg Endosc* 2008; **22**: 1070-1076 [PMID: 18188649 DOI: 10.1007/s00464-007-9737-3]

37 **Conze J**, Kingsnorth AN, Flament JB, Simmermacher R, Arlt G, Langer C, Schippers E, Hartley M, Schumpelick V. Randomized clinical trial comparing lightweight composite mesh with polyester or polypropylene mesh for incisional hernia repair. *Br J Surg* 2005; **92**: 1488-1493 [PMID: 16308855 DOI: 10.1002/bjs.5208]

38 **Agarwal BB**, Agarwal KA, Sahu T, Mahajan KC. Traditional polypropylene and lightweight meshes in totally extraperitoneal inguinal herniorrhaphy. *Int J Surg* 2010; **8**: 44-47 [PMID: 19853672 DOI: 10.1016/j.ijsu.2009.08.014]

39 **Klosterhalfen B**, Junge K, Klinge U. The lightweight and large porous mesh concept for hernia repair. *Expert Rev Med Devices* 2005; **2**: 103-117 [PMID: 16293033 DOI: 10.1586/17434440.2.1.103]

40 **Weyhe D**, Belyaev O, Müller C, Meurer K, Bauer KH, Papapostolou G, Uhl W. Improving outcomes in hernia repair by the use of light meshes--a comparison of different implant constructions based on a critical appraisal of the literature. *World J Surg* 2007; **31**: 234-244 [PMID: 17180568 DOI: 10.1007/s00268-006-0123-4]

41 **Weyhe D**, Schmitz I, Belyaev O, Grabs R, Müller KM, Uhl W, Zumtobel V. Experimental comparison of monofile light and heavy polypropylene meshes: less weight does not mean less biological response. *World J Surg* 2006; **30**: 1586-1591 [PMID: 16855805 DOI: 10.1007/s00268-005-0601-0]

42 **Muftuoglu MA**, Gungor O, Odabasi M, Ekinci O, Teyyareci A, Sekmen U, Saglam A. The comparison of heavyweight mesh and lightweight mesh in an incisional animal model. *Hernia* 2010; **14**: 397-400 [PMID: 20229105 DOI: 10.1007/s10029-010-0647-2]

43 **Zogbi L**, Trindade EN, Trindade MR. Comparative study of shrinkage, inflammatory response and fibroplasia in heavyweight and lightweight meshes. *Hernia* 2013; **17**: 765-772 [PMID: 23344668 DOI: 10.1007/s10029-013-1046-2]

44 ASTM D4850. Standard Terminology Relating to Fabrics and Fabric Test Methods. ASTM International, West Conshohocken, PA, 2013 [DOI: 10.1520/D4850]

45 **Hollinsky C**, Sandberg S. Measurement of the tensile strength of the ventral abdominal wall in comparison with scar tissue. *Clin Biomech* (Bristol, Avon) 2007; **22**: 88-92 [PMID: 16904247 DOI: 10.1016/j.clinbiomech.2006.06.002]

46 **Williams JF**, Kirkpatrick J, Syme GA. Force measurement in the abdominal wall. *Biomed Eng* 1975; **10**: 181-183 [PMID: 123792]

47 **Cobb WS**, Burns JM, Kercher KW, Matthews BD, James Norton H, Todd Heniford B. Normal intraabdominal pressure in healthy adults. *J Surg Res* 2005; **129**: 231-235 [PMID: 16140336 DOI: 10.1016/j.jss.2005.06.015]

48 **Deeken CR**, Abdo MS, Frisella MM, Matthews BD. Physico-mechanical evaluation of polypropylene, polyester, and polytetrafluoroethylene meshes for inguinal hernia repair. *J Am Coll Surg* 2011; **212**: 68-79 [PMID: 21115372 DOI: 10.1016/j.jamcollsurg.2010.09.012]

49 **Pott PP**, Schwarz ML, Gundling R, Nowak K, Hohenberger P, Roessner ED. Mechanical properties of mesh materials used for hernia repair and soft tissue augmentation. *PLoS One* 2012; **7**: e46978 [PMID: 23071685 DOI: 10.1371/journal.pone.0046978]

50 **Klinge U**, Klosterhalfen B, Conze J, Limberg W, Obolenski B, Ottinger AP, Schumpelick V. Modified mesh for hernia repair that is adapted to the physiology of the abdominal wall. *Eur J Surg* 1998; **164**: 951-960 [PMID: 10029391 DOI: 10.1080/11024159875000513 8]

51 **DuBay DA**, Wang X, Adamson B, Kuzon WM, Dennis RG, Franz MG. Mesh incisional herniorrhaphy increases abdominal wall elastic properties: a mechanism for decreased hernia recurrences in comparison with suture repair. *Surgery* 2006; **140**: 14-24 [PMID: 16857438 DOI: 10.1016/j.surg.2006.01.007]

52 **Bellón JM**, Rodríguez M, García-Honduvilla N, Gómez-Gil V, Pascual G, Buján J. Comparing the behavior of different polypropylene meshes (heavy and lightweight) in an experimental model of ventral hernia repair. *J Biomed Mater Res B Appl Biomater* 2009; **89**: 448-455 [PMID: 18837449 DOI: 10.1002/jbm.b.31234]

53 **Petro CC**, Nahabet EH, Criss CN, Orenstein SB, von Recum HA, Novitsky YW, Rosen MJ. Central failures of lightweight monofilament polyester mesh causing hernia recurrence: a cautionary note. *Hernia* 2015; **19**: 155-159 [PMID: 24659227 DOI: 10.1007/s10029-014-1237-5]

54 **Lintin LA**, Kingsnorth AN. Mechanical failure of a lightweight polypropylene mesh. *Hernia* 2014; **18**: 131-133 [PMID: 22824989 DOI: 10.1007/s10029-012-0959-5]

55 **Melman L**, Jenkins ED, Hamilton NA, Bender LC, Brodt MD, Deeken CR, Greco SC, Frisella MM, Matthews BD. Histologic and biomechanical evaluation of a novel macroporous polytetrafluoroethylene knit mesh compared to lightweight and heavyweight polypropylene mesh in a porcine model of ventral incisional hernia repair. *Hernia* 2011; **15**: 423-431 [PMID: 21279663 DOI: 10.1007/s10029-011-0787-z]

56 **Eliason BJ**, Frisella MM, Matthews BD, Deeken CR. Effect of repetitive loading on the mechanical properties of synthetic hernia repair materials. *J Am Coll Surg* 2011; **213**: 430-435 [PMID: 21705242 DOI: 10.1016/j.jamcollsurg.2011.05.018]

57 **Alizai PH**, Schmid S, Otto J, Klink CD, Roeth A, Nolting J, Neumann UP, Klinge U. Biomechanical analyses of prosthetic mesh repair in a hiatal hernia model. *J Biomed Mater Res B Appl Biomater* 2014; **102**: 1485-1495 [PMID: 24599834 DOI: 10.1002/jbm.b.33128]

58 **Deeken CR**, Thompson DM, Castile RM, Lake SP. Biaxial analysis of synthetic scaffolds for hernia repair demonstrates variability in mechanical anisotropy, non-linearity and hysteresis. *J Mech Behav Biomed Mater* 2014; **38**: 6-16 [PMID: 24997427 DOI: 10.1016/j.jmbbm.2014.06.001]

59 **Li X**, Kruger JA, Jor JW, Wong V, Dietz HP, Nash MP, Nielsen PM. Characterizing the ex vivo mechanical properties of synthetic polypropylene surgical mesh. *J Mech Behav Biomed Mater* 2014; **37**: 48-55 [PMID: 24942626 DOI: 10.1016/j.jmbbm.2014.05.005]

60 **Anurov MV**, Titkova SM, Oettinger AP. Biomechanical compatibility of surgical mesh and fascia being reinforced: dependence of experimental hernia defect repair results on anisotropic surgical mesh positioning. *Hernia* 2012; **16**: 199-210 [PMID: 21909779 DOI: 10.1007/s10029-011-0877-y]

61 **Ulrich D**, Edwards SL, White JF, Supit T, Ramshaw JA, Lo C, Rosamilia A, Werkmeister JA, Gargett CE. A preclinical evaluation of alternative synthetic biomaterials for fascial defect repair using a rat abdominal hernia model. *PLoS One* 2012; **7**: e50044 [PMID: 23185528 DOI: 10.1371/journal.pone.0050044]

62 **Schäfer-Nolte F**, Hennecke K, Reimers K, Schnabel R, Allmeling C, Vogt PM, Kuhbier JW, Mirastschijski U. Biomechanics and biocompatibility of woven spider silk meshes during remodeling in a rodent fascia replacement model. *Ann Surg* 2014; **259**: 781-792 [PMID: 23873006 DOI: 10.1097/SLA.0b013e3182917677]

63 **Kim M**, Oommen B, Ross SW, Lincourt AE, Matthews BD, Heniford BT, Augenstein VA. The current status of biosynthetic mesh for ventral hernia repair. *Surg Technol Int* 2014; **25**: 114-121 [PMID: 25396323]

64 **Powell BS**, Wandrey D, Voeller GR. A technique for placement of a bioabsorbable prosthesis with fibrin glue fixation for reinforcement of the crural closure during hiatal hernia repair. *Hernia* 2013; **17**: 81-84 [PMID: 22581201 DOI: 10.1007/s10029-012-0915-4]

65 **Symeonidis D**, Efthimiou M, Koukoulis G, Athanasiou E, Mamaloudis I, Tzovaras G. Open inguinal hernia repair with the use of polyglycolic acid/trimethylene carbonate absorbable mesh: a critical update of the long-term results. *Hernia* 2013; **17**: 85-87 [PMID: 23138860 DOI: 10.1007/s10029-012-1016-0]

66 **Martin DP**, Badhwar A, Shah DV, Rizk S, Eldridge SN, Gagne DH, Ganatra A, Darois RE, Williams SF, Tai HC, Scott JR. Characterization of poly-4-hydroxybutyrate mesh for hernia repair applications. *J Surg Res* 2013; **184**: 766-773 [PMID: 23582230 DOI: 10.1016/j.jss.2013.03.044]

67 **Ciritsis A**, Hansen NL, Barabasch A, Kuehnert N, Otto J, Conze J, Klinge U, Kuhl CK, Kraemer NA. Time-dependent changes of magnetic resonance imaging-visible mesh implants in patients. *Invest Radiol* 2014; **49**: 439-444 [PMID: 24651663 DOI: 10.1097/RLI.0000000000000051]

68 **Berrevoet F**, Vanlander A, Bontinck J, Troisi RI. Open pre-peritoneal mesh repair of inguinal hernias using a mesh with nitinol memory frame. *Hernia* 2013; **17**: 365-371 [PMID: 23686406 DOI: 10.1007/s10029-013-1110-y]

69 **Köckerling F**, Schug-Pass C. What do we know about titanized polypropylene meshes? An evidence-based review of the literature. *Hernia* 2014; **18**: 445-457 [PMID: 24253381 DOI: 10.1007/s10029-013-1187-3]

70 **Zhang Z**, Zhang T, Li J, Ji Z, Zhou H, Zhou X, Gu N. Preparation of poly(L-lactic acid)-modified polypropylene mesh and its antiadhesion in experimental abdominal wall defect repair. *J Biomed Mater Res B Appl Biomater* 2014; **102**: 12-21 [PMID: 23661568 DOI: 10.1002/jbm.b.32947]

71 **Wolf MT**, Carruthers CA, Dearth CL, Crapo PM, Huber A, Burnsed OA, Londono R, Johnson SA, Daly KA, Stahl EC, Freund

JM, Medberry CJ, Carey LE, Nieponice A, Amoroso NJ, Badylak SF. Polypropylene surgical mesh coated with extracellular matrix mitigates the host foreign body response. *J Biomed Mater Res A* 2014; **102**: 234-246 [PMID: 23873846 DOI: 10.1002/jbm.a.34671]

72 **Faulk DM**, Londono R, Wolf MT, Ranallo CA, Carruthers CA, Wildemann JD, Dearth CL, Badylak SF. ECM hydrogel coating mitigates the chronic inflammatory response to polypropylene mesh. *Biomaterials* 2014; **35**: 8585-8595 [PMID: 25043571 DOI: 10.1016/j.biomaterials.2014.06.057]

73 **Udpa N**, Iyer SR, Rajoria R, Breyer KE, Valentine H, Singh B, McDonough SP, Brown BN, Bonassar LJ, Gao Y. Effects of chitosan coatings on polypropylene mesh for implantation in a rat abdominal wall model. *Tissue Eng Part A* 2013; **19**: 2713-2723 [PMID: 23859182 DOI: 10.1089/ten.TEA.2012.0739]

74 **Letouzey V**, Lavigne JP, Garric X, Coudane J, de Tayrac R, Callaghan DO. Is degradable antibiotic coating for synthetic meshes provide protection against experimental animal infection after fascia repair? *J Biomed Mater Res B Appl Biomater* 2012; **100**: 471-479 [PMID: 22102417 DOI: 10.1002/jbm.b.31973]

75 **Plencner M**, East B, Tonar Z, Otáhal M, Prosecká E, Rampichová M, Krejčí T, Litvinec A, Buzgo M, Míčková A, Nečas A, Hoch J, Amler E. Abdominal closure reinforcement by using polypropylene mesh functionalized with poly-ε-caprolactone nanofibers and growth factors for prevention of incisional hernia formation. *Int J Nanomedicine* 2014; **9**: 3263-3277 [PMID: 25031534 DOI: 10.2147/IJN.S63095]

76 **Veleirinho B**, Coelho DS, Dias PF, Maraschin M, Pinto R, Cargnin-Ferreira E, Peixoto A, Souza JA, Ribeiro-do-Valle RM, Lopes-da-Silva JA. Foreign body reaction associated with PET and PET/chitosan electrospun nanofibrous abdominal meshes. *PLoS One* 2014; **9**: e95293 [PMID: 24740104 DOI: 10.1371/journal.pone.0095293]

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MINIREVIEWS

Risk factors and implications of anastomotic complications after surgery for Crohn's disease

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Abstract

Anastomotic complications occur more frequently in patients with Crohn's disease leading to postoperative intra-abdominal septic complications (IASC). Patients with IASC often require re-operation or drainage to control the sepsis and have an increased frequency of disease recurrence. The aim of this article was to examine the factors affecting postoperative IASC in Crohn's disease after anastomoses, since some risk factors remain controversial. Studies investigating IASC in Crohn's operations were included, and all risk factors associated with IASC were evaluated: nutritional status, presence of abdominal sepsis, medication use, Crohn's disease type, duration of disease, prior operations for Crohn's, anastomotic technique, extent of resection, operative timing, operative length, and perioperative bleeding. In this review, the factors associated with an increased risk of IASC are preoperative weight loss, abdominal abscess present at time of surgery, prior operation, and steroid use. To prevent IASC in Crohn's patients, preoperative optimization with nutritional supplementation or drainage of abscess should be performed, or a diverting stoma should be considered for patients with multiple risk factors.

Key words: Crohn's disease; Risk factors; Complications; Resection; Postoperative septic complications; Anastomosis

Core tip: Intra-abdominal sepsis is a common complication in intestinal anastomoses in Crohn's disease; therefore, identifying the risk factors prior to surgery can improve outcomes. This review identified preoperative weight loss, abdominal abscess present at surgery, prior surgery, and steroid use as risk factors for postoperative anastomotic complications. Outcomes in Crohn's operations with these risk factors may be improved with preoperative nutritional supplementation and drainage of the intra-abdominal abscess. If multiple risk factors are present and preoperative interventions are not feasible, a diverting stoma should be considered.

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INTRODUCTION

Crohn's disease is a chronic inflammatory disease which will eventually lead to surgical intervention in a majority of patients. Medical therapy can prolonged the time spent in remission and delay the need for surgery, but the rate of surgical intervention has not subsequently decreased as 70%-90% of patients will require an operation during their lifetime[1,2]. Although any portion of the bowel may be affected, Crohn's disease is found most commonly in the terminal ileum thus ileocolectomy is the most common operation[3,4]. Patients with Crohn's have a higher complication rate, especially anastomotic complications leading to intra-abdominal sepsis, than patients without an inflammatory state. Intra-abdominal septic complications (IASC) include anastomotic leak, intra-abdominal abscess, and development of a fistula with in approximately 30 d postoperatively. Multiple observational studies have investigated the risk factors associated with IASC in order to identify patients to optimize preoperatively or include a diverting stoma to decrease the severity of complications, although some risk factors remain controversial. This review will focus on risk factors for IASC in patients undergoing surgery with intestinal anastomoses, mainly with ileocolic anastomoses, with Crohn's disease.

A Medline search was performed using keywords Crohn's disease, complications, anastomosis, post-operative sepsis, and surgery. From the articles reviewed, additional articles from the references were also included. Articles after 1980 were considered. A total of 27 articles were finally used.

RISK FACTORS FOR ANASTOMOTIC COMPLICATIONS IN CROHN'S DISEASE

Nutritional status

The preoperative nutritional status of patients in most studies was assessed by at least one of three parameters: preoperative serum albumin level, weight loss, and body-mass index (BMI). There is no gold standard for nutritional assessment in inflammatory bowel disease (IBD). BMI and unintentional weight loss are agreed upon measures for nutrition in Crohn's patients[5,6]. Albumin is associated with nutritional status in IBD; however, during an acute phase response, such as active Crohn's disease, albumin levels can fall[5]. Thus low albumin could be indicative of the disease state rather than nutritional status alone.

Serum albumin was the most commonly assessed nutritional parameter in studies included in this review. One study found albumin less than 3.0 mg/dL to be associated with an increased risk of IASC in a multivariate analysis[7], while another study found association in a univariate but not multivariate analysis[8]. Other studies using the same cutoff value, albumin < 3.0 mg/dL, did not find a similar association[9-11]. These results are further complicated by a study including preoperative nutritional supplementation in patients with an albumin less than 3.0 mg/dL[9]. Moreover, albumin level less than 3.5 mg/dL[12,13] and less than 4.0 mg/dL[14] were reported to have no association with IASC. One study that did not find albumin to be associated with IASC did not define albumin parameters[15]. A recent meta-analysis using many of these described studies found a correlation with low albumin and increased risk of IASC[16], but the definition of low albumin is quite inconsistent in these studies making even the pooled results difficult to determine.

Unexpected weight loss described as loss of 5%-10% body weight from the pre-morbid condition provides inconsistent data. Weight loss is associated with increased IASC in some studies[17,18]. Another study did not identify weight loss as a risk factor for IASC, although the definition for weight loss included patients requiring the need for preoperative nutrition[15]. Including patients receiving preoperative nutrition may confound the results by improving nutritional status at the time of surgery. Serradori *et al*[19] also found that weight loss before surgery did not impact IASC rate and included patients receiving preoperative nutritional support, although without specification of parenteral or enteral nutrition. In addition, no patients receiving preoperative nutrition developed an IASC. This data could suggest that patients who have weight loss preoperatively may benefit from nutritional supplementation prior to surgery to ameliorate the risk of complications.

Multiple studies reported BMI, although no study found BMI to be a risk factor for ISAC[8,14,17,18]. Despite the lack of association between BMI and abdominal septic complications, it should be noted that in these studies there were multiple variations in reporting BMI, such as, mean BMI[17,19], BMI less than 18.5[8], less than 20[18], or BMI less than 25[14]. Although BMI may be a reliable measure of malnutrition in preoperative Crohn's patients, BMI is not a risk factor for post-operative abdominal sepsis.

Abdominal sepsis

Intra-abdominal sepsis includes intra-abdominal abscess and/or fistula present at the time of surgery. Studies that investigated the presence of intra-abdominal abscess at the time of surgery for Crohn's disease found these patients at an increased risk of IASC[7,15,17,20]. In contrast, abscess was not associated with abdominal complications in other studies[13,14]. The studies that combined presence of preoperative abscess and fistula were inconsistent. Some studies found no effect on the rate of IASC with abscess and fistula[9-11] while other studies reported an association in univariate

analysis[8,21], and one found association also in a logistic regression analysis[8]. Some studies included abscesses that were drained preoperatively and found no association with abscess and postoperative IASC[14,18]. In contrast, studies which excluded preoperatively drained abscesses from the analysis, abscess present at time of surgery increased the risk of IASC with an odds ratio (OR = 3.4, 95%CI: 1.2-9.8)[15] and (OR =7.5 , 95%CI: 1.5-37.69)[17]. A meta-analysis which included most studies discussed regarding intra-abdominal abscess, including studies which combined abscess and fistula or included drained abscesses, found an increased risk of IASC with intra-abdominal abscess. Thus, the risk of IASC is higher when an intra-abdominal abscess is present, but the risk is likely ameliorated if the abscess is drained preoperatively.

The presence of an intra-abdominal fistula at the time of surgery has conflicting results as well. Multiple studies found no correlation between presence of fistula and IASC[13-15,18]. One study found fistula to be an independent risk factor for IASC[7], and in addition, one study found an association of fistula and IASC in a univariate analysis but not in a multivariate analysis[17]. These observational studies are the best data currently, as a meta-analysis of fistula alone has not been performed. There is no clear consensus that fistula alone at the time of surgery increases the IASC rate.

Medications

Most patients undergoing surgery for Crohn's disease are on medical therapy, either a single medication or a combination of medications including immunosuppressive medications, biologics, and steroids. Many studies have investigated these medications, and a majority of those studies report overall complications or just septic complications without specifying intra-abdominal sepsis. This review will only discuss those publications reporting IASC.

The use of corticosteroids in managing Crohn's disease has decreased with the advent of immunomodulators and biologics, but corticosteroid use in the perioperative period is still prevalent. Many studies investigated the postoperative complications with perioperative steroid use. Studies prior to 2010 only include corticosteroids in the analyses[7,9,12,13,17,18], while the more recent studies also include other medications[8,10,11,14,19,21,22]. The inclusion criteria for steroids widely varies between studies, as some studies do not define steroid use[9,11,13,18,19,22,23] while others require at least 4 wk[7,8,14,15,21] or 3 mo of steroid use prior to surgery[10,17]. Multiple studies found preoperative steroid use to be an independent risk factor in multivariate analysis[7,9,15,17]. Other studies found that steroid use increased IASC in a univariate analysis but not with a multivariate analysis[10,19]. In contrast, one study found steroid use to be protective of IASC[21], while other studies did not find an association between steroid use and postoperative abdominal sepsis[8,10,11,13,14,18,22]. In a meta-analysis including many of the studies presented here, steroid use was identified as a risk factor for IASC[16]. Thus perioperative steroid use should be considered an independent risk factor for IASC.

Immunosuppressants investigated were most commonly azathioprine, but some studies also included 6-mercaptopurine and methotrexate. Since these medications are not widely used, there are fewer studies reporting the postoperative outcome in conjunction with immunosuppressants. Only two studies reported a length of use criteria for inclusion, greater than 3 mo[8,21], while other studies did not define the inclusion criteria for length of preoperative steroid use. Immunomodulators were an independent risk factor for IASC in two studies[8,11]. Other studies[10,14,19,21,22] did not find an association with IASC and immunosuppressants, nor did a meta-analysis[16]. Immunosuppressants do not definitively affect postoperative outcomes.

Anti-tumor necrosis factor alpha (anti-TNF-α) drugs, or biologics, are increasingly used in Crohn's disease especially since a "top-down" approach for severe Crohn's disease is becoming more common to facilitate remission and delay surgery. A meta-analysis in 2014 suggested increased infectious complications with the use of anti-TNF agents, but all types of infectious complication not only intra-abdominal septic complications were included[24]. Individual studies investigating only IASC with biologics did not have similar findings. These studies included patients with biologic use within 8-12 wk before surgery[19,21,25], and one study also included anti-TNF use up to 4 wk postoperatively[22]. Some studies found biologics to be independent risk factors for IASC[19,22] while others did not find an association[10,21,22]. Moreover, a meta-analysis found no clinical implication of IASC risk with biologic use[16]. Anti-TNF agents do not increase the risk of postoperative intra-abdominal sepsis, although the association with overall postoperative complications is beyond the scope of this review.

Disease characteristics

Crohn's disease can behave as penetrating, stricturing, or nonstricturing/nonpenetrating, in order from least to most common presentation[4]. Most studies do not differentiate disease type, but Kanazawa *et al*[14] found penetrating disease to have an increased risk of IASC. Other studies did not find that disease classification impacted the IASC rate[9,10,22]. Patients with obstructing disease can have progression to perforating behavior, so in studies that included recurrent resections it is unclear if the disease type was readdressed for patients undergoing subsequent operations. Due to the limited number of studies investigating disease type, the presence of an abscess likely is a more important risk factor for postoperative complications than the disease type.

Duration of disease and prior operations

The duration of disease prior to an operation is shown to correlate with IASC, but only one study found an

association with disease greater than 10 years and risk of IASC[10]. Another study further classified disease severity into less than 1 year, 1-10 years and greater than 10 years without finding the same correlation[7]. The average duration of disease was found to be associated with IASC in univariate but not multivariate analysis in some studies[17,21], while other studies found no association[9,12]. Moreover, a prior resection or operation for Crohn's disease was not correlated with the risk of postoperative IASC[7-10,14,15]. Regardless of these studies finding no influence of prior operation on IASC, a meta-analysis showed an increased risk with an OR of 1.5[16]. The duration of disease does not appear to be a clinical factor associated with IASC, but prior operation appears to be a risk factor for IASC from the meta-analysis results despite lack of significant finding in each study.

Anastomosis technique

The type of anastomosis, stapled side-to-side and hand-sewn end-to-end anastomoses, have been thoroughly investigated. Some studies found an increased risk of IASC with hand-sewn anastomoses compared to stapled anastomoses[13,14]. Multiple other studies found no difference in postoperative IASC between stapled and hand-sewn anastomoses[7,8,10,21]. Alves *et al*[17] found no difference with only hand-sewn side-to-side and hand-sewn end-to-end configuration of anastomoses. A meta-analysis did not find an association with the method of anastomotic configuration[16], therefore, there is no increased risk of IASC with either stapled or hand-sewn anastomosis. Although a majority of studies included only ileocolic resections or ileal strictureplasties, three of these studies included colocolonic anastomoses and found an independent increase risk for IASC with these anastomoses[8,10,21], but other studies found no association of large *vs* small bowel involvement at the time of operation, although the site of anastomosis was not specified[7,9]. Thus the method of creating an anastomosis does not affect early postoperative complications in ileocolic anastomoses; however, there is not enough data to support the same conclusion for colonic anastomoses.

Extent of resection and margins

The extent of resection was only investigated in one study, in which IASC was not associated with extent of resection[12]. The number of anastomoses was reported in multiple studies to have no association with postoperative intra-abdominal sepsis[8,9,14,21]; furthermore, multiple resections were associated with increased IASC in a univariate but was not associated in a multivariate analysis[18]. The presence of macroscopic disease in the margin was investigated in a randomized controlled trial by Fazio *et al*[26], which reported that recurrence rate is not affected by either the width of macroscopic margin or presence of microscopic Crohn's disease at the margins. Conflicting results were found in two studies which investigated the impact of microscopically positive margins on IASC. One study found histologically positive margins to be an independent risk factor for IASC[10], while another study found no increased risk of IASC with inflammation present at the margins[9]. Although no meta-analysis has been performed on these data, the majority of studies suggest that multiple resections and extent of resection are not associated with increased intra-abdominal sepsis.

Operative timing

Crohn's disease can require urgent or elective surgeries depending on the indication for surgery. Only one study found an association between emergent operation and increased risk for IASC although it was not an independent risk factor in a multivariate analysis[10]. In contrast, emergent surgery was not associated with IASC in other studies[14,17]. Thus the setting of emergent compared to elective operation does not greatly impact postoperative intra-abdominal complications.

Operative time

The length of time in the operating room has previously been identified as a risk factor for anastomotic leak in colorectal surgery[27]. The operative time was independently associated with IASC in two studies[14,21], however it was not associated with IASC in another study[17]. Like other colorectal surgeries, prolonged operations could increase the risk of IASC especially anastomotic leak, but larger studies or a meta-analysis would provide more definitive recommendations.

Perioperative bleeding

Blood loss in the operating room greater than 150 mL is an independent risk factor for IASC[21], and blood loss greater than 300 mL was associated with an increased risk of IASC in univariate but not multivariate analysis[14]. Some studies reported perioperative blood transfusion, suggesting increased blood loss; however, blood loss or transfusion does not clinically impact IASC[8,17].

Smoking

Cigarette smoking can affect the disease course as those who smoke have an increased need for surgery as well as increased risk of recurrence[20]. Smoking has been associated with an increased risk in overall complication rates after surgery for Crohn's disease[23], but intra-abdominal sepsis was not association with an increased rate of postoperative abdominal septic complications. Smoking did not affect the rate of IASC[10,11,15,17] thus smoking is not a risk factor for IASC.

DISCUSSION

Preoperative nutritional status in Crohn's patients, measured by unexpected weight loss, increased the risk for postoperative IASC. When patients with weight loss receive preoperative nutritional supplementation,

this effect is no longer seen. Albumin level also seems to be associated with higher IASC rate in meta-analyses, but the albumin ranges varied widely between studies, complicating the combined data interpretation for albumin. Preoperative malnutrition nonetheless is associated with increased IASC. Intra-abdominal sepsis, with presence of an abscess at time of surgery, increased the risk for IASC, and some studies showed preoperative drainage decreased this risk. Steroid use before surgery was associated with an increase in IASC. Prior operation was a risk factor in a meta-analysis, but each study included in that analysis did not find and association with IASC. Further investigations, such as a larger study, are needed to verify the increased IASC risk with prior operation for Crohn's disease. Although prolonged operative time was the final variable associated with a higher rate of IASC, this was based upon limited number of studies thus further investigation is warranted. Factors not associated with IASC are use of immunomodulators or biologics, duration of disease, operative setting: emergent or elective, blood loss, and smoking. Since IASC is associated with an increased risk of early recurrence, preventing IASC can assist in lowering the recurrence rate and subsequently the need for further surgery.

CONCLUSION

Risk factors associated with postoperative anastomotic complications in Crohn's disease include preoperative weight loss, abdominal abscess present at surgery, prior surgery, and steroid use. Preoperative optimization should be attempted to decrease postoperative complications in these patients, particularly nutritional supplementation and abscess drainage. Since IASC is associated with an increased risk of early recurrence, preventing IASC can assist in lowering the recurrence rate and subsequently the need for further surgery. In patients with multiple risk factors that cannot be optimized preoperatively, a diverting stoma should be considered.

REFERENCES

1 **Farmer RG**, Whelan G, Fazio VW. Long-term follow-up of patients with Crohn's disease. Relationship between the clinical pattern and prognosis. *Gastroenterology* 1985; **88**: 1818-1825 [PMID: 3922845]

2 **Cosnes J**, Nion-Larmurier I, Beaugerie L, Afchain P, Tiret E, Gendre JP. Impact of the increasing use of immunosuppressants in Crohn's disease on the need for intestinal surgery. *Gut* 2005; **54**: 237-241 [PMID: 15647188 DOI: 10.1136/gut.2004.045294]

3 **Michelassi F**, Balestracci T, Chappell R, Block GE. Primary and recurrent Crohn's disease. Experience with 1379 patients. *Ann Surg* 1991; **214**: 230-238; discussion 238-240 [PMID: 1929605]

4 **Langholz E**. Current trends in inflammatory bowel disease: the natural history. *Therap Adv Gastroenterol* 2010; **3**: 77-86 [PMID: 21180592 DOI: 10.1177/1756283X10361304]

5 **Mijac DD**, Janković GL, Jorga J, Krstić MN. Nutritional status in patients with active inflammatory bowel disease: prevalence of malnutrition and methods for routine nutritional assessment. *Eur J Intern Med* 2010; **21**: 315-319 [PMID: 20603043 DOI: 10.1016/j.ejim.2010.04.012]

6 **Valentini L**, Schulzke JD. Mundane, yet challenging: the assessment of malnutrition in inflammatory bowel disease. *Eur J Intern Med* 2011; **22**: 13-15 [PMID: 21238886 DOI: 10.1016/j.ejim.2010.07.021]

7 **Yamamoto T**, Allan RN, Keighley MR. Risk factors for intra-abdominal sepsis after surgery in Crohn's disease. *Dis Colon Rectum* 2000; **43**: 1141-1145 [PMID: 10950014]

8 **Myrelid P**, Olaison G, Sjödahl R, Nyström PO, Almer S, Andersson P. Thiopurine therapy is associated with postoperative intra-abdominal septic complications in abdominal surgery for Crohn's disease. *Dis Colon Rectum* 2009; **52**: 1387-1394 [PMID: 19617749 DOI: 10.1007/DCR.0b013e3181a7ba96]

9 **Post S**, Betzler M, von Ditfurth B, Schürmann G, Küppers P, Herfarth C. Risks of intestinal anastomoses in Crohn's disease. *Ann Surg* 1991; **213**: 37-42 [PMID: 1985536]

10 **Shental O**, Tulchinsky H, Greenberg R, Klausner JM, Avital S. Positive histological inflammatory margins are associated with increased risk for intra-abdominal septic complications in patients undergoing ileocolic resection for Crohn's disease. *Dis Colon Rectum* 2012; **55**: 1125-1130 [PMID: 23044672 DOI: 10.1097/DCR.0b013e318267c74c]

11 **Tay GS**, Binion DG, Eastwood D, Otterson MF. Multivariate analysis suggests improved perioperative outcome in Crohn's disease patients receiving immunomodulator therapy after segmental resection and/or strictureplasty. *Surgery* 2003; **134**: 565-572; discussion 572-573 [PMID: 14605616 DOI: 10.1016/S0039]

12 **Heimann TM**, Greenstein AJ, Mechanic L, Aufses AH. Early complications following surgical treatment for Crohn's disease. *Ann Surg* 1985; **201**: 494-498 [PMID: 3977451]

13 **Resegotti A**, Astegiano M, Farina EC, Ciccone G, Avagnina G, Giustetto A, Campra D, Fronda GR. Side-to-side stapled anastomosis strongly reduces anastomotic leak rates in Crohn's disease surgery. *Dis Colon Rectum* 2005; **48**: 464-468 [PMID: 15719193 DOI: 10.1007/s10350-004-0786-6]

14 **Kanazawa A**, Yamana T, Okamoto K, Sahara R. Risk factors for postoperative intra-abdominal septic complications after bowel resection in patients with Crohn's disease. *Dis Colon Rectum* 2012; **55**: 957-962 [PMID: 22874602 DOI: 10.1097/DCR.0b013e3182617716]

15 **Tzivanakis A**, Singh JC, Guy RJ, Travis SP, Mortensen NJ, George BD. Influence of risk factors on the safety of ileocolic anastomosis in Crohn's disease surgery. *Dis Colon Rectum* 2012; **55**: 558-562 [PMID: 22513434 DOI: 10.1097/DCR.0b013e318247c433]

16 **Huang W**, Tang Y, Nong L, Sun Y. Risk factors for postoperative intra-abdominal septic complications after surgery in Crohn's disease: A meta-analysis of observational studies. *J Crohns Colitis* 2015; **9**: 293-301 [PMID: 25572276 DOI: 10.1093/ecco-jcc/jju028]

17 **Alves A**, Panis Y, Bouhnik Y, Pocard M, Vicaut E, Valleur P. Risk factors for intra-abdominal septic complications after a first ileocecal resection for Crohn's disease: a multivariate analysis in 161 consecutive patients. *Dis Colon Rectum* 2007; **50**: 331-336 [PMID: 17252288 DOI: 10.1007/s10350-006-0782-0]

18 **Iesalnieks I**, Kilger A, Glass H, Müller-Wille R, Klebl F, Ott C, Strauch U, Piso P, Schlitt HJ, Agha A. Intraabdominal septic complications following bowel resection for Crohn's disease: detrimental influence on long-term outcome. *Int J Colorectal Dis* 2008; **23**: 1167-1174 [PMID: 18690466 DOI: 10.1007/s00384-008-0534-9]

19 **Serradori T**, Germain A, Scherrer ML, Ayav C, Perez M, Romain B, Palot JP, Rohr S, Peyrin-Biroulet L, Bresler L. The effect of immune therapy on surgical site infection following Crohn's Disease resection. *Br J Surg* 2013; **100**: 1089-1093 [PMID: 23649458 DOI: 10.1002/bjs.9152]

20 **Yamamoto T**. Factors affecting recurrence after surgery for Crohn's disease. *World J Gastroenterol* 2005; **11**: 3971-3979 [PMID: 15996018]

21 **El-Hussuna A**, Andersen J, Bisgaard T, Jess P, Henriksen M, Oehlenschlager J, Thorlacius-Ussing O, Olaison G. Biologic treatment or immunomodulation is not associated with postoperative anastomotic complications in abdominal surgery for Crohn's disease.

Scand J Gastroenterol 2012; **47**: 662-668 [PMID: 22486168 DOI: 10.3109/00365521.2012.660540]

22 **Nasir BS**, Dozois EJ, Cima RR, Pemberton JH, Wolff BG, Sandborn WJ, Loftus EV, Larson DW. Perioperative anti-tumor necrosis factor therapy does not increase the rate of early postoperative complications in Crohn's disease. *J Gastrointest Surg* 2010; **14**: 1859-1865; discussion 1865-1866 [PMID: 20872084 DOI: 10.1007/s11605-010-1341-5]

23 **Riss S**, Bittermann C, Zandl S, Kristo I, Stift A, Papay P, Vogelsang H, Mittlböck M, Herbst F. Short-term complications of wide-lumen stapled anastomosis after ileocolic resection for Crohn's disease: who is at risk? *Colorectal Dis* 2010; **12**: e298-e303 [PMID: 20041915 DOI: 10.1111/j.1463-1318.2009.02180.x]

24 **Ahmed Ali U**, Martin ST, Rao AD, Kiran RP. Impact of preoperative immunosuppressive agents on postoperative outcomes in Crohn's disease. *Dis Colon Rectum* 2014; **57**: 663-674 [PMID: 24819109 DOI: 10.1097/DCR.0000000000000099]

25 **Appau KA**, Fazio VW, Shen B, Church JM, Lashner B, Remzi F, Brzezinski A, Strong SA, Hammel J, Kiran RP. Use of infliximab within 3 months of ileocolonic resection is associated with adverse postoperative outcomes in Crohn's patients. *J Gastrointest Surg* 2008; **12**: 1738-1744 [PMID: 18709420 DOI: 10.1007/s11605-008-0646-0]

26 **Fazio VW**, Marchetti F, Church M, Goldblum JR, Lavery C, Hull TL, Milsom JW, Strong SA, Oakley JR, Secic M. Effect of resection margins on the recurrence of Crohn's disease in the small bowel. A randomized controlled trial. *Ann Surg* 1996; **224**: 563-571; discussion 571-573 [PMID: 8857860]

27 **Buchs NC**, Gervaz P, Secic M, Bucher P, Mugnier-Konrad B, Morel P. Incidence, consequences, and risk factors for anastomotic dehiscence after colorectal surgery: a prospective monocentric study. *Int J Colorectal Dis* 2008; **23**: 265-270 [PMID: 18034250 DOI: 10.1007/s00384-007-0399-3]

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MINIREVIEWS

New minimally invasive approaches for cholecystectomy: Review of literature

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Abstract

Laparoscopic cholecystectomy is the most commonly performed abdominal intervention in Western countries. In an attempt to reduce the invasiveness of the procedure, surgeons have developed single-incision laparoscopic cholecystectomy (SILC), minilaparoscopic cholecystectomy (MLC) and natural orifice transluminal endoscopic surgery (NOTES). The aim of this review was to determine the role of these new minimally invasive approaches for elective laparoscopic cholecystectomy in the treatment of gallstone related disease. Current literature remains insufficient for the correct assessment of emerging techniques for laparoscopic cholecystectomy. None of these procedures has demonstrated clear benefits over conventional laparoscopic cholecystectomy. SILC cannot be currently recommended as it can be associated with an increased risk of bile duct injury and incisional hernia incidence. NOTES cholecystectomy is still experimental, although hybrid transvaginal cholecystectomy is gaining popularity in clinical practice. As it is standardized and almost identical to the standard laparoscopic technique, MLC could lead to limited benefits without exposing patients to increased postoperative complications, being therefore adoptable for routine elective cholecystectomy. Technical challenges of SILC and NOTES cholecystectomy could be addressed with the evolution of new surgical tools that need to catch up with the innovative minds of surgeons. Regardless the place of these approaches in the future, robotization may be necessary to impose them as standard treatment.

Key words: Cholecystectomy; Laparoscopy; Single-incision laparoscopic surgery; Minilaparoscopy; Natural orifice transluminal endoscopic surgery; Review

Core tip: In an attempt to reduce the invasiveness of laparoscopic cholecystectomy, surgeons have developed single-incision laparoscopic cholecystectomy (SILC), minilaparoscopic cholecystectomy (MLC) and natural orifice transluminal endoscopic surgery (NOTES), which are hereby evaluated. SILC cannot be recommended as

it can be associated with an increased risk of bile duct injury. NOTES cholecystectomy is still experimental, although hybrid transvaginal cholecystectomy is gaining popularity. As it is standardized and almost identical to the standard laparoscopic technique, MLC could lead to limited benefits without exposing patients to increased postoperative complications, being therefore adoptable for routine elective cholecystectomy.

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INTRODUCTION

Laparoscopic cholecystectomy has become the procedure of choice for routine gallbladder removal and is currently the most commonly performed abdominal intervention in Western countries[1]. Compared to open cholecystectomy, laparoscopic cholecystectomy decreases postoperative pain and the need for postoperative analgesia, shortens hospital stay and return to full activity, with improved cosmesis and patient satisfaction[2]. The laparoscopic approach has gained acceptance not through organized and carefully conceived clinical trials but through commendation. Prospective randomized trials were late and irrelevant because advantages were already clear at the moment of their conception. Thus, laparoscopic cholecystectomy has received universal acceptance and is now considered the gold standard for the treatment of symptomatic cholecystolithiasis[3]. Moreover, trials have shown that day-case laparoscopic cholecystectomy was safe and successful, indicating that it should be offered to most patients in an outpatient basis[4].

Conventional laparoscopic cholecystectomy (CLC) is traditionally carried out with four ports (two 10-mm and two 5-mm ports). Since its introduction, investigators have attempted to achieve further improvements to the established technique, aiming to reduce the invasiveness of the procedure by decreasing the number and the size of the operating ports. The use of smaller incisions to complete the standard 4-port technique is broadly referred to as minilaparoscopic cholecystectomy[5] (MLC). Needlescopic surgery is a subcategory of minilaparoscopic surgery using ports and instruments that are less than or equal to 3 mm in diameter[6]. In reduced trocar surgery, cholecystectomy is performed with less than 4 incisions, up to single incision laparoscopic cholecystectomy (SILC)[7]. More recently, in an attempt to eliminate all skin incision, surgeons have described cholecystectomy with an endoscope through a natural orifice then through internal incision of a intraperitoneal viscus, so-called natural orifice transluminal endoscopic surgery (NOTES)[8].

The aim of the current review is to determine the role of these new minimally invasive approaches for elective laparoscopic cholecystectomy in the treatment of gallstone related disease.

FOREWORD TO LITERATURE REVIEW

CLC is a well-established technique, with minimal conversion to open surgery and low incidence of complications[9], allowing day-case surgery as a standard procedure[4]. Therefore, it is unlikely that the trials assessing minimally invasive approaches can be powered to measure either reduction in the complication rate or in the length of hospital stay. Use of pain as the primary outcome can also be misleading, as the clinical significance of reduction in pain scores measured by visual analogue scale is unknown for laparoscopic cholecystectomy[9]. Moreover, patient's perception of the cosmetic outcome after CLC is excellent[10,11], and improvements in cosmesis seems difficult to achieve when high rates of satisfaction exist with the established technique.

Another issue on the evaluation of these new minimally invasive approaches is the low quality of the existing studies[12,13], reporting mostly low samples with lack of blinding. There appears to be no standardization of the emerging techniques, limiting the relevance of a meta-analysis for comparison with CLC. In addition, a large majority of studies described follow-up of less than 12 mo, avoiding adequate interpretation of cosmetic outcome or incisional hernia rate[14,15].

It must be mentioned that existing studies comparing CLC to either SILC, MLC or NOTES cholecystectomy describe selected patients, including only uncomplicated cholecystolithiasis without previous upper abdominal laparotomy. At this time, no selection criteria for the optimal choice of minimally-invasive technique have been defined in the literature.

SINGLE-INCISION LAPAROSCOPIC CHOLECYSTECTOMY

The first SILC was described in 1997 by Navarra *et al*[7] in a report on 30 selected patients with favorable outcomes. The technique spread slowly until more recent years, with publication of numerous prospective randomized controlled trials. However, these randomized control trials had several drawbacks[16], most reporting small sample size. Moreover, there is significant heterogeneity amongst surgical procedures defined as single-incision surgery. A wide variation of techniques is described with regard to the use of multiport device or separate trocars in one incision, the instrumentation, the method of gallbladder anchorage and the exposure of Calot's triangle. Thus, there appears to be no standardization of the technique and comparison of SILC with standard multiport laparoscopic cholecystectomy suffers from this heterogeneity and lack a firm evidence base.

Proximity of instruments when used through a single incision results in inadequate retracting abilities and loss of triangulation, which may lead to suboptimal exposure of Calot's triangle. Furthermore, clashing of instruments is common and complicates a smooth and meticulous dissection. In the literature, SILC is associated with a longer operative time than the standard technique. The addition of at least one instrument is necessary in 5% to 8.4% of SILC procedures[12,17].

Potential advantages of SILC were that it could reduce postoperative pain, allow earlier return to work, result in greater patient satisfaction, and especially improve cosmetic results. A total of 16 meta-analysis have compared the outcomes of SILC to conventional 4-ports laparoscopic cholecystectomy[9,12,16-29]. The majority of these studies observed comparable post-operative pain[17,19,21-28] and time to return to normal activities[16,25], although 3 meta-analysis describe better postoperative pain scores within 24 h following SILC[12,16,20]. Likewise, SILC does not seem to provide a better quality of life[9,28]. Ten meta-analyses showed that SILC offered a better cosmetic score than CLC, three reported no difference, but all report short-time evaluation[9,12,16,17,19,20,22-28]. Interestingly, recent studies assessed long-term cosmesis after 4-port laparoscopic cholecystectomy, showing excellent cosmetic outcome with this standardized technique[10,11]. Moreover, these studies suggest that the umbilical port is the most related to wound-related issues such as pain, infection, or cosmesis dissatisfaction, problems that will not be eradicated with the use of a single-port approach.

Complication rates are low after laparoscopic cholecystectomy, thus no meta-analysis found statistical differences between single-incision and CLC. However, Allemann *et al*[18] specifically assessed the risk of bile duct injuries following these two procedures and observed a non statistically significant increase in the rate of bile duct injury (0.4%) and other biliary complications (1.6%) after SILC (0% and 0.5% respectively for CLC). A possible increased risk of port-site hernia after SILC is also difficult to evaluate, firstly because it is underestimated due to the lack of long-term results and secondly because of its low incidence. One meta-analysis[22] showed a higher risk of incisional hernia after SILC, while others observed a trend towards a higher rate of incisional hernia after SILC without reaching statistical significance[16,17,19]. Moreover, although data regarding cost-effectiveness is scarce, a longer average operative time and the need for advanced surgical supplies could lead to potential added costs[30,31].

Finally, it appears that SILC is at present unable to preserve the well-established safe principles of laparoscopic cholecystectomy and could thus be associated with an increased risk of complications. No distinct benefit of SILC over CLC has been identified to date, with the arguable exception of cosmesis. Therefore, until further trials demonstrate the safety of SILC, it cannot currently be recommended as a routine procedure for laparoscopic cholecystectomy. Technical challenges of SILC could be eradicated with the evolution of novel instrumentation. Regardless the role of this approach in the future, robotization may be necessary in order to propose it as standard treatment.

MINILAPAROSCOPIC CHOLECYSTECTOMY

The benefits, safety and feasibility of MLC were established in small series at the late 1990s[5,6,32,33]. Several prospective randomized controlled trials comparing MLC with CLC were published in the past decade, gathered in two systematic reviews[34,35] and three meta-analyses[13,36,37], although the latter include studies reporting less than 3-port laparoscopic cholecystectomy as minilaparoscopic approach.

By definition, MLC is carried out with the use of smaller diameter instruments than the 5-mm instruments used for CLC, a range of 1.7 to 3.5 mm being described. Most surgeons perform dissection of Calot's triangle with a 10-mm laparoscope in the umbilical site, only reverting to a 2- or 3-mm laparoscope for clipping the cystic duct and cystic artery[3,38-40]. Others reported using the 10-mm umbilical port for instrumental introduction and a 2- or 3-mm laparoscope[33]. The only difference between MLC and CLC being the size of the incisions made and the instruments used, the surgical technique remains almost identical, offering satisfactory triangulation and retraction. In our experience, MLC can be easily standardized, with a relatively short learning curve. MLC can be completed successfully in more than 80% of patients, the remaining being mostly converted to CLC[34]. In addition, the rate of conversion to open approach is similar for minilaparoscopic and CLC[13,35]. Operative time can be increased when performing MLC, but various studies did not observe a statistically significant difference[13,34,35].

The available data in the literature suggest that the advantages of MLC over CLC are limited. There appears to be no advantage of MLC over CLC regarding postoperative pain, length of hospital stay and return to professional activities[34-36]. The impact of minilaparoscopic approach on cosmetic outcomes is inconsistent, the evaluation being challenged by the heterogeneity of the studies[13,34,37], the excellent results of the conventional laparoscopic approach[10,11] and the absence of a reliable objective evaluation scale. Postoperative morbidity is not affected by the minilaparoscopic approach[34,35,37], demonstrating that MLC is a safe alternative to CLC. Additional cost related to the acquisition of minilaparoscopic instruments and ports is not assessed in the literature. However, instruments and ports are reusable and can be employed routinely for other laparoscopic procedures, such as hernia repair[41].

Finally, it seems that the use of smaller incisions in selected patients could lead to limited benefits (mainly cosmetic), without exposing them to increased

occurrence of adverse events. MLC appears as a standardizable and safe procedure, suitable for routine elective cholecystectomy.

NATURAL ORIFICE TRANSLUMINAL ENDOSCOPIC CHOLECYSTECTOMY

A new evolution in the history of gallbladder surgery occurred in the past few years with the first cases of cholecystectomy by NOTES. After several reports in animal models[42], Marescaux *et al*[8] performed the first NOTES cholecystectomy in a patient using transvaginal access and a single 2-mm abdominal entry port. Subsequently, several teams joined the development of NOTES cholecystectomy. Pure NOTES techniques have been described, using transvaginal access in humans or transgastric and transcolonic approaches in animal models[43-45]. However, in clinical practice, the hybrid technique is widely used, aiming to further add benefits of decreased invasiveness. Hybrid transgastric cholecystectomy has been reported in small case series[46], but the procedure is still technically challenging with the currently existing instrumentation. To date, due to the established safety of colpotomy, the majority of clinical NOTES cholecystectomy is performed through hybrid transvaginal access (TVC), which is hereby analyzed.

The novelty of the technique and the lack of operative standardization lead to heterogeneity between the studies in the literature. However, a trend towards standardization appeared in the last years, as the majority of studies use a 5-mm umbilical incision for initial laparoscopic visualization and deployment of instrumentation, and a transvaginal incision for insertion of a laparoscope along with a grasping forceps and for extraction of the specimen. This technique is associated with longer operative time than CLC, and the conversion rate of TVC to CLC is estimated at 10%[47].

To date, three randomized control trials have been published, comparing transvaginal hybrid cholecystectomy to conventional[47,48] or needlescopic[49] laparoscopic cholecystectomy, along with one meta-analysis[50]. The proponents of NOTES cite reduced postoperative pain as an advantage of TVC over CLC. However, a recent meta-analysis showed a non-significant reduction in postoperative pain but a significant decrease in time for return to normal activities[50]. Another clear benefit of TVC is improved cosmesis. Importantly, there appears to be no significant difference in postoperative complications or rate of bile duct injury between TVC and CLC in these trials, conducted in centers of excellence and on selected patients[50]. Moreover, several studies reported no dyspareunia or difference in return to sexual activity between TVC and CLC groups after short-term follow-up[47-49].

Therefore, the hybrid transvaginal technique is a promising minimally invasive approach for cholecystectomy, though it demands further standardization. Despite the lack of high-powered studies, TVC seems safe in selected patients when performed by skilled surgeons. Furthermore, it has a similar morbidity to CLC and may be associated with decreased postoperative pain and time for return to normal activities. The major drawback of TVC is its applicability to only half of the patients with symptomatic cholecystolithiasis. In addition, even among women, the use of the transvaginal approach should be evaluated with regards to potential risks on subsequent fertility and discomfort during sexual intercourse.

Impediments for the adoption of other types of NOTES cholecystectomy include skepticism on transgressing and closing mucosal barriers[51], but also the lack of technological evolution of surgical tools and platforms that need to catch up with the innovative minds of surgeons.

CONCLUSION

Technical innovation within surgery is laudable and the progress that results is generally a consequence of the quest to achieve optimum outcomes for patients. To date, current literature remains insufficient for the correct assessment of new minimally invasive approaches for laparoscopic cholecystectomy. None of these emerging techniques has demonstrated clear benefits over CLC. SILC cannot be currently recommended as it appears to be associated with an increased risk of bile duct injuries and a potential for increased incisional hernia incidence. NOTES cholecystectomy is still experimental, although hybrid TVC is gaining popularity in clinical practice. As it is standardized and almost identical to the conventional technique, MLC could provide limited benefits without exposing patients to increased postoperative complications, and is therefore suitable for routine elective cholecystectomy.

REFERENCES

1 **Litwin DE**, Cahan MA. Laparoscopic cholecystectomy. *Surg Clin North Am* 2008; **88**: 1295-1313, ix [PMID: 18992596 DOI: 10.1016/j.suc.2008.07.005]

2 **McMahon AJ**, Russell IT, Baxter JN, Ross S, Anderson JR, Morran CG, Sunderland G, Galloway D, Ramsay G, O'Dwyer PJ. Laparoscopic versus minilaparotomy cholecystectomy: a randomised trial. *Lancet* 1994; **343**: 135-138 [PMID: 7904002 DOI: 10.1016/S0140-6736(94)90932-6]

3 Gallstones and laparoscopic cholecystectomy. *NIH Consens Statement* 1992; **10**: 1-28 [PMID: 1301217]

4 **Gurusamy K**, Junnarkar S, Farouk M, Davidson BR. Meta-analysis of randomized controlled trials on the safety and effectiveness of day-case laparoscopic cholecystectomy. *Br J Surg* 2008; **95**: 161-168 [PMID: 18196561 DOI: 10.1002/bjs.6105]

5 **Yuan RH**, Lee WJ, Yu SC. Mini-laparoscopic cholecystectomy: a cosmetically better, almost scarless procedure. *J Laparoendosc Adv Surg Tech A* 1997; **7**: 205-211 [PMID: 9448114 DOI: 10.1089/lap.1997.7.205]

6 **Ngoi SS**, Goh P, Kok K, Kum CK, Cheah WK. Needlescopic or minisite cholecystectomy. *Surg Endosc* 1999; **13**: 303-305 [PMID: 10064772 DOI: 10.1007/s004649900971]

7 **Navarra G**, Pozza E, Occhionorelli S, Carcoforo P, Donini I. One-

wound laparoscopic cholecystectomy. *Br J Surg* 1997; **84**: 695 [PMID: 9171771]

8 **Marescaux J**, Dallemagne B, Perretta S, Wattiez A, Mutter D, Coumaros D. Surgery without scars: report of transluminal cholecystectomy in a human being. *Arch Surg* 2007; **142**: 823-826; discussion 826-827 [PMID: 17875836 DOI: 10.1001/archsurg.142.9.823]

9 **Gurusamy KS**, Vaughan J, Rossi M, Davidson BR. Fewer-than-four ports versus four ports for laparoscopic cholecystectomy. *Cochrane Database Syst Rev* 2014; **2**: CD007109 [PMID: 24558020 DOI: 10.1002/14651858.CD007109.pub2]

10 **Bignell M**, Hindmarsh A, Nageswaran H, Mothe B, Jenkinson A, Mahon D, Rhodes M. Assessment of cosmetic outcome after laparoscopic cholecystectomy among women 4 years after laparoscopic cholecystectomy: is there a problem? *Surg Endosc* 2011; **25**: 2574-2577 [PMID: 21424204 DOI: 10.1007/s00464-011-1589-1]

11 **Monkhouse SJ**, Court EL, Beard LA, Bunni J, Burgess P. A retrospective wound review of standard four-port laparoscopic cholecystectomy: is there need for single-port laparoscopic surgery? *Surg Endosc* 2012; **26**: 255-260 [PMID: 21858572 DOI: 10.1007/s00464-011-1863-2]

12 **Arezzo A**, Scozzari G, Famiglietti F, Passera R, Morino M. Is single-incision laparoscopic cholecystectomy safe? Results of a systematic review and meta-analysis. *Surg Endosc* 2013; **27**: 2293-2304 [PMID: 23355161 DOI: 10.1007/s00464-012-2763-9]

13 **Thakur V**, Schlachta CM, Jayaraman S. Minilaparoscopic versus conventional laparoscopic cholecystectomy a systematic review and meta-analysis. *Ann Surg* 2011; **253**: 244-258 [PMID: 21183848 DOI: 10.1097/SLA.0b013e318207bf52]

14 **Gurtner GC**, Werner S, Barrandon Y, Longaker MT. Wound repair and regeneration. *Nature* 2008; **453**: 314-321 [PMID: 18480812 DOI: 10.1038/nature07039]

15 **Bunting DM**. Port-site hernia following laparoscopic cholecystectomy. *JSLS* 2010; **14**: 490-497 [PMID: 21605509 DOI: 10.4293/108680810x12924466007728]

16 **Geng L**, Sun C, Bai J. Single incision versus conventional laparoscopic cholecystectomy outcomes: a meta-analysis of randomized controlled trials. *PLoS One* 2013; **8**: e76530 [PMID: 24098522 DOI: 10.1371/journal.pone.0076530]

17 **Trastulli S**, Cirocchi R, Desiderio J, Guarino S, Santoro A, Parisi A, Noya G, Boselli C. Systematic review and meta-analysis of randomized clinical trials comparing single-incision versus conventional laparoscopic cholecystectomy. *Br J Surg* 2013; **100**: 191-208 [PMID: 23161281 DOI: 10.1002/bjs.8937]

18 **Allemann P**, Demartines N, Schäfer M. Remains of the day: biliary complications related to single-port laparoscopic cholecystectomy. *World J Gastroenterol* 2014; **20**: 843-851 [PMID: 24574757 DOI: 10.3748/wjg.v20.i3.843]

19 **Garg P**, Thakur JD, Garg M, Menon GR. Single-incision laparoscopic cholecystectomy vs. conventional laparoscopic cholecystectomy: a meta-analysis of randomized controlled trials. *J Gastrointest Surg* 2012; **16**: 1618-1628 [PMID: 22580841 DOI: 10.1007/s11605-012-1906-6]

20 **Hao L**, Liu M, Zhu H, Li Z. Single-incision versus conventional laparoscopic cholecystectomy in patients with uncomplicated gallbladder disease: a meta-analysis. *Surg Laparosc Endosc Percutan Tech* 2012; **22**: 487-497 [PMID: 23238374 DOI: 10.1097/SLE.0b013e3182685d0a]

21 **Markar SR**, Karthikesalingam A, Thrumurthy S, Muirhead L, Kinross J, Paraskeva P. Single-incision laparoscopic surgery (SILS) vs. conventional multiport cholecystectomy: systematic review and meta-analysis. *Surg Endosc* 2012; **26**: 1205-1213 [PMID: 22173546 DOI: 10.1007/s00464-011-2051-0]

22 **Milas M**, Devećija S, Trkulja V. Single incision versus standard multiport laparoscopic cholecystectomy: up-dated systematic review and meta-analysis of randomized trials. *Surgeon* 2014; **12**: 271-289 [PMID: 24529791 DOI: 10.1016/j.surge.2014.01.009]

23 **Pisanu A**, Reccia I, Porceddu G, Uccheddu A. Meta-analysis of prospective randomized studies comparing single-incision laparoscopic cholecystectomy (SILC) and conventional multiport laparoscopic cholecystectomy (CMLC). *J Gastrointest Surg* 2012; **16**: 1790-1801 [PMID: 22767084 DOI: 10.1007/s11605-012-1956-9]

24 **Qiu J**, Yuan H, Chen S, He Z, Han P, Wu H. Single-port versus conventional multiport laparoscopic cholecystectomy: a meta-analysis of randomized controlled trials and nonrandomized studies. *J Laparoendosc Adv Surg Tech A* 2013; **23**: 815-831 [PMID: 24079960 DOI: 10.1089/lap.2013.0040]

25 **Sajid MS**, Ladwa N, Kalra L, Hutson KK, Singh KK, Sayegh M. Single-incision laparoscopic cholecystectomy versus conventional laparoscopic cholecystectomy: meta-analysis and systematic review of randomized controlled trials. *World J Surg* 2012; **36**: 2644-2653 [PMID: 22855214 DOI: 10.1007/s00268-012-1719-5]

26 **Wang Z**, Huang X, Zheng Q. Single-incision versus conventional laparoscopic cholecystectomy: a meta-analysis. *ANZ J Surg* 2012; **82**: 885-889 [PMID: 23009184 DOI: 10.1111/j.1445-2197.2012.06284.x]

27 **Wu XS**, Shi LB, Gu J, Dong P, Lu JH, Li ML, Mu JS, Wu WG, Yang JH, Ding QC, Zhang L, Liu YB. Single-incision laparoscopic cholecystectomy versus multi-incision laparoscopic cholecystectomy: a meta-analysis of randomized clinical trials. *J Laparoendosc Adv Surg Tech A* 2013; **23**: 183-191 [PMID: 23234334 DOI: 10.1089/lap.2012.0189]

28 **Zehetner J**, Pelipad D, Darehzereshki A, Mason RJ, Lipham JC, Katkhouda N. Single-access laparoscopic cholecystectomy versus classic laparoscopic cholecystectomy: a systematic review and meta-analysis of randomized controlled trials. *Surg Laparosc Endosc Percutan Tech* 2013; **23**: 235-243 [PMID: 23751985 DOI: 10.1097/SLE.0b013e31828b8b4e]

29 **Tamini N**, Rota M, Bolzonaro E, Nespoli L, Nespoli A, Valsecchi MG, Gianotti L. Single-incision versus standard multiple-incision laparoscopic cholecystectomy: a meta-analysis of experimental and observational studies. *Surg Innov* 2014; **21**: 528-545 [PMID: 24608182 DOI: 10.1177/1553350614521017]

30 **Henriksen NA**, Al-Tayar H, Rosenberg J, Jorgensen LN. Cost assessment of instruments for single-incision laparoscopic cholecystectomy. *JSLS* 2012; **16**: 353-359 [PMID: 23318059 DOI: 10.4293/108680812x13427982377021]

31 **Leung D**, Yetasook AK, Carbray J, Butt Z, Hoeger Y, Denham W, Barrera E, Ujiki MB. Single-incision surgery has higher cost with equivalent pain and quality-of-life scores compared with multiple-incision laparoscopic cholecystectomy: a prospective randomized blinded comparison. *J Am Coll Surg* 2012; **215**: 702-708 [PMID: 22819642 DOI: 10.1016/j.jamcollsurg.2012.05.038]

32 **Kimura T**, Sakuramachi S, Yoshida M, Kobayashi T, Takeuchi Y. Laparoscopic cholecystectomy using fine-caliber instruments. *Surg Endosc* 1998; **12**: 283-286 [PMID: 9502715]

33 **Reardon PR**, Kamelgard JI, Applebaum B, Rossman L, Brunicardi FC. Feasibility of laparoscopic cholecystectomy with miniaturized instrumentation in 50 consecutive cases. *World J Surg* 1999; **23**: 128-131; discussion 131-132 [PMID: 9880420]

34 **Gurusamy KS**, Vaughan J, Ramamoorthy R, Fusai G, Davidson BR. Miniports versus standard ports for laparoscopic cholecystectomy. *Cochrane Database Syst Rev* 2013; **8**: CD006804 [PMID: 23908012 DOI: 10.1002/14651858.CD006804.pub3]

35 **McCloy R**, Randall D, Schug SA, Kehlet H, Simanski C, Bonnet F, Camu F, Fischer B, Joshi G, Rawal N, Neugebauer EA. Is smaller necessarily better? A systematic review comparing the effects of minilaparoscopic and conventional laparoscopic cholecystectomy on patient outcomes. *Surg Endosc* 2008; **22**: 2541-2553 [PMID: 18810546 DOI: 10.1007/s00464-008-0055-1]

36 **Hosono S**, Osaka H. Minilaparoscopic versus conventional laparoscopic cholecystectomy: a meta-analysis of randomized controlled trials. *J Laparoendosc Adv Surg Tech A* 2007; **17**: 191-199 [PMID: 17484646 DOI: 10.1089/lap.2006.0051]

37 **Sajid MS**, Khan MA, Ray K, Cheek E, Baig MK. Needlescopic versus laparoscopic cholecystectomy: a meta-analysis. *ANZ J Surg* 2009; **79**: 437-442 [PMID: 19566866 DOI: 10.1111/j.1445-2197.2009.04945.x]

38 **Huang MT**, Wang W, Wei PL, Chen RJ, Lee WJ. Minilaparoscopic and laparoscopic cholecystectomy: a comparative study. *Arch Surg* 2003; **138**: 1017-1023 [PMID: 12963662 DOI: 10.1001/archsurg.138.9.1017]

39 **Lee PC**, Lai IR, Yu SC. Minilaparoscopic (needlescopic) cholecystectomy: a study of 1,011 cases. *Surg Endosc* 2004; **18**: 1480-1484

[PMID: 15791373 DOI: 10.1007/s00464-003-8247-1]
40 **Saad S**, Strassel V, Sauerland S. Randomized clinical trial of single-port, minilaparoscopic and conventional laparoscopic cholecystectomy. *Br J Surg* 2013; **100**: 339-349 [PMID: 23188563]
41 **Wada H**, Kimura T, Kawabe A, Sato M, Miyaki Y, Tochikubo J, Inamori K, Shiiya N. Laparoscopic transabdominal preperitoneal inguinal hernia repair using needlescopic instruments: a 15-year, single-center experience in 317 patients. *Surg Endosc* 2012; **26**: 1898-1902 [PMID: 22223115 DOI: 10.1007/s00464-011-2122-2]
42 **Park PO**, Bergström M, Ikeda K, Fritscher-Ravens A, Swain P. Experimental studies of transgastric gallbladder surgery: cholecystectomy and cholecystogastric anastomosis (videos). *Gastrointest Endosc* 2005; **61**: 601-606 [PMID: 15812420 DOI: 10.1016/S0016-5107(04)02774-9]
43 **Gumbs AA**, Fowler D, Milone L, Evanko JC, Ude AO, Stevens P, Bessler M. Transvaginal natural orifice translumenal endoscopic surgery cholecystectomy: early evolution of the technique. *Ann Surg* 2009; **249**: 908-912 [PMID: 19474690 DOI: 10.1097/SLA.0b013e3181a802e2]
44 **Asakuma M**, Perretta S, Allemann P, Cahill R, Dallemagne B, Tanigawa N, Marescaux J. Multimedia article. Per-oral dual scope NOTES cholecystectomy in porcine model (with video). *Surg Endosc* 2010; **24**: 2624-2625 [PMID: 20354867 DOI: 10.1007/s00464-010-0992-3]
45 **Auyang ED**, Hungness ES, Vaziri K, Martin JA, Soper NJ. Natural orifice translumenal endoscopic surgery (NOTES): dissection for the critical view of safety during transcolonic cholecystectomy. *Surg Endosc* 2009; **23**: 1117-1118 [PMID: 19263107 DOI: 10.1007/s00464-009-0407-5]
46 **Salinas G**, Saavedra L, Agurto H, Quispe R, Ramírez E, Grande J, Tamayo J, Sánchez V, Málaga D, Marks JM. Early experience in human hybrid transgastric and transvaginal endoscopic cholecystectomy. *Surg Endosc* 2010; **24**: 1092-1098 [PMID: 19997754 DOI: 10.1007/s00464-009-0733-7]
47 **Borchert DH**, Federlein M, Fritze-Büttner F, Burghardt J, Liersch-Löhn B, Atas Y, Müller V, Rückbeil O, Wagenpfeil S, Gräber S, Gellert K. Postoperative pain after transvaginal cholecystectomy: single-center, double-blind, randomized controlled trial. *Surg Endosc* 2014; **28**: 1886-1894 [PMID: 24464385 DOI: 10.1007/s00464-013-3409-2]
48 **Noguera JF**, Cuadrado A, Dolz C, Olea JM, García JC. Prospective randomized clinical trial comparing laparoscopic cholecystectomy and hybrid natural orifice transluminal endoscopic surgery (NOTES) (NCT00835250). *Surg Endosc* 2012; **26**: 3435-3441 [PMID: 22648123 DOI: 10.1007/s00464-012-2359-4]
49 **Bulian DR**, Knuth J, Cerasani N, Sauerwald A, Lefering R, Heiss MM. Transvaginal/transumbilical hybrid--NOTES--versus 3-trocar needlescopic cholecystectomy: short-term results of a randomized clinical trial. *Ann Surg* 2015; **261**: 451-458 [PMID: 24108196 DOI: 10.1097/sla.0000000000000218]
50 **Sodergren MH**, Markar S, Pucher PH, Badran IA, Jiao LR, Darzi A. Safety of transvaginal hybrid NOTES cholecystectomy: a systematic review and meta-analysis. *Surg Endosc* 2015; **29**: 2077-2090 [PMID: 25424364 DOI: 10.1007/s00464-014-3915-x]
51 **Sodergren MH**, Pucher P, Clark J, James DR, Sockett J, Matar N, Teare J, Yang GZ, Darzi A. Disinfection of the Access Orifice in NOTES: Evaluation of the Evidence Base. *Diagn Ther Endosc* 2011; **2011**: 245175 [PMID: 21785559 DOI: 10.1155/2011/245175]

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MINIREVIEWS

Bursectomy at radical gastrectomy

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Abstract

Radical gastrectomy with extended lymph node dissection and prophylactic resection of the omentum, peritoneum over the posterior lesser sac, pancreas and/or spleen was advocated at the beginning of the 1960s in Japan. In time, prophylactic routine resections of the pancreas and/or spleen were abandoned because of the high incidence of postoperative complications. However, omentectomy and bursectomy continued to be standard parts of traditional radical gastrectomy. The bursa omentalis was thought to be a natural barrier against invasion of cancer cells into the posterior part of the stomach. The theoretical rationale for bursectomy was to reduce the risk of peritoneal recurrences by eliminating the peritoneum over the lesser sac, which might include free cancer cells or micrometastases. Over time, the indication for bursectomy was gradually reduced to only patients with posterior gastric wall tumors penetrating the serosa. Despite its theoretical advantages, its benefit for recurrence or survival has not been proven yet. The possible reasons for this inconsistency are discussed in this review. In conclusion, the value of bursectomy in the treatment of gastric cancer is still under debate and large-scale randomized studies are necessary. Until clear evidence of patient benefit is obtained, its routine use cannot be recommended.

Key words: Gastric cancer; Gastrectomy; Bursectomy; Omentum; Pancreas

Core tip: Components of radical gastrectomy have decreased over time but bursectomy has been still accepted as an integral part of radical gastrectomy by Far East surgeons but not world-wide. More large-scale comparative studies are necessary to determine its benefits for cancer recurrence and patient survival. Until patient benefits are demonstrated by future studies, its routine application cannot be justified.

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INTRODUCTION

The top three causes of cancer deaths in the world are lung cancers (1.4 million deaths/year), stomach

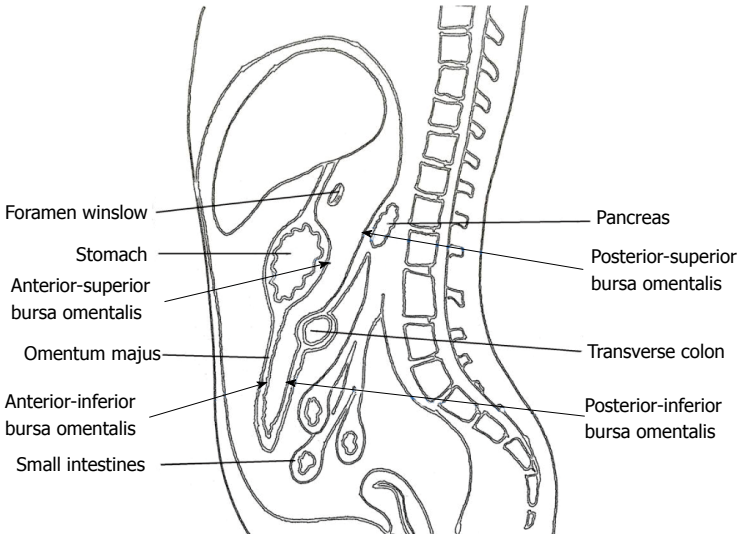

Figure 1 Anatomy of the bursa omentalis.

cancers (738000 deaths/year), and liver cancers (695900 deaths/year), respectively[1]. Stomach cancer refers to several different histological types of stomach tumors (stromal, carcinoid, lymphoma) but more than 90% of stomach cancers arise from the gastric mucosa as adenocarcinoma. The incidence of gastric adenocarcinoma shows a certain geographic distribution and it is highest in the Far East. A gender difference is also present and it is almost twice as common in men as in women. Surgery with curative intent such as radical gastrectomy and regional lymph node dissection produces the best treatment outcomes for advanced (beyond the submucosa) gastric adenocarcinomas. The extent of surgical resection includes gastrectomy (total or subtotal), lymphadenectomy (D1, D2 or D3), and prophylactic or therapeutic resection of the surrounding organs or tissues (*e.g.*, omentum, peritoneum, pancreas, spleen, colon, liver). Prophylactic or therapeutic peritonectomy over the lesser sac during radical gastrectomy is called bursectomy. The value of bursectomy in the treatment of gastric cancer is still under debate. This surgical technique is usually preferred by Far East surgeons[2] but is not accepted in the rest of the world. The aim of this article is to review the current data about the role of bursectomy in the treatment of gastric cancers.

HISTORY AND LOGIC OF BURSECTOMY

Radical gastrectomy with extended lymph node dissection was advocated at the beginning of the 1960s in Japan by Jinnai[3]. At that time, additional prophylactic resection of the omentum, the peritoneum over the posterior lesser sac, the pancreas and/or spleen had been justified as the standard procedure to perform during complete radical gastectomy. In time, prophylactic routine resections of the pancreas and/or spleen were abandoned because of the high incidence of postoperative complications[4]. However, omentectomy and bursectomy continued to be standard parts of traditional radical gastrectomy.

The omental bursa, also known as the lesser sac, is a posterior cavity in the abdomen and is demarcated anteriorly by the liver, stomach, and omentum. Posteriorly it is marked by the pancreas, left surrenal, and kidney (Figure 1). It is connected with the main anterior peritoneal cavity *via* the foramen of Winslow. The bursa omentalis was thought to be a natural barrier against invasive of cancer cells at the posterior part of the stomach and resection of the peritoneum lining over this cavity as bursectomy was accepted as a integral part of radical gastrectomy. The theoretical rationale for this procedure was to reduce the risk of peritoneal recurrences by eliminating the peritoneum over the lesser sac that might have included free cancer cells or micrometastases[5].

Bursectomy includes the removal of the peritoneal lining covering the pancreas (anterior pancreatic capsule) and the anterior plane of the transverse mesocolon along with a total omentectomy. Omentectomy has two objectives in a radical gastrectomy. First, it eliminates the perigastric lymph nodes along the greater curvature of the stomach, and second, it provides for the excision of the gastrocolic ligament that covers the anterior/inferior part of the lesser sac (Figure 1). The anterior/superior part of the lesser sac is removed by the gastrectomy itself. The posterior wall of the bursectomy is completed by removing the peritoneal sheath over the transverse mesocolon and the pancreas.

This Japanese-originated surgical technique has been known for 50 years and is mainly accepted by Far East surgeons but also by some other groups[6-9]. It was routinely recommended in the Japanese Gastric Cancer Treatment Guidelines as a part of radical surgery for gastric cancer without any supporting evidence, but was included due to traditional acceptance (version 1, 2001)[10]. The Japanese Gastric Cancer Association revised the gastric cancer treatment guidelines three years after the first version and recommended bursectomy only for serosa-invading tumors (version 2, 2004)[11]. Recently, they changed the guidelines again and this time they limited the indication of bursectomy only to posterior gastric wall tumors penetrating the

serosa (version 3, 2010)[12].

WEAKNESSES OF BURSECTOMY

Gastric cancers can penetrate the serosa at the anterior or posterior gastric walls. Penetrating tumors can cause seeding of the micrometastatic tumor cells to the free peritoneal surfaces. Anterior-wall-located serosal invasions can cause implantation into the entire intraperitoneal abdominopelvic cavity (greater sac) and prophylactic peritonectomy of all of the peritoneum is not justified. In theory, the risk of posteriorly located serosa-invading cancers may be reduced by peritonectomy of the lesser sac (bursectomy) and the posterior location itself can provide an advantage for controlling the tumor cells.

In 2004, Yoshikawa *et al*[13] analyzed the clinical records of patients who underwent radical gastrectomy with bursectomy for gastric cancer invading the serosa, with special reference to the location of tumor invasion. A total of 134 patients were divided into two groups, which included patients with serosa positive tumors that invaded only the posterior or anterior gastric walls. Survival rates at 3 and 5 years were 67.3% and 53.0% for the posterior group and 68.8% and 53.8% for the anterior group, respectively. There was no significant difference in survival between the two groups and multivariate analyses demonstrated that the significant independent factor for survival was the stage of the tumor, not the location as anterior or posterior. They suggested that bursectomy for posterior-located serosa invading tumors did not provide any survival benefit over their anterior counterparts. This was one of the first studies to raise doubts about the bursa omentalis being a natural barrier against implanted cancer cells and the role of bursectomy.

Histopathological confirmation of invisible tumor deposits in the retro-gastric cavity and on the peritoneum of the lesser sac can be good supporting evidence for prophylactic bursectomy. To study this, we sent bursectomy specimens (the anterior layer of the mesocolon and the pancreas) from 40 gastric cancer patients separately from the main gastrectomy specimens for pathological examination[14]. We also examined the cytology of bursa omentalis wash-out of these patients. Only four bursectomy specimens (10%) demonstrated positive cancer cells, and all of these patients already had macroscopic tumors on the peritoneal surfaces of the transverse mesocolon or pancreas. The cytology of bursa omentalis wash-out results was parallel to these pathological reports. Therefore, we failed to demonstrate invisible tumor cells in or on the lesser sac by conventional histopathology.

Anatomically, the cavity of the bursa omentalis is not a closed space and it is connected with the greater sac *via* the foramen of Winslow. Demonstration of the migration of tumor cells from the lesser sac to the greater sac or the contrary demonstration of the restriction of tumor cells to the lesser sac are important issues for the justification of bursectomy.

Yamamura *et al*[15] in 2007 examined the cytology of the peritoneal washes obtained from the Douglas pouch, left subphrenic cavity, and the inside of the omental bursa in 136 patients by real-time reverse transcriptase-polymerase chain reaction (RT-PCR) analysis. Cancer-related cells were detected in one or more samples from the three different sites of peritoneal washes in 43 (31.6%) patients. In 14 patients, these tumor cells were detected in the samples obtained from the bursa omentalis and in 12 (85.7%) of these 14 patients, cancer-related cells were also detected in the samples taken from the Douglas pouch or subpherenic cavity. This study demostrated that viable cancer cells disseminated into the bursa omentalis and did not remain restricted to this cavity. The authors suggested that these cells are unlikely to be optimal targets for surgical removal, and the emergence of more effective locoregional therapy is urgently needed to improve the survival of serosa-positive patients.

Lastly, quality control of the complete *en-bloc* bursectomy is not easy. It depends on both the experience of the surgeon and the patient's mesenteric fat content. While bursectomy is technically more comfortable in slim patients, finding the right plane over the transverse mesocolon in fatty patients can be troublesome. In some fatty patients, we tried to inject normal saline between the peritoneum and the mesenteric fat of the transverse colon to provide an easier bursectomy technique; however, this hydrodissection method failed.

TECHNIQUE OF BURSECTOMY

We usually prefer to begin bursectomy with the entrance to the avascular plane between the greater omentum and the transverse mesocolon in the midline. To facilitate finding the correct plane, the first assistant should hang the greater omentum up for retraction and the transverse colon should be retracted to the opposite site by the surgeon (Figure 2). Diathermy can be used for entering the embryonic avascular plane just over the colon and can improve these dissections. Care must be taken not to damage the appendicular arteries of the colon and dissections should be skipped over these arteries. Once entered into the avascular plane, it is easier to extend the dissections to the hepatic and splenic flexure of the mesocolon. During this peritoneal peeling, continuous counter-traction to both sides of the mesocolon and to the omentum is mandatory. We usually prefer sharp dissections but sometimes gentle blunt dissection can provide an easy and fast peritonectomy. *En-bloc* resection without any window on the peritoneum is desired, but it is not always possible. If there is a tear in the peritoneum over the mesocolon, patiently going back a few steps to work on removal from the free edge of the torn peritoneum should be the preferred approach. Care should also be taken to not damage the mesocolic vessels at the bottom. When the procedure reaches

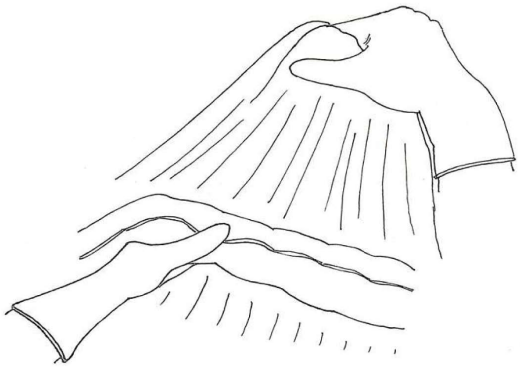

Figure 2 Traction and counter-traction of the omentum, stomach and colon.

the lower border of the pancreas, the dissection should be extended over it lengthwise. The entire posterior leaf of the peritoneum covering the lesser sac over the transverse mesocolon and the pancreas should be excised *en-bloc*.

CLINICAL RESULTS OF BURSECTOMY

There are only a limited number of studies that analyzed the influence of bursectomy on the survival of patients with gastric cancers[5,13,16-20]. Three studies are from Japan, one from South Korea, and one from the Ukraine. One of the early studies by Yoshikawa *et al*[13] compared the outcomes of bursectomy and non-bursectomy groups in a total of 134 serosa-positive gastric cancers. They suggested that there was no survival benefit of bursectomy in patients with gastric cancer[13]. In 2012, Fujita *et al*[5] reported the first results of their randomized study including 210 patients with T2-T3 gastric cancers. They found that bursectomy could improve survival and should not be abandoned as a futile procedure until more definitive data can be obtained[5].

Recently, the same group reported their updated results with the same conclusions[17]. However, their study included only 48 serosa-positive gastric cancers and there were no data about the comparability of the serosa-positive patients between groups. Cox multivariate analysis of the overall survival in that study pointed out that the most important independent factor for survival was the stage of the tumor (T stage, $P < 0.001$). Although nonbursectomy was found to be an independent risk factor ($P = 0.034$), male sex was also determined to be an independent risk factor in the same multivariated analysis ($P = 0.032$). These findings indicate that there were too few patients in that study to allow for clear conclusions.

The third study from Japan by Kochi *et al*[18] had a similar deficit in that only 41 of 254 patients had serosa-positive gastric cancers, and these authors found no survival benefit of bursectomy. In 2013, a congress abstract reported from the Ukraine that included 108 patients (T1-4) with gastric cancers concluded that the bursectomy group had a better 5-year survival, but the details of this study have not yet been published[19]. Eom *et al*[20] from South Korea compared bursectomy and nonbursectomy patients in a total of 381 serosa positive gastric cancers (nonbursectomy = 284 *vs* bursectomy = 97) and found in multivariate analyses that bursectomy was not a significant independent factor for survival.

CONCLUSION

Recently a meta-analysis that included all published studies on prophylactic bursectomy at radical gastrectomy was published[21]. According to the available data, the bursectomy did not show superiority to non-bursectomy in terms of survival in gastric cancer patients. Although the subgroup analyses suggested that bursectomy may improve survival in serosa-positive patients, this was not statistically significant and a definitive conclusion could not be made[21]. Because of the risk of potential morbidities[22], unless the exact benefits are demonstrated by forthcoming studies, its routine application cannot be justified. A large-scale multicentric Phase Ⅲ trial is currently underway for macroscopically subserosa or serosa-positive gastric cancer in Japan (JCOG 1001)[23]. This study included only patients from Japan, and it has already closed patient enrollment[23]. The long-term outcomes of this study will provide important information about the role of bursectomy at radical gastrectomy.

REFERENCES

1 **Jemal A**, Bray F, Center MM, Ferlay J, Ward E, Forman D. Global cancer statistics. *CA Cancer J Clin* 2011; **61**: 69-90 [PMID: 21296855 DOI: 10.3322/caac.20107]

2 **Shen L**, Shan YS, Hu HM, Price TJ, Sirohi B, Yeh KH, Yang YH, Sano T, Yang HK, Zhang X, Park SR, Fujii M, Kang YK, Chen LT. Management of gastric cancer in Asia: resource-stratified guidelines. *Lancet Oncol* 2013; **14**: e535-e547 [PMID: 24176572 DOI: 10.1016/S1470-2045(13)70436-4]

3 **Nakajima T**. Historical Review of Research and Treatment of Gastric Cancer in Japan: Clinical Aspect. The Diversity of Gastric Carcinoma: Pathogenesis, Diagnosis, and Therapy. In: Kaminishi M, Takubo K, Mafune K, editors. Springer, 2005: 29-47

4 **Maruyama K**, Sasako M, Kinoshita T, Sano T, Katai H. Surgical treatment for gastric cancer: the Japanese approach. *Semin Oncol* 1996; **23**: 360-368 [PMID: 8658220]

5 **Fujita J**, Kurokawa Y, Sugimoto T, Miyashiro I, Iijima S, Kimura Y, Takiguchi S, Fujiwara Y, Mori M, Doki Y. Survival benefit of bursectomy in patients with resectable gastric cancer: interim analysis results of a randomized controlled trial. *Gastric Cancer* 2012; **15**: 42-48 [PMID: 21573917 DOI: 10.1007/s10120-011-0058-9]

6 **Vural V**, Saylam B, Çomçalı B, Düzgün AP, Özer MV, Coşkun F. D1 versus D2 dissection in gastric carcinoma: Evaluation of postoperative mortality and complications. *Ulus Cerrahi Derg* 2013; **29**: 1-6 [PMID: 25931833]

7 **Bostanci EB**, Kayaalp C, Ozogul Y, Aydin C, Atalay F, Akoglu M. Comparison of complications after D2 and D3 dissection for gastric cancer. *Eur J Surg Oncol* 2004; **30**: 20-25 [PMID: 14736518 DOI: 10.1016/j.ejso.2003.10.008]

8 **Kung CH**, Lindblad M, Nilsson M, Rouvelas I, Kumagai K, Lundell L, Tsai JA. Postoperative pancreatic fistula formation according to ISGPF criteria after D2 gastrectomy in Western

patients. *Gastric Cancer* 2014; **17**: 571-577 [PMID: 24105422 DOI: 10.1007/s10120-013-0307-1]

9 **Blouhos K**, Boulas KA, Hatzigeorgiadis A. Bursectomy in gastric cancer surgery: surgical technique and operative safety. *Updates Surg* 2013; **65**: 95-101 [PMID: 23592040 DOI: 10.1007/s13304-013-0210-7]

10 **Japanese Gastric Cancer Association**. Commentary of gastric cancer treatment guidelines (in Japanese). Tokyo: JGCA, 2001

11 **Japanese Gastric Cancer Association**. Gastric cancer treatment guidelines (in Japanese). Tokyo: Kanehara, 2004: 9-10

12 **Japanese Gastric Cancer Association**. Japanese gastric cancer treatment guidelines 2010 (ver. 3). *Gastric Cancer* 2011; **14**: 113-123 [PMID: 21573742 DOI: 10.1007/s10120-011-0042-4]

13 **Yoshikawa T**, Tsuburaya A, Kobayashi O, Sairenji M, Motohashi H, Hasegawa S, Ishiwa N, Morinaga S, Noguchi Y, Yamamoto Y, Matsumoto A. Is bursectomy necessary for patients with gastric cancer invading the serosa? *Hepatogastroenterology* 2004; **51**: 1524-1526 [PMID: 15362792]

14 **Kayaalp C**, Olmez A, Piskin T. Prophylactic bursectomy at radical gastrectomy for gastric cancer. *Gastric Cancer* 2011; **14**: 399-400 [PMID: 21837456 DOI: 10.1007/s10120-011-0084-7]

15 **Yamamura Y**, Ito S, Mochizuki Y, Nakanishi H, Tatematsu M, Kodera Y. Distribution of free cancer cells in the abdominal cavity suggests limitations of bursectomy as an essential component of radical surgery for gastric carcinoma. *Gastric Cancer* 2007; **10**: 24-28 [PMID: 17334714 DOI: 10.1007/s10120-006-0404-5]

16 **Imamura H**, Kurokawa Y, Kawada J, Tsujinaka T, Takiguchi S, Fujiwara Y, Mori M, Doki Y. Influence of bursectomy on operative morbidity and mortality after radical gastrectomy for gastric cancer: results of a randomized controlled trial. *World J Surg* 2011; **35**: 625-630 [PMID: 21161652 DOI: 10.1007/s00268-010-0914-5]

17 **Hirao M**, Kurokawa Y, Fujita J, Imamura H, Fujiwara Y, Kimura Y, Takiguchi S, Mori M, Doki Y. Long-term outcomes after prophylactic bursectomy in patients with resectable gastric cancer: Final analysis of a multicenter randomized controlled trial. *Surgery* 2015; **157**: 1099-1105 [PMID: 25704429 DOI: 10.1016/j.surg.2014.12.024]

18 **Kochi M**, Fujii M, Kanamori N, Kaiga T, Mihara Y, Funada T, Tamegai H, Takayama Y, Yoshida N, Takayama T. D2 gastrectomy with versus without bursectomy for gastric cancer. *Am J Clin Oncol* 2014; **37**: 222-226 [PMID: 22892432 DOI: 10.1097/COC.0b013e31825eb734]

19 **Shchepotin I**, Kolesnik O, Lukashenko A, Rozumiy D, Burlaka A. D2 Gastrectmoy with versus without bursectomy for gastric cancer: Results of single center randomized trial. *Ann Oncol* 2013; **24**: P-0103 [DOI: 10.1093/annonc/mdt203.101]

20 **Eom BW**, Joo J, Kim YW, Bae JM, Park KB, Lee JH, Ryu KW, Kook MC. Role of bursectomy for advanced gastric cancer: result of a case-control study from a large volume hospital. *Eur J Surg Oncol* 2013; **39**: 1407-1414 [PMID: 24119717 DOI: 10.1016/j.ejso.2013.09.013]

21 **Shen WS**, Xi HQ, Wei B, Chen L. Effect of gastrectomy with bursectomy on prognosis of gastric cancer: a meta-analysis. *World J Gastroenterol* 2014; **20**: 14986-14991 [PMID: 25356060 DOI: 10.3748/wjg.v20.i40.14986]

22 **Kayaalp C**, Piskin T, Olmez A. Complications of bursectomy after radical gastrectomy for gastric cancer. *World J Surg* 2012; **36**: 229; author reply 230 [PMID: 21833663 DOI: 10.1007/s00268-011-1218-0]

23 **Japan Clinical Oncology Group**. Clinical Trials. Available from: URL: http: //www.jcog.jp/en/trials/index.html

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ORIGINAL ARTICLE

Retrospective Study

Iatrogenic bile duct injury with loss of confluence

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Abstract

AIM: To describe our experience concerning the surgical treatment of Strasberg E-4 (Bismuth Ⅳ) bile duct injuries.

METHODS: In an 18-year period, among 603 patients referred to our hospital for surgical treatment of complex bile duct injuries, 53 presented involvement of the hilar confluence classified as Strasberg E4 injuries. Imagenological studies, mainly magnetic resonance imaging showed a loss of confluence. The files of these patients were analyzed and general data were recorded, including type of operation and postoperative outcome with emphasis on postoperative cholangitis, liver function test and quality of life. The mean time of follow-up was of 55.9 ± 52.9 mo (median = 38.5, minimum = 2, maximum = 181.2). All other patients with Strasberg A, B, C, D, E1, E2, E3, or E5 biliary injuries were excluded from this study.

RESULTS: Patients were divided in three groups: G1 (n = 21): Construction of neoconfluence + Roux-en-Y hepatojejunostomy. G2 (n = 26): Roux-en-Y porto-enterostomy. G3 (n = 6): Double (right and left) Roux-en-Y hepatojejunostomy. Cholangitis was recorded in two patients in group 1, in 14 patients in group 2, and in one patient in group 3. All of them required transhepatic instrumentation of the anastomosis and six patients needed live transplantation.

CONCLUSION: Loss of confluence represents a surgical

challenge. There are several treatment options at different stages. Roux-en-Y bilioenteric anastomosis (neoconfluence, double-barrel anastomosis, porto-enterostomy) is the treatment of choice, and when it is technically possible, building of a neoconfluence has better outcomes. When liver cirrhosis is shown, liver transplantation is the best choice.

Key words: Bile duct injury; Hepatojejunostomy; Biliary repair; Portoenterostomy; Neoconfluence; Double-barrel anastomosis

Core tip: Strasberg E-4 (Bismuth Ⅳ) bile duct injuries represent a surgical challenge. These injuries which involve two separated right and left ducts are of multifactorial etiology, and may be the result of ischemic or thermal damage, an inflammatory reaction, or anatomical variants that predispose the patient to injury. The treatment options are many, mainly surgical. Best results are obtained with Roux-en-Y hepatojejunostomies, as we describe in this article.

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INTRODUCTION

Bile duct injuries following laparoscopic approach have been extensively studied. Several classifications have been developed to describe both the mechanism by which the injury occurs and the anatomic result. Classification of these injuries is challenging, although possible, since each lesion is not only anatomically unique, but also the final result of several factors, such as duct ischemia, thermal injury and ablation, and transection of the duct. These injuries have been found to have a constant rate, regardless of the surgeon's experience or the hospital (0.3%-0.6%).

One of the most feared types of injury is that which involves the confluence. They are classified as Bismuth IV and Strasberg E4 injuries, and represent a surgical and multidisciplinary challenge (Figure 1). Loss of the confluence, in which one or two right ducts are separated from the left duct, represent a technical challenge with several therapeutic options. These include various types of bilioenteric anastomosis as well as major hepatectomy. Here we describe our experience with this type of injury and the results of our surgical treatment, which in most instances, is the only option available to treat this type of injuries.

MATERIALS AND METHODS

During an 18-year period we studied 603 patient candidates for surgical treatment of iatrogenic bile duct injury. The conditions in which these patients arrived at our center are highly variable; each patient has an individual history and timeline. Several have received previous endoscopical, radiological, or surgical therapy.

Patients were evaluated by a multidisciplinary group that selects patients with ductal continuity for endoscopical and/or radiological treatment. Those with loss of continuity are selected for surgical management. Patient selection and injury classification are carried out based on results of several imaging studies, including magnetic resonance cholangiography, computerized tomography, and ultrasound. Endoscopic retrograde cholangiography is selectively performed on patients in whom there is a suspicion of a lateral injury that can be resolved with a stent. Patients who arrive with acute cholangitis, or in whom injury classification cannot be determined, are studied by percutaneous cholangiography. Surgery is programmed according to the general condition of the patient. When patients present multiple organ failure and/or evident sepsis, the procedure is delayed as long as needed. Until the general condition of the patient improves, percutaneous or surgical placement of a drain is the treatment of choice. Injuries are classified according to the Strasberg and Bismuth classifications.

All cases in which there is loss of duct continuity and thickness, duct transection is treated surgically by means of a Roux-en-Y hepatojejunostomy. The type and characteristics of the anastomosis have been described previously[1,2].

Medical records of all patients in whom loss of confluence was found (injuries classified as Bismuth IV, Strasberg E4) were analyzed and their general data were recorded. Type of surgical procedure, postoperative outcome with emphasis on postoperative cholangitis, liver function tests, and quality of life were also recorded. The mean time of follow-up of these patients was of 55.9 ± 52.9 mo (median = 38.5, minimum = 2, maximum = 181.2). For analysis purposes, patients were divided into three groups according to type of surgical repair. These groups and their characteristics are described on Table 1.

RESULTS

Among the 603 cases of biliary duct injuries, 53 cases with loss of confluence were identified. Most of the cases had a preoperative external biliary fistula (n = 27) with different types of abdominal or percutaneous drains. There was a wide range of time between the index surgery (where the injury was produced) and the attempts to repair in our institution (mean 14 d). In 28 cases the diagnosis of loss of confluence was

Table 1 Patient groups according to surgical procedure followed

Group	Surgical procedure to repair loss of confluence	*n* (%)
G1	Construction of neo-confluence + Roux-en-Y hepatojejunostomy	21 (40%)
G2	Roux-en-Y Portoenterostomy	26 (49%)
G3	Separated (right and left) Roux-en-Y hepatojejunostomy	6 (11%)

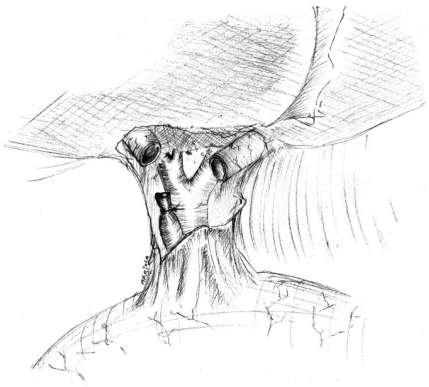

Figure 1 Strasberg E-4 injury.

established preoperatively through the imaging methods mentioned, with magnetic resonance cholangiography being the method of choice for injury classification, as it has been for the last 10 years. If bilomas, abscesses, and/or fluid collection were identified, drainage (usually percutaneously) was carried out.

During the surgical procedure, loss of confluence was confirmed after completely dissecting the porta hepatis and lowering the hilar plate to expose the right and left ducts. In all cases, a 40 cm long Roux-en-Y hepatojejunostomy was performed.

Group 1: Loss of confluence, neoconfluence, Roux-en-Y hepatojejunostomy

In 21 cases, after a wedged resection of segments Ⅳ and Ⅴ over the hilar plate, and after identification of the right and left ducts, a neo-confluence was constructed with fine everted stiches with a 6-0 hydrolysable monofilament. Also, the anterior aspect of the left duct (if necessary the right duct as well) was opened in order to obtain a wide, tension-free bilio-intestinal anastomosis that included the neo-confluence (Figure 2A).

Group 2: Loss of confluence, portoenterostomy

Twenty-six patients were treated by means of a Roux-en-Y portoenterostomy: after partial resection of segments Ⅳ and Ⅴ the two ducts were found separated and partially scarred and/or ischemic. In 9 of these cases a transhepatic transanastomotic stent was placed; in the remaining 17 no stent was placed. These were considered as portoenterostomies since in more than 50% of the circumference of the anastomosis a high quality bilioenteric anastomosis was not achieved due that the biliaryepithelium could not be joined with

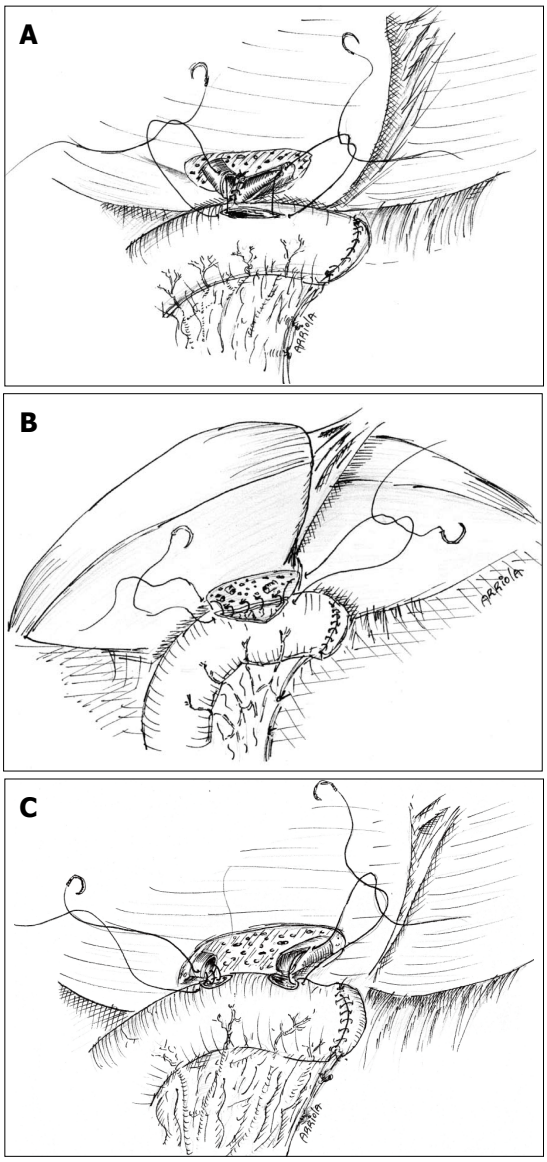

Figure 2 Hepatojejunostomy. A: Neoconfluence; B: Portoenterostomy; C: Double-barrel.

the intestinal mucosa (Figure 2B).

The 9 cases in which stents were placed have had an adequate postoperative evolution without symptoms and cholangitis. Stents were removed between the 6th and the 9th postoperative months. In two cases they were left in place longer, one for 12 mo due to patient non-compliance, and one for 84 mo due to patient's request. After this, the patients were left without a stent. In the other 7 patients whose stent was removed, 4 remained asymptomatic, 1 patient died in the fourth postoperative year because of secondary biliary cirrhosis, 1 patient in whom cirrhosis and liver failure were recorded was lost to follow-up, and 1 has developed cirrhosis and jaundice.

Group 3: Loss of confluence and double-barrel anastomosis

In 6 cases, both ducts were identified, but construction of a neo-confluence was not possible. Therefore, a

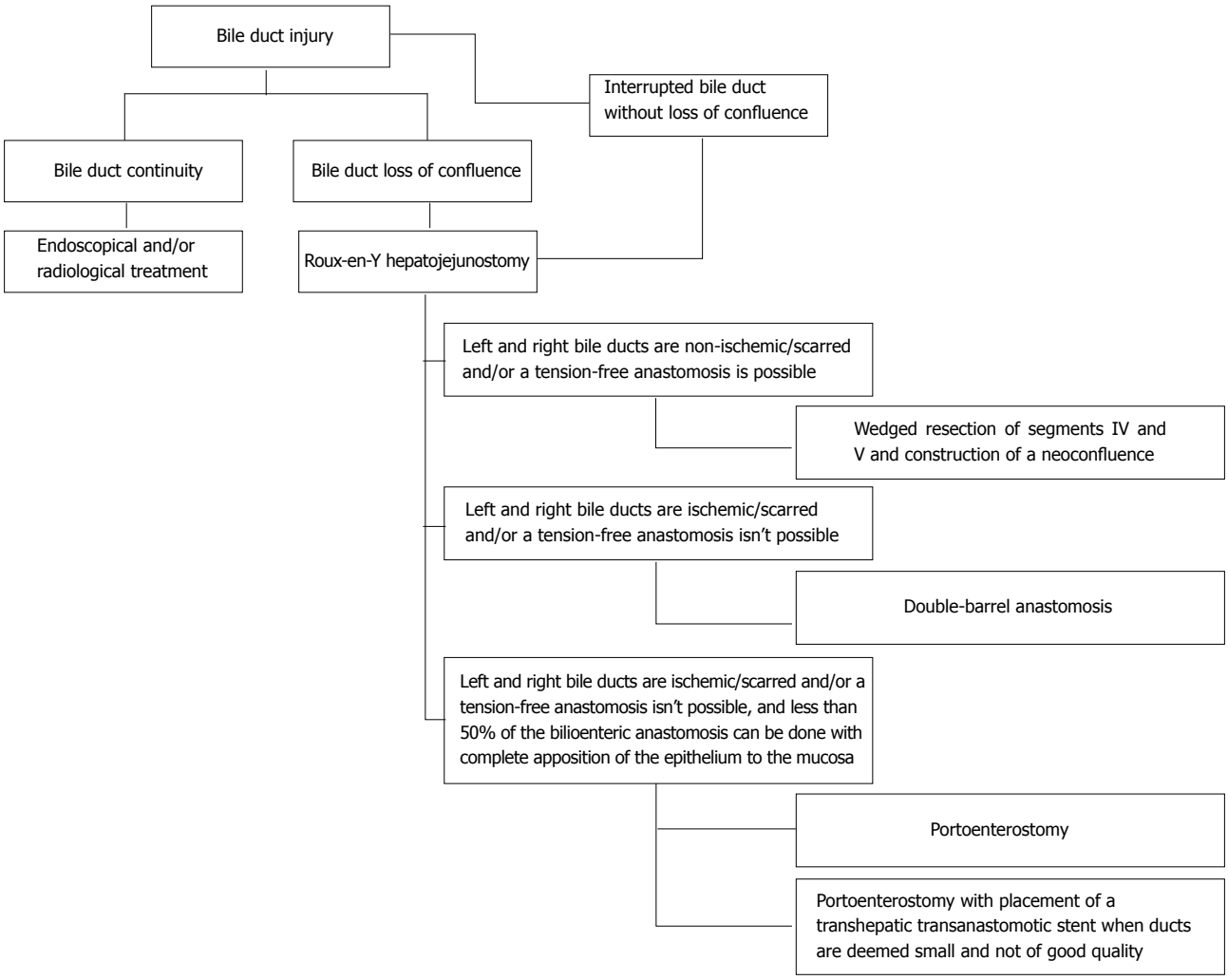

Figure 3 Surgical treatment strategy followed in patients with bile duct injury.

double-barrel anastomosis was performed. Three of these patients remained asymptomatic in the postoperative period (mean 6 years, range 3-12). Two cases required a right hepatectomy several months after the reconstruction because of persistent sectionary (unilobar) cholangitis. They are currently doing well, with patent bilioenteric anastomosis. One patient had persistent cholangitis and developed cirrhosis in the 4th postoperative year after one reoperation and attempts to perform radiological percutaneous dilation and surgical and radiological placement of stents (Figure 2C).

Figure 3 shows a summary of the surgical treatment strategy followed for bile duct injuries with loss of confluence.

Results after first reconstruction

The frequency of perioperative complications in patients treated by means of a Roux-en-Y portoenterostomy (group 2) was of 57.6%. The postoperative complications of these patients according to the Clavien-Dindo grading system are shown in Table 2.

Sixteen (61.5%) group 2 patients presented cirrhosis during follow-up, while 10 (38.4%) haven't developed cirrhosis to the last moment of follow-up. Thirteen patients (50%) have been referred for hepatic transplant evaluation, and 3 (11.5%) haven't been sent because of compensated cirrhosis.

On the other hand, 14 (53.8%) group 2 patients developed cholangitis. The cholangitis free survival rate was of 45 ± 9.17 mo (95%CI: 27.1-63) as shown in Figure 4.

Of these patients, 4 out of 9 patients in which a T-tube was placed (44.5%) required percutaneous interventions after their removal. Two patients (22.2%) needed the placement of an internal-external biliary drainage catheter after removal of the T-tube, while in the other 2 patients (22.2%) the T-tube was replaced with a percutaneous biliary catheter which wasn't removed until 11.1 mo after.

Four patients out of the 17 in which a T-tube wasn't placed (65.3%) required the placement of an internal-external biliary drainage. Only one of them (25%) is free of drainages at 63.7 mo.

Seven (77.8%) group 2 patients in which a T-tube was placed developed cholangitis during follow-up.

Table 2 Group 2 postoperative complications according to the Clavien-Dindo grading system

Classification	Frequency (%)	Description (frequency)
Ⅰ	1 (3.8%)	Superficial surgical site infection (1)
Ⅱ	7 (26.9%)	Intra-abdominal collection not requiring surgical intervention (5) Superficial surgical site infection not requiring surgical intervention (1) Cholangitis (1)
Ⅲa	0 (0%)	-
Ⅲb	3 (11.5%)	Intra-abdominal collection requiring surgical intervention (1) Biliary anastomosis remodeling (1) Intra-abdominal collection requiring transendoscopic ultrasound drainage (1)
Ⅳa	3 (11.5%)	Septic shock (3)
Ⅳb	0 (0%)	-
Ⅴ	1 (3.8%)	Atrioventricular block (1)

Those in which a T-tube wasn't placed, 7 (41.2%) presented this complication. Nonetheless, there was no significant difference between these two subgroups (P = 0.075). Cholangitis free survival rate tended to be greater in those patients without placement of a T-tube (60.1 ± 11.6 mo, 95%CI: 37.4-82.9; *vs* 23.1 ± 8.6, 95%CI: 6.2-40; log-rank P = 0.056) (Figure 5).

DISCUSSION

Surgical treatment of bile duct injury is indicated when loss of duct continuity is found and endoscopic and/or radiological approach is ruled out[2]. Roux-en-Y hepatojejunostomy has been proven to be the best treatment option by several groups[3]. A high quality bilioenteric anastomosis, which is defined as tension-free, wide, with adequate suture material, done in healthy, non-scarred non-ischemic ducts that are anastomosized to an afferent Roux-en-Y jejunal limb, offers the best results[4]. There are several technical maneuvers that can be done in order to reach this goal, including the anterior opening of the confluence and the left duct, as well as partial removal of segments Ⅳ and Ⅴ[5,6].

Our group has shown that an anastomosis done in a patient with preserved confluence offers the best results[7]. These results can be also optimized if the patient has no stones or sludge, usually the result of secondary colonization of bile.

Loss of confluence, depicted in Bismuth classification as Ⅳ and in Strasberg classification as E-4, is one of the most feared scenarios for surgeons, because of the technical challenge that it represents.

Loss of confluence can be the result of several issues. In some instances, it is the result of an anatomical variation in which the given patient has a low extrahepatic confluence that is injured during dissection, and also in subsequent section, transection or occlusion of the duct can be performed at this level. There is no

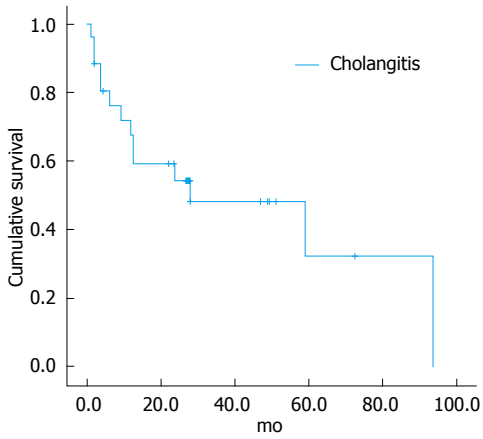

Figure 4 Group 2 cholangitis free survival rate.

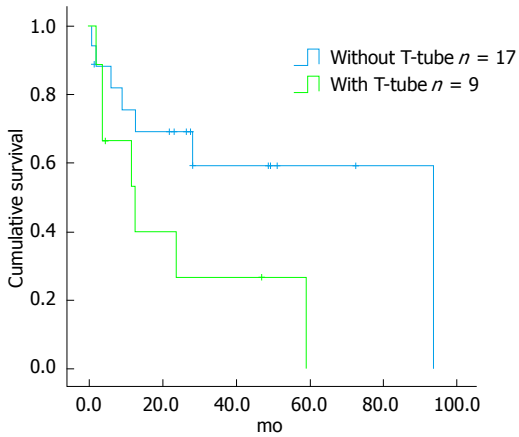

Figure 5 Group 2 cholangitis free survival rate in patients with and without T-tube placement. Log-rank P = 0.056.

available data on how many individuals have a low extrahepatic confluence. In the majority of people the confluence, although extrahepatic, is not low. In these cases, loss of confluence is the result of ischemic damage, thermal damage or both.

After section of the common duct, the proximal stump (near to the plane of section) becomes ischemic. It has been stated by Strasberg *et al*[5] that one of the key features for successful repair and successful bilio-enteric anastomosis is to wait enough time, so that the injury stabilizes and the exact level of duct ischemia is reached[8]. So, in some cases the ischemia level reaches the confluence. Bismuth has also stated that the level of the injury is always higher than it is appreciated in the initial stump[9].

In other cases, loss of confluence is the consequence of the local inflammatory reaction produced by either bile leakage or drains placed for a long time in the common duct, which lead to consequent destruction. This is especially true when patients in whom a non-silastic drain is placed subhepatically and fixed to the bile duct, establishing an external fistula, are referred late. Right hepatic arterial injuries are usually seen in this type of injury. Stewart *et al*[10] have shown that

the higher the injury the higher the probability of arterial damage. They have also shown that this has no impact in the final results of reconstruction, with the condition that the procedure is done by an interested and experienced hepatobiliary surgeon. In some cases, the artery can be reconstructed[11] by carrying out a primary anastomosis or planning an interposition graft. In our experience these arteries are not suitable for repair. The circulatory status of the ducts at the confluence level has a vascular net that allows a compensatory supply from the left to the right. This is why an anastomosis done at the confluence level warrants a good result, regardless of the patency of the right artery.

Ischemia of the duct is usually secondary to the type of the dissection inherent to the laparoscopic procedure. The common duct is easily confused with the cystic duct, and lateral traction of it causes damage to the small duct lateral vessels. Also, thermal injury is more likely because the higher the dissection goes, small bleedings can be found that are cauterized *via* thermal energy. In every repair, we do everything possible in order to cannulate the right and left hepatic ducts for identification purposes. In some of these cases we have found isolated right posterior injuries, with the right anterior duct reaching the left duct.

In some cases the separated duct can be reunited by removing the adjacent parenchyma and placing everted stitches that allow the construction of a neoconfluence. This could be done in 6 of the 37 cases (17%). There are other cases in which this maneuver could not be done and a portoenterostomy was constructed. Pickleman *et al*[12] published their experience obtaining good results with this type of approach. Some of our cases required placement of a transhepatic transanastomotic stent. The decision to place them was made according to the characteristics of the duct found at the time of operation. In our first three cases treated by means of portoenterostomy, we observed a difficult postoperative evolution. In other cases, it was deemed that a hepatectomy was necessary because of the characteristics of the duct and the lobe. In these two cases, a right hepatic injury was shown so that the lobectomy was done with a left duct jejunostomy. Laurent *et al*[13] have shown that in 15% of their cases with a complete injury a major hepatectomy was required, and resulted in excellent postoperative results. For cases with major vascular injury and bad quality major ducts, hepatectomy must be considered.

In other cases, the construction of two separated anastomosis could be done. This approach was selected when adequate separated ducts were found.

Rebuilding the confluence is not always possible. After removal of the liver parenchyma at the hilar level, both ducts are identified at the hilar plate. It is very important not to manipulate the ducts excessively because of the danger of devascularization. When both ducts are deemed "healthy", a tension free approximation of the posterior lateral edge of the left duct is done to the medial aspects of the right duct. Usually with three to four everted stitches the approximation is obtained. The anterior aspect of the left duct is opened and then an anastomosis to the jejunal limb (almost in a side to side fashion) is done. If the ducts are ischemic and/or the approximation of both foramens is not tension free, the surgeon must decide to do separate anastomosis of the ducts to the jejunum.

When a two anastomoses approach is decided, our preference is to open the anterior aspect of the left duct as well as right one in the same fashion, as described by Strasberg *et al*[5].

Portoenterostomy is decided when it is deemed that less than 50% of the anastomosis is done with complete apposition of the epithelium to the mucosa. Everted stitches are placed between the jejunal mucosa and the bile duct where it is possible and the remaining part of the anastomosis is done to the liver capsule and/or parenchyma.

The decision to place a transanastomotic stent is always difficult. When our group first started, we decided to place stents in all cases, but we evolved to selective placing when needed[14], specifically when ducts were deemed small and not of good quality. As we have stated, each patient has an individual type of injury and resulting anatomy.

Overall, considering all the treatments modalities, the procedure was successful in 88% of the cases, obtaining good postoperative results without cholangitis, good quality of life and without requiring reintervention.

In conclusion, an injury that includes the loss of confluence of the duct represents a surgical challenge. There are several options to be considered (neoconfluence, double-barrel anastomosis and portoenterostomy) that must be shaped and selected according to the individual characteristics of a given patient.

COMMENTS

Background

One of the most complex bile duct injuries is that which involves the loss of confluence of the right and left bile ducts, namely a Strasberg E-4 injury. Initially, the authors' team's surgical approach to this problem was the forming of a double-barrel anastomosis; however, it resulted in long term dysfunction. By descending the hilar plate, performing a partial resection of segment IV, and liberating both bile ducts so as to approximate them and include them in a single anastomosis, the outcomes seen in these patients became comparable to those in patients in which the confluence was preserved.

Research frontiers

Many surgical treatments for loss of confluence bile duct injuries have been proposed, including the creation of a two-barrel anastomosis, a portoenterostomy, or a neoconfluence. Few have described results regarding any of these reconstructions.

Innovations and breakthroughs

To our knowledge, this is the first retrospective study that analyzes long term outcomes of neoconfluences in iatrogenic bile duct injuries. They have only

been described in Blumgart's textbook of hepatic and biliary surgery, although without mentioning the removal of segment IV, which the authors consider necessary to facilitate the construction of an anastomosis.

Applications

Roux-en-Y hepatojejunostomies offer the best outcomes in patients with bile duct injuries with loss of confluence, as reported in the authors' observations. Individual characteristics of the patient must be taken into account in order to decide the most suitable surgical approach, although creating a neoconfluence should be of top priority.

Terminology

Bile duct injuries represent all deleterious consequences on the intra- or extrahepatic bile ducts, as a result of the removal of the gallbladder or of any endoscopic and surgical instrumentation of the ducts. Cholangitis is one of the most important complications that arise from these injuries, usually due to inflammation and fibrosis caused by biliary leaks.

Peer-review

The manuscript is interesting and well written.

REFERENCES

1 **Mercado MA**, Orozco H, de la Garza L, López-Martínez LM, Contreras A, Guillén-Navarro E. Biliary duct injury: partial segment IV resection for intrahepatic reconstruction of biliary lesions. *Arch Surg* 1999; **134**: 1008-1010 [PMID: 10487598 DOI: 10.1001/archsurg.134.9.1008]

2 **Chapman WC**, Abecassis M, Jarnagin W, Mulvihill S, Strasberg SM. Bile duct injuries 12 years after the introduction of laparoscopic cholecystectomy. *J Gastrointest Surg* 2003; **7**: 412-416 [PMID: 12654568 DOI: 10.1016/S1091-255X(02)00162-2]

3 **Sicklick JK**, Camp MS, Lillemoe KD, Melton GB, Yeo CJ, Campbell KA, Talamini MA, Pitt HA, Coleman J, Sauter PA, Cameron JL. Surgical management of bile duct injuries sustained during laparoscopic cholecystectomy: perioperative results in 200 patients. *Ann Surg* 2005; **241**: 786-792; discussion 793-795 [PMID: 15849514 DOI: 10.1097/01.sla.0000161029.27410.71]

4 **Mercado MA**, Orozco H, Chan C, Quezada C, Barajas-Olivas A, Borja-Cacho D, Sánchez-Fernandez N. Bile duct growing factor: an alternate technique for reconstruction of thin bile ducts after iatrogenic injury. *J Gastrointest Surg* 2006; **10**: 1164-1169 [PMID: 16966037 DOI: 10.1016/j.gassur.2006.04.004]

5 **Strasberg SM**, Picus DD, Drebin JA. Results of a new strategy for reconstruction of biliary injuries having an isolated right-sided component. *J Gastrointest Surg* 2001; **5**: 266-274 [PMID: 11360050 DOI: 10.1016/S1091-255X(01)80047-0]

6 **Mercado MA**, Chan C, Orozco H, Villalta JM, Barajas-Olivas A, Eraña J, Domínguez I. Long-term evaluation of biliary reconstruction after partial resection of segments IV and V in iatrogenic injuries. *J Gastrointest Surg* 2006; **10**: 77-82 [PMID: 16368494 DOI: 10.1016/j.gassur.2005.07.003]

7 **Mercado MA**, Chan C, Orozco H, Hinojosa CA, Podgaetz E, Ramos-Gallardo G, Gálvez-Treviño R, Valdés-Villarreal M. Prognostic implications of preserved bile duct confluence after iatrogenic injury. *Hepatogastroenterology* 2005; **52**: 40-44 [PMID: 15782990]

8 **Mercado MA**. Early versus late repair of bile duct injuries. *Surg Endosc* 2006; **20**: 1644-1647 [PMID: 17063286 DOI: 10.1007/s00464-006-0490-9]

9 **Bismuth H**, Majno PE. Biliary strictures: classification based on the principles of surgical treatment. *World J Surg* 2001; **25**: 1241-1244 [PMID: 11596882 DOI: 10.1007/s00268-001-0102-8]

10 **Stewart L**, Robinson TN, Lee CM, Liu K, Whang K, Way LW. Right hepatic artery injury associated with laparoscopic bile duct injury: incidence, mechanism, and consequences. *J Gastrointest Surg* 2004; **8**: 523-530; discussion 530-531 [PMID: 15239985 DOI: 10.1016/j.gassur.2004.02.010]

11 **Li J**, Frilling A, Nadalin S, Paul A, Malagò M, Broelsch CE. Management of concomitant hepatic artery injury in patients with iatrogenic major bile duct injury after laparoscopic cholecystectomy. *Br J Surg* 2008; **95**: 460-465 [PMID: 18161898 DOI: 10.1002/bjs.6022]

12 **Pickleman J**, Marsan R, Borge M. Portoenterostomy: an old treatment for a new disease. *Arch Surg* 2000; **135**: 811-817 [PMID: 10896375 DOI: 10.1001/archsurg.135.7.811]

13 **Laurent A**, Sauvanet A, Farges O, Watrin T, Rivkine E, Belghiti J. Major hepatectomy for the treatment of complex bile duct injury. *Ann Surg* 2008; **248**: 77-83 [PMID: 18580210 DOI: 10.1097/SLA.0b013e31817b65f2]

14 **Mercado MA**, Chan C, Orozco H, Cano-Gutiérrez G, Chaparro JM, Galindo E, Vilatobá M, Samaniego-Arvizu G. To stent or not to stent bilioenteric anastomosis after iatrogenic injury: a dilemma not answered? *Arch Surg* 2002; **137**: 60-63 [PMID: 11772217 DOI: 10.1001/archsurg.137.1.60]

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ORIGINAL ARTICLE

Prospective Study

Obese patients have similar short-term outcomes to non-obese in laparoscopic colorectal surgery

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Abstract

AIM: To determine whether obese patients undergoing laparoscopic surgery within an enhanced recovery program had worse short-term outcomes.

METHODS: A prospective study of consecutive patients undergoing laparoscopic colorectal resection was carried out between 2008 and 2011 in a single institution. Patients were divided in groups based on body mass index (BMI). Short-term outcomes including operative data, length of stay, complications and readmission rates were recorded and compared between the groups. Continuous data were analysed using *t*-test or one-way Analysis of Variance. χ^2 test was used to compare categorical data.

RESULTS: Two hundred and fifty four patients were included over the study period. The majority of individuals (41.7%) recruited were of a healthy weight (BMI < 25), whilst 50 patients were classified as obese (19.6%). Patients were matched in terms of the presence of co-morbidities and previous abdominal surgery. Obese patients were found to have a statistically significant difference in The American Society of Anesthesiologists grade. Length of surgery and intra-operative blood loss were no different according to BMI.

CONCLUSION: Obesity (BMI > 25) does not lead to worse short-term outcomes in laparoscopic colorectal surgery and therefore such patients should not be precluded from laparoscopic surgery.

Key words: Laparoscopic surgery; Colorectal cancer; Obese: body mass index; Outcomes

Core tip: Laparoscopic colorectal surgery for cancer

can be safely performed in obese patients without an increase in adverse events or outcomes. Patients should not be precluded from laparoscopy in such cases based on their body mass index. However it is important for the team to assess patients pre-operatively to decide on whether additional or more intensive peri-operative care is needed to ensure optimal outcomes.

Chand M, De'Ath HD, Siddiqui M, Mehta C, Rasheed S, Bromilow J, Qureshi T. Obese patients have similar short-term outcomes to non-obese in laparoscopic colorectal surgery. *World J Gastrointest Surg* 2015; 7(10): 261-266 Available from: URL: http://www.wjgnet.com/1948-9366/full/v7/i10/261.htm DOI: http://dx.doi.org/10.4240/wjgs.v7.i10.261

INTRODUCTION

Obesity is a considerable and growing healthcare concern, and more patients treated for colorectal cancer are obese with a body mass index (BMI) of greater than 30. Historically, individuals with an increased BMI have been thought of as having a higher risk of poorer outcomes following surgery with an increased rate of peri-operative complications and longer hospital stays, however more recent studies have challenged this view[1-3].

The surgical management of colorectal cancer has shifted towards a minimally-invasive approach and the current expectation is that the majority of patients should undergo laparoscopic surgery. It is now recognised as a safe and more advantageous alternative to laparotomy for most patients as benefits include reduced morbidity and shorter hospital stays with comparable oncological outcomes to open surgery[4-7].

However, obesity has long been considered a relative contraindication to laparoscopic surgery due to the perceived associated technical difficulty and increased morbidity[8-10]. Despite more recent reports of good short-term outcomes in colorectal cancer resections[11-13], there remains a reluctance to offer laparoscopic surgery to obese patients. Consequently, an increasing number of patients with a high BMI are being denied the benefits of laparoscopic surgery.

The aim of this study was to determine whether obesity was an acceptable contraindication to laparoscopic colorectal surgery by comparing the short-term outcomes of patients with an increased BMI to those of a healthy weight-to-height ratio.

MATERIALS AND METHODS

Study design and setting

A prospective cohort study conducted between 2008 and 2011 at a single colorectal surgery institution in the United Kingdom.

Study population

All consecutive patients undergoing laparoscopic colorectal surgery were included. There were no exclusion criteria. Consistent with the surgical protocol of the unit, all individuals were enrolled into its enhanced recovery after surgery (ERAS) program. A standardised approach to both the anaesthetic and the surgery was performed in all patients.

Data collection

Data were collected prospectively on each individual patient and recorded anonymously on a database. These included patient demographics and BMI, The American Society of Anesthesiologists (ASA) grade, nature of surgery, operative and anaesthetic time, stoma formation, intra-operative blood loss, complications including anastomotic leak, unplanned high dependency unit (HDU) admission, length of hospital stay and readmission rates. Complications were recorded according to the Clavien-Dindo classification system.

The ERAS protocol

All patients were counselled by a nurse specialist prior to surgery and given a detailed explanation of what to expect throughout the course of their hospital stay. Each patient was given contact details for a member of the ERAS team.

Patients were admitted on the day of surgery. The evening before admission each patient received a 100 g of Pre-Load (96 g of carbohydrate; osmolarity of 285 mOsm) mixed in 400 mL of water. On the morning of admission, a further 50 g of Pre-Load in 400 mL of water was given 2 h before surgery. Following discharge, a dedicated nurse practitioner telephoned the patients at 48 h to enquire about any concerns. Patients were followed up in the out-patient department at 6 wk regardless of any concurrent oncological referral.

Peri-operative anaesthetic regime

A standardised anaesthetic protocol was used for all patients. This consisted of a spinal anaesthetic before induction using 2 mL 0.5% plain bupivacaine with 700 mcg of diamorphine. Routine doses of propofol and remifentanil were used for induction and atracurium for neuromuscular blockade. Intraoperative medication included 6.6 mg of dexamethasone, 4 mg of ondansetron, 1.5 g cefuroxime and 500 mg metronidazole. In addition to the intrathecal diamorphine, perioperative analegesia included 1 g Ⅳ paracetamol and 75 mg Ⅳ diclofenac. An orogastric tube and urinary catheter were sited with the former removed at the end of the procedure. Routine maintenance fluids during the procedure consisted of 1.5 L Hartmann's solution. Temperature was maintained using a Bair Hugger® blanket. Post-operative fluid regime included 1 L Hartmann's solution given over 10 h in addition to oral fluids and high calorie drinks. All patients were given oral paracetamol 1 g QD and Ibuprofen 400 mg TD.

Table 1 Patient characteristics *n* (%)

	All	BMI < 25	BMI 26-30	BMI > 30	*P* value
Number	254	106 (41.7)	98 (38.6)	50 (19.7)	< 0.001
Males	122 (48)	41 (38.7)	58 (59.2)	23 (46)	0.01
BMI	26 (23-30)	22.5 (2.1)	27.8 (1.5)	35.3 (5.9)	< 0.001
ASA grade	2 (0.6)	1.9 (0.6)	2.0 (0.6)	2.2 (0.6)	0.04
Previous abdominal surgery	80 (31.5)	34 (32)	30 (30.6)	16 (32)	0.972
Co-morbidities	187 (73.6)	76 (71.7)	75 (76.5)	36 (72)	0.789

Data presented as mean (standard deviation) unless otherwise indicated. Comparisons are between the three BMI groups. BMI: Body mass index; ASA: American Society of Anesthesiologists.

Patients were managed on an elective surgical ward and allowed oral fluids on the night of surgery. The urinary catheter was removed on the first operative day and patients were encouraged to take a solid oral diet and to mobilise.

Surgical technique

All surgical procedures were carried out using a standardised modular technique. Patients were placed in the modified Lloyd-Davies position for all resections with the legs in stirrups but with the femurs horizontal to the floor, the arms positioned by the sides and high-friction gel pads were used. Arm boards and shoulder supports were avoided. Routine port positions were used for left and right-sided procedures with the use of a 10 mm 30 degree camera. Dissection was predominantly performed using the "hook" with diathermy attached and occasional use of an energy device. Specimens were extracted through a wound protector device using either lower right- or left-sided transverse muscle splitting incisions for right and left-sided resections, respectively. Extraction sites were closed in layers making sure to avoid muscle in the suture line and infiltrated with maximal safe dosage of bupivacaine 0.375%. For left-sided resections a leak test was performed with a flexible sigmoidoscope which was also used to inspect the anastomosis, but was not passed through it.

Statistical analysis

Individuals were classified according to their BMI as healthy weight (< 25), overweight (26-30) and obese (> 30). Outcomes were compared between the three groups.

Continuous data are expressed as mean with standard deviation and categorical data as an absolute number and percentage. Continuous data were analysed using Analysis of Variance (ANOVA). Fisher's exact test or χ^2 test was used to compare categorical data. A two-sided *P* value of less than 0.05 was considered significant. All data analyses were performed using SPSS version 21 (SPSS Inc., Chicago IL).

RESULTS

Two hundred and fifty four patients were included over the study period. The majority of individuals (41.7%) recruited were of a healthy weight (BMI < 25), whilst 50 patients were classified as obese (19.6%). In all groups, there were more female patients than males. Overall, patients were well matched in terms of the presence of co-morbidities and previous abdominal surgery. Obese patients were found to have a statistically significant difference in ASA grade. Patient characteristics are shown in Table 1.

Anterior resection and right hemicolectomy were the two most frequently performed operations, accounting together for three quarters of the procedures undertaken (Table 2). There were no significant differences in the incidence and nature of operations across the BMI cohorts.

There were few significant differences in outcomes between obese patients and healthier weight individuals (Table 3). Only readmission rates with rectal bleeding were higher in the obese (2 patients in the obese group compared with none in the other groups), whilst there was a non-significant trend towards increasing anaesthetic time and length of stay associated with higher BMI. Unplanned HDU admission rates favoured patients with a higher BMI, whilst the rate of stoma formation was lower although not significant. Length of surgery and intra-operative blood loss were no different according to BMI.

DISCUSSION

This study revealed that obese patients with an increased BMI have comparable short-term outcomes to healthy weight individuals. Furthermore, outcomes of overweight patients with a BMI of between 26 and 30 were also similar. In particular, there was no significant increase in post-operative complications or length of stay, both of which are historically associated with obese patients. Additionally, the length of operating time and intra-operative blood loss were similar in all groups, suggesting a comparable degree of operative difficulty. Finally of note, all patients in the study underwent an ERAS protocol with no adverse outcomes as a result of this approach, in spite of the traditional caution in patients with an increased BMI.

The relationship between obesity and various conditions has been clearly established including with type

Table 2 Nature and number of operations

Operation	Total	BMI < 25	BMI 26-30	BMI > 30	*P* value
Anterior resection	107 (42.1)	46 (43.4)	37 (37.8)	24 (48)	0.462
Right hemicolectomy	82 (32.3)	32 (30.2)	34 (34.7)	16 (32)	0.789
Left hemicolectomy	7 (2.8)	3 (2.8)	2 (2.1)	2 (2)	0.787
Ileocaecal resection	10 (3.9)	5 (4.7)	5 (5.1)	0 (0)	0.277
Panproctocolectomy	7 (2.8)	5 (4.7)	2 (2.1)	0 (0)	0.209
Abdominoperineal resection	2 (0.8)	0 (0)	2 (2.1)	0 (0)	0.201
Sigmoid colectomy	5 (2)	1 (0.9)	3 (3.1)	1 (2)	0.553
Subtotal/total colectomy	11 (4.4)	6 (5.7)	3 (3.1)	2 (4)	0.426
Hartmann's	3 (1.2)	1 (0.9)	2 (2.1)	0 (0)	0.530
Miscellaneous	20 (7.9)	7 (6.6)	8 (8.2)	5 (10)	0.756

Data presented as absolute number (percentage). Comparisons are between the three BMI groups. BMI: Body mass index.

Table 3 Outcomes split by body mass index

	BMI < 25	BMI 26-30	BMI > 30	*P* value
Anaesthetic time, min mean (SD)	41.10 (50.9)	52.62 (62.6)	67.55 (70.9)	0.080
Length of surgery, min mean (SD)	181.1 (65.4)	177.8 (56.6)	192.63 (61.5)	0.421
Intra-op blood loss, mL mean (SD)	33.18 (31.9)	44.00 (67.1)	38.33 (33.6)	0.309
Stoma	22 (20.8)	22 (22.5)	8 (16)	0.600
LOS, d, mean (SD)	4.1 (4.1)	3.9 (3.9)	5.8 (7.7)	0.076
All complications	23 (21.7)	15 (15.3)	14 (28)	0.686
Anastomotic leak	2 (1.9)	0 (0)	1 (2)	0.771
Re-admission	8 (7.5)	12 (12.2)	3 (6)	0.984
Wound infection	1 (0.9)	1 (1)	1 (2)	0.609
Abdominal collection	1 (0.9)	5 (5.1)	0 (0)	0.859
PR bleeding	0 (0)	0 (0)	2 (4)	0.021
DVT/PE	0 (0)	1 (1)	0 (0)	0.769
Obstruction/ileus	3 (2.8)	2 (2)	0 (0)	0.254
Vomiting/diarrhoea	3 (2.8)	1 (1)	0 (0)	0.156
Non-specfic abdo pain	0 (0)	2 (2)	0 (0)	0.677

Data are presented as absolute number (percentage) unless otherwise indicated. LOS: Length of stay; BMI: Body mass index.

2 diabetes, cardiovascular disease, cerebrovascular disease, pulmonary disease, and more recently, cancer[14-17]. Therefore, it would be expected that more perioperative complications would be likely in the obese population consistent with associated co-morbidities. It has been well documented that wound complications are significantly more common in obese patients following, in particular, those receiving long midline incisions[18-20]. Given that this may be the case, it is even more important in this group of patients to limit the surgical stress, so it is felt that they may actually be better off undergoing laparoscopic rather than open surgery. The relationship between obesity and laparoscopic colorectal surgery has evolved over the years. Initial reports investigating the feasibility of laparoscopy in patients with an increased BMI resulted in worse outcomes compared to the non-obese. This included more post-operative complications, conversions to open procedures and an increased length of stay. In cases of cancer resections, however, this was shown to be oncologically safe. Nonetheless, as techniques have improved and there is greater familiarity and capability with laparoscopic surgery, short-term outcomes have become more comparable to open surgery[21-23]. Yet there remains a reluctance to offer laparoscopy to obese patients. It is important to recognise that open surgery in obese patients also takes longer and is more difficult.

Technically, the surgery can be demanding and has been shown repeatedly to lead to a higher learning curve[9]. A thicker, heavier mesentery creates difficulty in recognising the planes of dissection and causes limited space to operate within the abdomen. In those series which show comparable operating times and peri-operative outcomes such as blood loss, improved technology in the form of instruments and high-definition laparoscopes have been cited as factors. Classically, the obese male patient with a narrow pelvis has been considered the most challenging of surgery for colorectal surgeons.

The present study has shown that despite increased BMI, the intra-operative outcomes of blood loss and operating time are no different to non-obese patients. Previous reports have shown an increased operating time in obese patients which is most likely a reflection

of the difficulty in operating in these patients[10]. Interestingly, studies which showed an increase in the number of complications in obese patients also reported an increased length of stay. However, these two outcomes are intrinsically linked. For example, ileus is the most common cause of prolonged hospital admission after colorectal surgery[24]. This can be attributed to longer operating time and post-operative complications which need resolution prior to discharge. Therefore, it is not surprising that if the number of complications is reduced, so is the length of stay.

The rate of stoma formation was similar across groups. Stomas may often be formed to protect an anastomosis which is at risk of leaking, a concern associated with technically challenging surgery. It must be noted that stoma formation is also technically more challenging in obese patients due to the increased distance from the abdominal cavity to the skin.

The peri-operative approaches to laparoscopic cases in our institution are identical regardless of whether the resection is right or left-sided. This includes anaesthesia, patient preparation and positioning, and post-operative care. Clearly, there will be modifications in the port positioning although for the vast majority of cases no more than 4 ports and a transverse incision extraction site are used. Using a standardised approach allows clarity for all staff involved in the peri-operative care of the patient.

This study has shown that using a standardised peri-operative protocol including anaesthesia and surgical technique, obese patients can safely be offered laparoscopic surgery for colorectal cancer resections. The short-term outcomes including post-operative complications and length of stay are comparable to non-obese patients. Consequently, obesity should not preclude laparoscopic surgery being offered to patients for colorectal cancer.

COMMENTS

Background

An increased body mass index (BMI) has been traditionally associated with a higher rate of complications. Initial reports on laparoscopy stated the increased BMI should be a preclusion for laparoscopic approaches in colorectal cancer surgery. However as techniques have improved and become more standardised it is possible to safely operate on patients with a high BMI.

Research frontiers

There is still some contention as to whether laparoscopic surgery can be safely performed for colorectal cancer without compromising oncological outcomes.

Innovations and breakthroughs

This study demonstrates that patients can undertake laparoscopy without additional complications and similar short-term outcomes as non-obese patients.

Applications

This study should allow clinicians to assess patients with a high BMI confidently and not preclude them from laparoscopy based solely on BMI.

Peer-review

The study is clear, well-written and easy to read.

REFERENCES

1 **Choban PS**, Flancbaum L. The impact of obesity on surgical outcomes: a review. *J Am Coll Surg* 1997; **185**: 593-603 [PMID: 9404886 DOI: 10.1016/S1072-7515(97)00109-9]

2 **Mullen JT**, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Ann Surg* 2009; **250**: 166-172 [PMID: 19561456 DOI: 10.1097/SLA.0b013e3181ad8935]

3 **Dindo D**, Muller MK, Weber M, Clavien PA. Obesity in general elective surgery. *Lancet* 2003; **361**: 2032-2035 [PMID: 12814714 DOI: 10.1016/S0140-6736(03)13640-9]

4 **Lacy AM**, García-Valdecasas JC, Delgado S, Castells A, Taurá P, Piqué JM, Visa J. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomised trial. *Lancet* 2002; **359**: 2224-2229 [PMID: 12103285 DOI: 10.1016/S0140-6736(02)09290-5]

5 **Guillou PJ**, Quirke P, Thorpe H, Walker J, Jayne DG, Smith AM, Heath RM, Brown JM. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet* 2005; **365**: 1718-1726 [PMID: 15894098 DOI: 10.1016/S0140-6736(05)66545-2]

6 **Kuhry E**, Schwenk WF, Gaupset R, Romild U, Bonjer HJ. Long-term results of laparoscopic colorectal cancer resection. *Cochrane Database Syst Rev* 2008; **(2)**: CD003432 [PMID: 18425886 DOI: 10.1002/14651858.cd003432.pub2]

7 **Veldkamp R**, Kuhry E, Hop WC, Jeekel J, Kazemier G, Bonjer HJ, Haglind E, Påhlman L, Cuesta MA, Msika S, Morino M, Lacy AM. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. *Lancet Oncol* 2005; **6**: 477-484 [PMID: 15992696 DOI: 10.1016/S1470-2045(05)70221-7]

8 **Pikarsky AJ**, Saida Y, Yamaguchi T, Martinez S, Chen W, Weiss EG, Nogueras JJ, Wexner SD. Is obesity a high-risk factor for laparoscopic colorectal surgery? *Surg Endosc* 2002; **16**: 855-858 [PMID: 11997837]

9 **Tekkis PP**, Senagore AJ, Delaney CP, Fazio VW. Evaluation of the learning curve in laparoscopic colorectal surgery: comparison of right-sided and left-sided resections. *Ann Surg* 2005; **242**: 83-91 [PMID: 15973105 DOI: 10.1097/01.sla.0000167857.14690.68]

10 **Zhou Y**, Wu L, Li X, Wu X, Li B. Outcome of laparoscopic colorectal surgery in obese and nonobese patients: a meta-analysis. *Surg Endosc* 2012; **26**: 783-789 [PMID: 22011944 DOI: 10.1007/s00464-011-1952-2]

11 **Hemandas AK**, Abdelrahman T, Flashman KG, Skull AJ, Senapati A, O'Leary DP, Parvaiz A. Laparoscopic colorectal surgery produces better outcomes for high risk cancer patients compared to open surgery. *Ann Surg* 2010; **252**: 84-89 [PMID: 20562603 DOI: 10.1097/SLA.0b013e3181e45b66]

12 **Benoist S**, Panis Y, Alves A, Valleur P. Impact of obesity on surgical outcomes after colorectal resection. *Am J Surg* 2000; **179**: 275-281 [PMID: 10875985 DOI: 10.1016/S0002-9610(00)00337-8]

13 **Makino T**, Shukla PJ, Rubino F, Milsom JW. The impact of obesity on perioperative outcomes after laparoscopic colorectal resection. *Ann Surg* 2012; **255**: 228-236 [PMID: 22190113 DOI: 10.1097/SLA.0b013e31823dcbf7]

14 **Flegal KM**, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA* 2013; **309**: 71-82 [PMID: 23280227 DOI: 10.1001/jama.2012.113905]

15 **Wolin KY**, Carson K, Colditz GA. Obesity and cancer. *Oncologist* 2010; **15**: 556-565 [PMID: 20507889 DOI: 10.1634/theoncologist.2009-0285]

16 **Calle EE**, Rodriguez C, Walker-Thurmond K, Thun MJ. Overweight, obesity, and mortality from cancer in a prospectively studied cohort of U.S. adults. *N Engl J Med* 2003; **348**: 1625-1638 [PMID: 12711737 DOI: 10.1056/NEJMoa021423]

17 **Basen-Engquist K**, Chang M. Obesity and cancer risk: recent review

and evidence. *Curr Oncol Rep* 2011; **13**: 71-76 [PMID: 21080117 DOI: 10.1007/s11912-010-0139-7]

18 **Balentine CJ**, Wilks J, Robinson C, Marshall C, Anaya D, Albo D, Berger DH. Obesity increases wound complications in rectal cancer surgery. *J Surg Res* 2010; **163**: 35-39 [PMID: 20605591 DOI: 10.1016/j.jss.2010.03.012]

19 **Power K**, Davies MM, Hargest R, Phillips S, Torkington J, Morris C. A case-control study of risk factors for wound infection in a colorectal unit. *Ann R Coll Surg Engl* 2014; **96**: 37-40 [PMID: 24417828 DOI: 10.1308/003588414X13824511650137]

20 **Dobson MW**, Geisler D, Fazio V, Remzi F, Hull T, Vogel J. Minimally invasive surgical wound infections: laparoscopic surgery decreases morbidity of surgical site infections and decreases the cost of wound care. *Colorectal Dis* 2011; **13**: 811-815 [PMID: 20456462 DOI: 10.1111/j.1463-1318.2010.02302.x]

21 **Senagore AJ**, Delaney CP, Madboulay K, Brady KM, Fazio VW. Laparoscopic colectomy in obese and nonobese patients. *J Gastrointest Surg* 2003; **7**: 558-561 [PMID: 12763416 DOI: 10.1016/S1091-255X(02)00124-5]

22 **Leroy J**, Ananian P, Rubino F, Claudon B, Mutter D, Marescaux J. The impact of obesity on technical feasibility and postoperative outcomes of laparoscopic left colectomy. *Ann Surg* 2005; **241**: 69-76 [PMID: 15621993]

23 **Poulsen M**, Ovesen H. Is laparoscopic colorectal cancer surgery in obese patients associated with an increased risk? Short-term results from a single center study of 425 patients. *J Gastrointest Surg* 2012; **16**: 1554-1558 [PMID: 22688417 DOI: 10.1007/s11605-012-1928-0]

24 **Schwenk W**, Böhm B, Haase O, Junghans T, Müller JM. Laparoscopic versus conventional colorectal resection: a prospective randomised study of postoperative ileus and early postoperative feeding. *Langenbecks Arch Surg* 1998; **383**: 49-55 [PMID: 9627171 DOI: 10.1007/s004230050091]

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ORIGINAL ARTICLE

Prospective Study

Laparoscopic *vs* mini-incision open appendectomy

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Abstract

AIM: To compare laparoscopic *vs* mini-incision open appendectomy in light of recent data at our centre.

METHODS: The data of patients who underwent appendectomy between January 2011 and June 2013 were collected. The data included patients' demographic data, procedure time, length of hospital stay, the need for pain medicine, postoperative visual analog scale of pain, and morbidities. Pregnant women and patients with previous lower abdominal surgery were excluded. Patients with surgery converted from laparoscopic appendectomy (LA) to mini-incision open appendectomy (MOA) were excluded. Patients were divided into two groups: LA and MOA done by the same surgeon. The patients were randomized into MOA and LA groups a computer-generated number. The diagnosis of acute appendicitis was made by the surgeon with physical examination, laboratory values, and radiological tests (abdominal ultrasound or computed tomography). All operations were performed with general anaesthesia. The postoperative vision analog scale score was recorded at postoperative hours 1, 6, 12, and 24. Patients were discharged when they tolerated normal food and passed gas and were followed up every week for three weeks as outpatients.

RESULTS: Of the 243 patients, 121 (49.9%) underwent MOA, while 122 (50.1%) had laparoscopic appendectomy. There were no significant differences in operation time between the two groups (P = 0.844), whereas the visual analog scale of pain was significantly higher in the open appendectomy group at the 1st hour (P = 0.001), 6th hour (P = 0.001), and 12th hour (P = 0.027). The need for analgesic medication was significantly higher in the MOA group (P = 0.001). There were no differences between the two groups in terms of morbidity rate (P = 0.599). The rate of total complications was similar between the two groups (6.5% in LA *vs* 7.4% in OA, P = 0.599). All wound infections were treated non-surgically. Six out of seven patients with pelvic abscess were successfully treated with percutaneous drainage; one patient required

surgical drainage after a failed percutaneous drainage. There were no differences in the period of hospital stay, operation time, and postoperative complication rate between the two groups. Laparoscopic appendectomy decreases the need for analgesic medications and the visual analog scale of pain.

CONCLUSION: The laparoscopic appendectomy should be considered as a standard treatment for acute appendicitis. Mini-incision appendectomy is an alternative for a select group of patients.

Key words: Appendicitis; Surgical wound infections; Laparoscopic surgical procedure; Abdominal abscess; Mini-incision open appendectomy

Core tip: Acute appendicitis is mostly encountered disease in a daily routine. Researchs regarding decreasing morbidity and mortality are still needed, although it is very well known. Hospital stay, operation time, postoperative complication rates are important for the management of acute appendicitis. Therefore, we suggest that laparoscopic appendectomy should be accepted as a standard treatment for acute appendicitis. Mini-incision appendectomy is an alternative for a select group of patients.

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INTRODUCTION

The most common reason for admission to the emergency room is acute appendicitis (AA), and appendectomy is a daily surgical procedure performed around the world[1,2]. Open appendectomy (OA) is accepted as a standard treatment for (AA); its morbidity and mortality are very low[1,2]. However, laparoscopic appendectomy (LA) has recently become more accepted[1,2]. Many advantages of LA have been shown such as lower hospital stay, shorter recovery period, shorter period for returning to daily activities, lower postoperative pain, and lower postoperative infections[1-6]. In spite of these advantages, there is controversy over the best model of appendectomy techniques in the literature. Any extra potential advantages resulting from the laparoscopic approach are hard to prove because OA has the advantages of minimally invasive surgery such as a small incision, faster return to daily activities, and short hospital stays[3,7]. Moreover, there are some discouragements for LA such as longer operation time, higher intra-abdominal abscess, and higher failure rate in complicated appendicitis cases[2,4,5,8]. Therefore, there is no consensus in the literature about whether LA should be chosen as a routine procedure for all acute appendicitis cases or only for selected cases such as young women, obese patients, and professional workers[3,7,9].

MATERIALS AND METHODS

Our hypothesis is that for treatment of AA, whether complicated or not, in all adult patients, LA is superior to mini-incision open appendectomy (MOA) in terms of safety and effectivity. The longer operation time and higher intra-abdominal abscess rate in LA will improve in advanced laparoscopic surgical centres with increased laparoscopic experience. Therefore, we compared the shorter and longer outcomes of LA and MOA in patients with AA.

Patients

From January 2011 to June 2013, the data of patients who underwent MOA and LA were recorded at the general surgery department of Safa Hospital. Patients with completed follow-up were included in the study. Pregnant women and patients with previous lower abdominal surgery were excluded. The patients were randomized into MOA and LA groups a computer-generated number. Patients with surgery converted from LA to MOA were excluded. Patients were divided into two groups: LA and MOA done by the same surgeon. All patients gave their informed consent. Patients' demographic data, procedure time, histopathologic reports, the need for analgesics, postoperative visual analog scale (VAS) score at 1, 6, 12 and 24 h, the hospital stay period, the period of time to return to daily activity, morbidity, and mortality were recorded. The diagnosis of AA was made by the surgeon with physical examination, laboratory values, and radiological tests (abdominal ultrasound or computed tomography). All operations were performed with general anaesthesia.

Methods

LA was performed based on the three trocars technique: a 10 mm port was placed at the umbilical area for the scope; a 5 mm port was placed in the left lower quadrant; a 5 mm port was inserted in the suprapubic area. The mesoappendix was transected with ultrasonic energy, and the appendix was tied at the radix. Appendectomy was completed by endo scissors and was removed from the abdomen through a 10 mm port in the umbilical area in an endo-loop (EndoLoop, Vicryl Coated Ligature, Ethicon UK Ltd., Edinburgh, United Kingdom). The appendix stump was not embedded. A drain tube was placed in the rectovesical area when considered necessary.

MOA was performed as a standard treatment. A 3 cm Mc Burney incision was made to enter the peritoneum. Appendectomy was completed followed

Table 1 Patients' characteristics and operative data *n* (%)

	LA (*n* = 122)	MOA (*n* = 121)	*P* value
Age (yr)[1]	25.9 ± 9.6	28.8 ± 11.1	0.249
(median, range)	(26.91-99)	(29.81-97)	
Gender (F/M)	56/66	50/70	0.389[2]
ASA score	108/16/3	106/11/4	0.449
BMI[3] (kg/m^2)	24.1 ± 2.9	24.6 ± 3.1	0.998
Operative time (min)	51.0 ± 13.9	50.9 ± 19.9	0.844
Surgeon	122	121	
Appendix			
Normal	8 (6.5)	18 (14.8)	0.009
Gangrenous	14 (11.4)	11 (9.0)	0.149
Phlegmonous	93 (76.2)	86 (71.0)	0.079
Perforated	7 (5.7)	6 (4.9)	0.073

[1]Students' *t* test; [2]χ^2 test; [3]mean ± SD. BMI: Body mass index; ASA: American Society of Anaesthesiology; MOA: Mini-incision open appendectomy; LA: Laparoscopic appendectomy.

by tying off of the mesoappendix and radix of the appendix. The appendix stump was embedded. A drain tube was placed in the rectovesical area when considered necessary. All appendectomy specimens were sent for histopathological examination. All patients received intravenous 3rd generation cephalosporin as a prophylactic antibiotic (Seftriakson - Novosef, 1000 mg iv, Zentiva, İstanbul, Türkiye). Patients with complicated AA received both 3rd generation cephalosporin and metronidazole (Biteral, 500 mg iv, Deva, Istanbul, Turkey) as prophylactic antibiotics. All patients received a dose of analgesic medication (diclofenac sodium, 75 mg im, Deva, İstanbul, Turkey) prior to intubation in the operating room. In the postoperative period, patients received analgesic medication based on the need for pain medication. The postoperative VAS score was recorded at postoperative hours 1, 6, 12, and 24. Patients were discharged when they tolerated normal food and passed gas and were followed up every week for three weeks as outpatients. Sutures were removed one week after surgery. Follow-ups for complications occurred in postoperative weeks two and three. Patients with complications were admitted to the hospital.

Statistical analysis

Results for categorical variables are given as frequencies and proportions (%), and results for continuous variables are given as mean ± SDs. Results for categorical variables were compared by χ^2 tests; results for continuous, normally distributed variables were compared by student *t*-tests; and results for non-normally distributed continuous variables were compared using a Mann Whitney *U* test. Variables were considered statistically significant if the *P*-value $\leqslant$ 0.05 was in the 95%CI. Statistical analyses used SPSS for SPSS 16.0 software (SPSS Inc., Chicago, Illinois, United States).

RESULTS

The study's 243 patients were randomly divided into two groups, either MOA (*n* = 121) or LA (*n* = 122). Five patients who had undergone conversion from LA to OA were excluded from the study. As shown in Table 1, there were no statistical differences in demographics between the two groups. The data of the operations are shown in Table 1. The mean operating time was similar in both groups. Between the two groups, diagnoses of gangrenous, inflamed, and perforated appendicitis histopathologically were normally distributed. However, the rate of false appendicitis was statistically lower in the LA group (*P* = 0.009). The early postoperative VAS was statistically lower in LA, whereas the differences were similar at the postoperative 24 h mark (*P* = 0.056, Table 2). The need for analgesics in the LA group was lower in the postoperative period (*P* = 0.001). The length of hospital stay was lower in LA, but the difference was not statistically significant (*P* = 0.071, Table 2). The rate of total complications was similar between the two groups (6.5% in LA *vs* 7.4% in OA, *P* = 0.599). All wound infections were treated non-surgically. Six out of seven patients with pelvic abscess were successfully treated with percutaneous drainage; one patient required surgical drainage after a failed percutaneous drainage (Table 2). There were no other complications such as bowel obstruction or incisional hernia. The follow-up period was similar in both groups (14.7 mo for OA and 15.6 mo for LA, *P* = 0.449). No mortality was reported in the follow-up period.

DISCUSSION

As a minimally invasive technique, controversy regarding the superiority of LA over OA has existed for several years[1,9,10]. Because there are no differences in surgical outcomes between the two groups, OA is considered the better option due to lower cost[3]. However, lower postoperative pain, diagnostic accuracy, especially in women and the elderly, shorter periods of healing, and better cosmetic results have been considered advantages of LA over OA[2,4,9]. There were different protocols in previous studies, which resulted in various outcomes reported in the literature[3]. The longer operating time required for LA is a factor in comparing the two groups, and it extends farther in laparoscopic procedures done by inexperienced surgeons[1,4,9]. A previous study reported that operating time is shorter if the procedure is performed by an experienced surgeon due to better exposure[11]. Because our surgical team has laparoscopic procedure experience, we have concluded that the operating times for LA and MOA are similar. In our institution, ultrasonic energy is used for transsecting the mesoappendix. But it is not actually mandatory, electro-cautery and other devices can be preferred[12-14]. Moreover, the similar operating time should be considered a positive factor for LA. The hospital stay period is directly dependent on a patient's general condition[4], and a shorter hospital stay in LA has been shown in previous studies; this outcome was proven by meta-analysis studies[3,6,7,9].

Table 2 Result of mini-incision open appendectomy *vs* laparoscopic appendectomy *n* (%)

		LA (*n* = 122)	OA (*n* = 121)	*P* value
Hospital stay (h)[3]		25.61 ± 23.72	28.92 ± 21.93	0.071[4]
Return to daily activities (d)		4 (2–12)	5 (3-15)	
Overall morbidity		8 (6.5)	9 (7.4)	0.599[2]
Mortality		0	0	-
VAS score[3]	1st hour	7.1 ± 0.5	7.6 ± 0.7	0.001[1]
	6th hour	3.9 ± 1.1	4.5 ± 1.2	0.001[1]
	12th hour	2.6 ± 1.3	3.1 ± 1.4	0.027[1]
	24th hour	2.4 ± 0.7	2.9 ± 0.9	0.056[1]
Number of analgesics	1	33 (27.0)	18 (14.8)	
	2	46 (37.7)	42 (34.7)	
	3	25 (20.4)	27 (22.3)	0.00[4]
	4	17 (13.9)	33 (27.2)	
Postoperative complications	Pelvic abscess	4	3	
	Wound infection	1	5	
	Atelectasis	1	-	

[1]Student's *t* test; [2]χ^2 test; [3]mean ± SD; [4]Mann-Whitney test. LA: Laparoscopic appendectomy; OA: Open appendectomy.

The 48 h discharge policy recommended for both OA and LA by previous studies has caused confusion due to different policies of individual hospitals[3,9]. Many studies list hospital stay periods by the number of days *vs* hours because They may be affected by social standards, insurance systems, and hospital discharge policies[3,4,9,15]. In this study, we used hours to define hospital stay periods to reflect differences between the two groups. The hospital stay period was shorter by three hours in LA; it is unclear if this is clinically significant. A meta-analysis done by Cochrane Colorectal Cancer Group revealed that returning to daily activities in a shorter amount of time is considered as an advantage for LA[3,9,16]. Minimal trauma to the abdominal wall is considered the main reason for faster healing and lower pain for LA[3,11,17-28]. Early mobilisation after LA is another advantage, and this is achieved by minimal manipulation of the cecum and ileum during the procedure[3]. While the recovery period was shorter in LA, it was not considered significant.

Postoperative pain on day one was evaluated by the need for analgesics and VAS[3]. Evaluating pain was difficult due to the use of different analgesics, administration of those analgesics in different forms, and different cultures' perceptions of pain. Therefore, to obtain a better result in regard to pain evaluation, we used two methods. Many previous studies have shown lower needs for analgesics and VAS[3,9]. In this study, postoperative pain was measured by VAS, and the need for analgesics was statistically lower in the LA group. All of these results supported LA as the preferred option for AA. The presence and degree of postoperative complications are generally considered as safety indicators for a procedure. The most common complications of AAs are wound infections, intra-abdominal abscess, and ileus[9]. It has been shown that postoperative complications are lower in LA *vs* OA[3,4,7,9]. Lower complications in LA, as shown in this study, are due to the lower incidence of wound infections. There is considerable controversy regarding the occurrence of intra-abdominal abscess after appendectomy, which is a serious and life threating complication[9]. Some studies in the literature have shown that the rate of intra-abdominal abscess is higher in OA[1-3,5,15,16]. Moreover, some studies have favoured LA in terms of these complications. The laparoscopic technique has some advantages such as the removal of intra-abdominal infected fluid with suction. However, it can spread infected fluid into the peritoneum, especially in perforated appendicitis and when using more irrigation. Additionally, carbon dioxide insufflation can spread bacterial contamination into the peritoneum[3,9,13]. It is believed that using advanced surgical techniques and gaining more laparoscopic experience may decrease the intra-abdominal abscess rate in LA[3]. Overall, the lower rate of wound infection is an advantage for LA because the infected appendix can be removed from a small incision in an endobag[3,4,9]. The economical analysis of these two techniques is another issue that must be addressed. Although there are many studies about the cost analysis between LA and OA[29,30], we did not make an actual consideration, which needs to be addressed in further studies. In this study, pregnancy group was excluded, because we believe in that MOA *vs* LA in the pregnant should be evaluated in a separate study[31].

In conclusion, LA has a similar hospital stay, operating time, and rate of postoperative complications as MOA, yet decreases the need for analgesics and VAS. Therefore, LA should be the suggested treatment for AA. MOA is still a viable alternative for selected patients.

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COMMENTS

Background

Laparoscopic appendectomy is still not accepted as a standard management for acute appendicitis due to longer operation time and higher cost. In the literature, there are few studies on surgical treatment comparing laparoscopic and mini-incision open appendectomy.

Research frontiers

Hospital stay, operation time, postoperative complication rates are important for the management of acute appendicitis. It is important for the patient's comfort to understand the best technique with regard to mini-incision open and laparoscopic techniques.

Innovations and breakthroughs

Acute appendicitis is mostly-encountered disease in a daily routine. Researches regarding decreasing morbidity and mortality are still needed, although it is very well known. There were no differences in the period of hospital stay, operation time, and postoperative complication rate between the two groups. Laparoscopic appendectomy decreases the need for analgesic medications and the visual analog scale of pain. Therefore, the author suggests that laparoscopic appendectomy should be accepted as a standard treatment for acute appendicitis. Mini-incision appendectomy is an alternative for a select group of patients.

Applications

The author suggests that laparoscopic appendectomy should be accepted as a standard treatment for acute appendicitis. Mini-incision appendectomy is an alternative for a select group of patients.

Peer-review

The author describes the differences between two techniques about the acute appendicitis. This is an interesting issue.

REFERENCES

1 **Tzovaras G**, Baloyiannis I, Kouritas V, Symeonidis D, Spyridakis M, Poultsidi A, Tepetes K, Zacharoulis D. Laparoscopic versus open appendectomy in men: a prospective randomized trial. *Surg Endosc* 2010; **24**: 2987-2992 [PMID: 20552369 DOI: 10.1007/s00464-010-1160-5]

2 **Shaikh AR**, Sangrasi AK, Shaikh GA. Clinical outcomes of laparoscopic versus open appendectomy. *JSLS* 2009; **13**: 574-580 [PMID: 20202400 DOI: 10.4293/108680809X1258998404524]

3 **Oravsky M**, Bak V, Schnorrer M. Laparoscopic versus open appendectomy in treatment of acute appendicitis. *Bratisl Lek Listy* 2014; **115**: 660-662 [PMID: 25573735]

4 **Özsan İ**, Karabuğa T, Yoldaş Ö, Alpdoğan Ö, Aydın Ü. Laparoscopic Appendectomy versus Mini-Incision Appendectomy in Patients with Lower Body Mass Index and Noncomplicated Appendicitis. *Gastroenterol Res Pract* 2014; **2014**: 138648 [PMID: 25580110 DOI: 10.1155/2014/138648]

5 **Ward NT**, Ramamoorthy SL, Chang DC, Parsons JK. Laparoscopic appendectomy is safer than open appendectomy in an elderly population. *JSLS* 2014; **18**: e2014.00322 [PMID: 25392668 DOI: 10.4293/JSLS.2014.00322]

6 **Cipe G**, Idiz O, Hasbahceci M, Bozkurt S, Kadioglu H, Coskun H, Karatepe O, Muslumanoglu M. Laparoscopic versus open appendectomy: where are we now? *Chirurgia* (Bucur) 2014; **109**: 518-522 [PMID: 25149616]

7 **Sakpal SV**, Bindra SS, Chamberlain RS. Laparoscopic appendectomy conversion rates two decades later: an analysis of surgeon and patient-specific factors resulting in open conversion. *J Surg Res* 2012; **176**: 42-49 [PMID: 21962732 DOI: 10.1016/j.jss.2011.07.019]

8 **Fahrner R**, Schöb O. Laparoscopic appendectomy as a teaching procedure: experiences with 1,197 patients in a community hospital. *Surg Today* 2012; **42**: 1165-1169 [PMID: 22426772 DOI: 10.1007/s00595-012-0163-3]

9 **Gurrado A**, Faillace G, Bottero L, Frola C, Stefanini P, Piccinni G, Longoni M. Laparoscopic appendectomies: experience of a surgical unit. *Minim Invasive Ther Allied Technol* 2009; **18**: 242-247 [PMID: 20334502 DOI: 10.1080/13645700903053840]

10 **McGrath B**, Buckius MT, Grim R, Bell T, Ahuja V. Economics of appendicitis: cost trend analysis of laparoscopic versus open appendectomy from 1998 to 2008. *J Surg Res* 2011; **171**: e161-e168 [PMID: 21962815 DOI: 10.1016/j.jss.2011.06.067]

11 **Lim SG**, Ahn EJ, Kim SY, Chung IY, Park JM, Park SH, Choi KW. A Clinical Comparison of Laparoscopic versus Open Appendectomy for Complicated Appendicitis. *J Korean Soc Coloproctol* 2011; **27**: 293-297 [PMID: 22259744 DOI: 10.3393/jksc.2011.27.6.293]

12 **Caglià P**, Tracia A, Spataro D, Borzì L, Lucifora B, Tracia L, Amodeo C. Appendix stump closure with endoloop in laparoscopic appendectomy. *Ann Ital Chir* 2014; **85**: 606-609 [PMID: 25712546]

13 **Yeh CC**, Jan CI, Yang HR, Huang PH, Jeng LB, Su WP, Chen HC. Comparison and efficacy of LigaSure and rubber band ligature in closing the inflamed cecal stump in a rat model of acute appendicitis. *Biomed Res Int* 2015; **2015**: 260312 [PMID: 25699264 DOI: 10.1155/2015/260312]

14 **Shaikh FM**, Bajwa R, McDonnell CO. Management of appendiceal stump in laparoscopic appendectomy-clips or ligature: a systematic review and meta-analysis. *J Laparoendosc Adv Surg Tech* 2015; **25**: 21-27 [PMID: 25548964 DOI: 10.1089/lap.2014.0470]

15 **Pokala N**, Sadhasivam S, Kiran RP, Parithivel V. Complicated appendicitis--is the laparoscopic approach appropriate? A comparative study with the open approach: outcome in a community hospital setting. *Am Surg* 2007; **73**: 737-741; discussion 741-742 [PMID: 17879676]

16 **Masoomi H**, Nguyen NT, Dolich MO, Wikholm L, Naderi N, Mills S, Stamos MJ. Comparison of laparoscopic versus open appendectomy for acute nonperforated and perforated appendicitis in the obese population. *Am J Surg* 2011; **202**: 733-738; discussion 738-739 [PMID: 21992808 DOI: 10.1016/j.amjsurg.2011.06.034]

17 **Swank HA**, Eshuis EJ, van Berge Henegouwen MI, Bemelman WA. Short- and long-term results of open versus laparoscopic appendectomy. *World J Surg* 2011; **35**: 1221-1226; discussion 1227-1228 [PMID: 21472367 DOI: 10.1007/s00268-011-1088-5]

18 **Li X**, Zhang J, Sang L, Zhang W, Chu Z, Li X, Liu Y. Laparoscopic versus conventional appendectomy--a meta-analysis of randomized controlled trials. *BMC Gastroenterol* 2010; **10**: 129 [PMID: 21047410 DOI: 10.1186/1471-230X-10-129]

19 **Sauerland S**, Jaschinski T, Neugebauer EA. Laparoscopic versus open surgery for suspected appendicitis. *Cochrane Database Syst Rev* 2010; **(10)**: CD001546 [PMID: 20927725 DOI: 10.1002/14651858]

20 **Wei B**, Qi CL, Chen TF, Zheng ZH, Huang JL, Hu BG, Wei HB. Laparoscopic versus open appendectomy for acute appendicitis: a metaanalysis. *Surg Endosc* 2011; **25**: 1199-1208 [PMID: 20848140 DOI: 10.1007/s00464-010-1344-z]

21 **Yau KK**, Siu WT, Tang CN, Yang GP, Li MK. Laparoscopic versus open appendectomy for complicated appendicitis. *J Am Coll Surg* 2007; **205**: 60-65 [PMID: 17617333]

22 **Khalil J**, Muqim R, Rafique M, Khan M. Laparoscopic versus open appendectomy: a comparison of primary outcome measures. *Saudi J Gastroenterol* 2011; **17**: 236-240 [PMID: 21727728 DOI: 10.4103/1319-3767.82574]

23 **Thomson JE**, Kruger D, Jann-Kruger C, Kiss A, Omoshoro-Jones JA, Luvhengo T, Brand M. Laparoscopic versus open surgery for complicated appendicitis: a randomized controlled trial to prove safety. *Surg Endosc* 2015; **29**: 2027-2032 [PMID: 25318368]

24 **Concha JA**, Cartes-Velásquez R, Delgado CM. Single-incision laparoscopic appendectomy versus conventional laparoscopy in adults. A systematic review. *Acta Cir Bras* 2014; **29**: 826-831 [PMID: 25517497 DOI: 10.1590/S0102-86502014001900010]

25 **Werkgartner G**, Cerwenka H, El Shabrawi A, Bacher H, Hauser H, Mischinger HJ, Wagner M, Wagner D. Laparoscopic versus open appendectomy for complicated appendicitis in high risk patients. *Int J Colorectal Dis* 2015; **30**: 397-401 [PMID: 25510816 DOI:

10.1007/s00384-014-2095-4]

26 **Sohn M**, Hoffmann M, Hochrein A, Buhr HJ, Lehmann KS. Laparoscopic Appendectomy Is Safe: Influence of Appendectomy Technique on Surgical-site Infections and Intra-abdominal Abscesses. *Surg Laparosc Endosc Percutan Tech* 2015; **25**: e90-e94 [PMID: 25462984]

27 **Masoomi H**, Mills S, Dolich MO, Ketana N, Carmichael JC, Nguyen NT, Stamos MJ. Comparison of outcomes of laparoscopic versus open appendectomy in children: data from the Nationwide Inpatient Sample (NIS), 2006-2008. *World J Surg* 2012; **36**: 573-578 [PMID: 22270985 DOI: 10.1007/s00268-011-1417-8]

28 **Ingraham AM**, Cohen ME, Bilimoria KY, Pritts TA, Ko CY, Esposito TJ. Comparison of outcomes after laparoscopic versus open appendectomy for acute appendicitis at 222 ACS NSQIP hospitals. *Surgery* 2010; **148**: 625-635; discussion 635-637 [PMID: 20797745 DOI: 10.1016/j.surg.2010.07.025]

29 **Casarotto A**, Zarantonello FR, Rebonato M. Appendectomy in women. Is the laparoscopic approach always better than the "open" approach in uncomplicated appendicitis? *Surg Laparosc Endosc Percutan Tech* 2014; **24**: 406-409 [PMID: 24910936 DOI: 10.1097/SLE.0000000000000063]

30 **Lee HJ**, Park YH, Kim JI, Choi PW, Park JH, Heo TG, Lee MS, Kim CN, Chang SH. Comparison of clinical outcomes and hospital cost between open appendectomy and laparoscopic appendectomy. *J Korean Surg Soc* 2011; **81**: 321-325 [PMID: 22148124 DOI: 10.4174/jkss.2011.81.5]

31 **de Moya MA**, Sideris AC, Choy G, Chang Y, Landman WB, Cropano CM, Cohn SM. Appendectomy and pregnancy: gestational age does not affect the position of the incision. *Am Surg* 2015; **81**: 282-288 [PMID: 25760205]

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ORIGINAL ARTICLE

Prospective Study

Anal cushion lifting method is a novel radical management strategy for hemorrhoids that does not involve excision or cause postoperative anal complications

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Author contributions: Ishiyama G and Nishidate T designed the study; Ishiyama G, Ishiyama Y, Nishio A, Tarumi K and Kawamura M acquired the data; Ishiyama G, Nishidate T, Mizuguchi T, Fujimiya M and Hirata K analyzed and interpreted the data; Ishiyama G, Nishidate T, Mizuguchi T and Hirata K drafted this paper; Okita K provided the statistical advice.

Institutional review board statement: The study was reviewed and approved by the Ishiyama Clinic and Hospital Institutional Review Board.

Clinical trial registration statement: This study is registered at http://www.ishiyamahp.jp/index.html [Anorectal clinical trial registry (ACTR)]. The registration identification number is #IS 10012006.

Informed consent statement: All study participants, or their legal guardian, provided informed written consent prior to study enrollment.

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Abstract

AIM: To describe the anal cushion lifting (ACL) method with preliminary clinical results.

METHODS: Between January to September 2007, 127 patients who received ACL method for hemorrhoid was investigated with informed consent. In this study, three surgeons who specialized in anorectal surgery performed the procedures. Patients with grade two or more severe hemorrhoids according to Goligher's classification were considered to be indicated for surgery. The patients were given the choice to undergo either the ACL method or the

ligation and excision method. ACL method is an original technique for managing hemorrhoids without excision. After dissecting the anal cushion from the internal sphincter muscle, the anal cushion was lifted to oral side and ligated at the proper position. Clinical characteristics and outcomes of patients were recorded including complications after surgery.

RESULTS: A total of 127 patients were enrolled. Their median age was 42 (19-84) years, and 74.8% were female. In addition, more than 99% of the patients had grade 3 or worse hemorrhoids. The median follow-up period was 26 (0-88) mo, and the median operative time was 15 (4-30) min. After surgery, analgesics were used for a median period of three days (0-21). Pain control was achieved using extra-oral analgesic drugs, although some patients required intravenous injections of analgesic drugs. The median duration of the patients' postoperative hospital stay was 7 (2-13) d. A total of 10 complications (7.9%) occurred. Bleeding was observed in one patient and was successfully controlled with manual compression. Urinary retention occurred in 6 patients, but it disappeared spontaneously in all cases. Recurrent hemorrhoids developed in 3 patients after 36, 47, and 61 mo, respectively. No anal stenosis or persistent anal pain occurred.

CONCLUSION: We consider that the ACL method might be better than all other current methods for managing hemorrhoids.

Key words: Hemorrhoidectomy; Anal stenosis; Anal cushion lifting method

Core tip: Hemorrhoidectomy, *e.g.*, the ligation and excision method, is still the gold standard surgical technique for hemorrhoids. All of the classical surgical techniques for hemorrhoids are fundamentally based on the resectioning of the hemorrhoids, which can result in anal stenosis. We developed the anal cushion lifting method, in which the prolapsed anal cushion is restored to its original position, as a way of preventing various postoperative complications. We recruited 127 patients and conducted a prospective clinical study. By the end of the study, none of the patients had suffered anal stenosis or persistent anal pain.

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INTRODUCTION

Hemorrhoids are the most common symptomatic disorder among adults, although its exact incidence is unclear[1-4]. In the Austrian national screening program, 39% of the adult population was found to have symptomatic hemorrhoids[5]. However, hospital-based proctoscopic studies have suggested that after including asymptomatic cases the prevalence of hemorrhoids is 86%[6]. Hemorrhoids can be caused by abnormal downward displacement of the anal cushions due to straining associated with constipation or traditional lifestyles. Thereafter, the hemorrhoids gradually enlarge until they become symptomatic[1-4]. Surgical management primarily aims to control hemorrhoid prolapse in cases in which conservative treatment has been ineffective[1-4,7]. In addition to symptom management, anal function should be maintained after surgery.

Hemorrhoidectomy is still the gold standard surgical procedure for hemorrhoids, and various techniques have been developed such as the Milligan-Morgan (MM), Ferguson, and stapled hemorrhoidectomy (procedure for prolapse and hemorrhoids) methods, *etc*[2]. All of the classical surgical techniques for treating hemorrhoids aim to resect the hemorrhoids together with the anoderm and the perianal epithelium, which occasionally causes anal stenosis and persistent anal pain[8]. In a previous study, anal stenosis occurred in 2.4%-5% of cases in which the Ferguson or MM method was employed[9,10]. Furthermore, severe anal stenosis was reported to occur in 1.8% of cases in which the MM method was performed[11]. In addition to anal stenosis, postoperative pain, bleeding, and long hospital stays are clinical problems that need to be overcome[1]. We developed a novel surgical method for treating hemorrhoids, in which the prolapsed anal cushion is returned to its native position and sutured, that does not involve any resectioning of the anoderm. The main advantages of this technique, which we have named the anal cushion lifting method [the anal cushion lifting (ACL) method], are that it is very simple and does not cause anal stenosis or persistent pain. Herein, we describe the ACL method in detail and report preliminary clinical results for the procedure.

MATERIALS AND METHODS

We used the ACL method to treat 127 patients who gave their informed consent from January to September 2007. In this study, three surgeons who specialized in anorectal surgery (board certified anorectal surgeons belonging to the Japan Society of Coloproctology; No. 1857 for Ishiyama G, No. 0021S for Ishiyama Y, and No. 1829 for Tarumi K) performed the procedures. Before the study, we decided that the study would be terminated if any of the patients suffered anal stenosis or persistent pain. Otherwise, it would be terminated

Table 1 Classification of internal hemorrhoids

Grade	Physical findings
Ⅰ	Prominent hemorrhoidal vessels, no prolapse
Ⅱ	Prolapse with Valsalva maneuver; spontaneous reduction
Ⅲ	Prolapse with Valsalva maneuver; requires manual reduction
Ⅳ	Chronically prolapsed; manual reduction ineffective

at the end of the month in which the 100th patient was recruited. Patients with grade two or more severe hemorrhoids according to Goligher's classification were considered to be indicated for surgery (Table 1)[12]. The patients were given the choice to undergo either the ACL method or the ligation and excision (LE) method. During the study period, 189 patients selected the LE method. The study protocol was consistent with the Declaration of Helsinki, and all of the patients gave their informed consent.

Procedure of the ACL method

Caudal epidural anesthesia or low lumber anesthesia was used. The procedure was usually performed whilst the patient was in the prone position, but the Jack-knife position was sometimes selected in cases involving patients with muscular bodies. A good surgical field was obtained by taping and pulling using packing tape. The anal field was sterilized using disinfectant before the operation.

After careful assessment of any anal conditions or other disorders that the patient was suffering from, the anus was gently stretched using the fingers. Some patients had already suffered stenosis, which resulted in the internal sphincter exhibiting reduced elasticity muscle due to fibrosis. This manual manipulation procedure partially restored the hemorrhoids to their native position (Figure 1A and B).

Five to six small straight incisions of 1-2 cm in length were made in the swollen epithelium of the perianal skin (Figure 1C and D). Then, we dissected the tissue between the anal cushion and internal sphincter muscle (Figure 1E and F). No significant bleeding occurred, providing that the dissection was performed accurately. In most cases, the hemorrhoids were spontaneously restored to their native position after this part of the procedure.

Next, we sutured the cranial side and middle portion of the anal cushion to the internal sphincter muscles (Figure 1G and H) using 3-0 VICRYL® Rapide sutures (Ethicon Endo-Surgery Inc., Blue Ash, OH, United States). The anal cushion shrank after its circumferential ligation, and the anal prolapse was completely resolved (Figure 1I and J).

Postoperative medication

No antibiotics were administered after the surgery. Non-steroidal anti-inflammatory drugs (NSAID) were administered on the first three postoperative days unless the patient experienced pain. If the patient complained of pain, intravenous analgesic injections or extra-oral analgesic medication were administered, and NSAID were administered the next day.

Table 2 Clinical characteristics and outcomes of patients that underwent the anal cushion method (n = 127)

Characteristics and outcomes	Values (95%CI)
Age (yr)	42 (19-84)
Gender (male:female)	32 (25.2%): 95 (74.8%)
Grade (2:3:4)	1 (0.8%): 113 (89.0%): 13 (10.2%)
Follow-up time (mo)	26 (0-88)
Operative time (min)	15 (4-30)
Duration of analgesic treatment (d)	3 (2-13)
No. of intravenous analgesic injections	0 (0-9)
No. of doses of extra-oral analgesic medication administered	3 (0-21)
Duration of hospital stay (d) (Time to resumption of normal activity)	7 (2-13)
Total complications	10/127 (7.9%)
Bleeding	1 (0.8%)
Urinary retention	6 (4.7%)
Recurrence	3 (2.4%)
Anal stenosis	0
Infection	0
Persistent anal pain during hospital stay	0

Statistical analysis

All data were analyzed using SPSS 16.0 (SPSS Inc., Chicago, IL). A statistical review of the study was performed by a biomedical statistician.

RESULTS

A total of 127 patients were enrolled in this study (Table 2). Their median age was 42 years old, and 74.8% were female. In addition, more than 99% of the patients had grade 3 or worse hemorrhoids. The median follow-up period was 26 mo, and the median operative time was 15 min. After surgery, analgesics were used for a median period of three days. Pain control was achieved using extra-oral analgesic drugs in most cases, and such drugs were administered a median of three times, although some patients required intravenous injections of analgesic drugs. The median duration of the patients' postoperative hospital stay was 7 d.

A total of 10 complications occurred. Bleeding was observed in one patient and was successfully controlled with manual compression. Urinary retention occurred in 6 patients, but it disappeared spontaneously in all cases. Recurrent hemorrhoids developed in 3 patients after 36, 47, and 61 mo, respectively. No anal stenosis or persistent anal pain occurred.

DISCUSSION

We developed a novel surgical procedure for hemorrhoids,

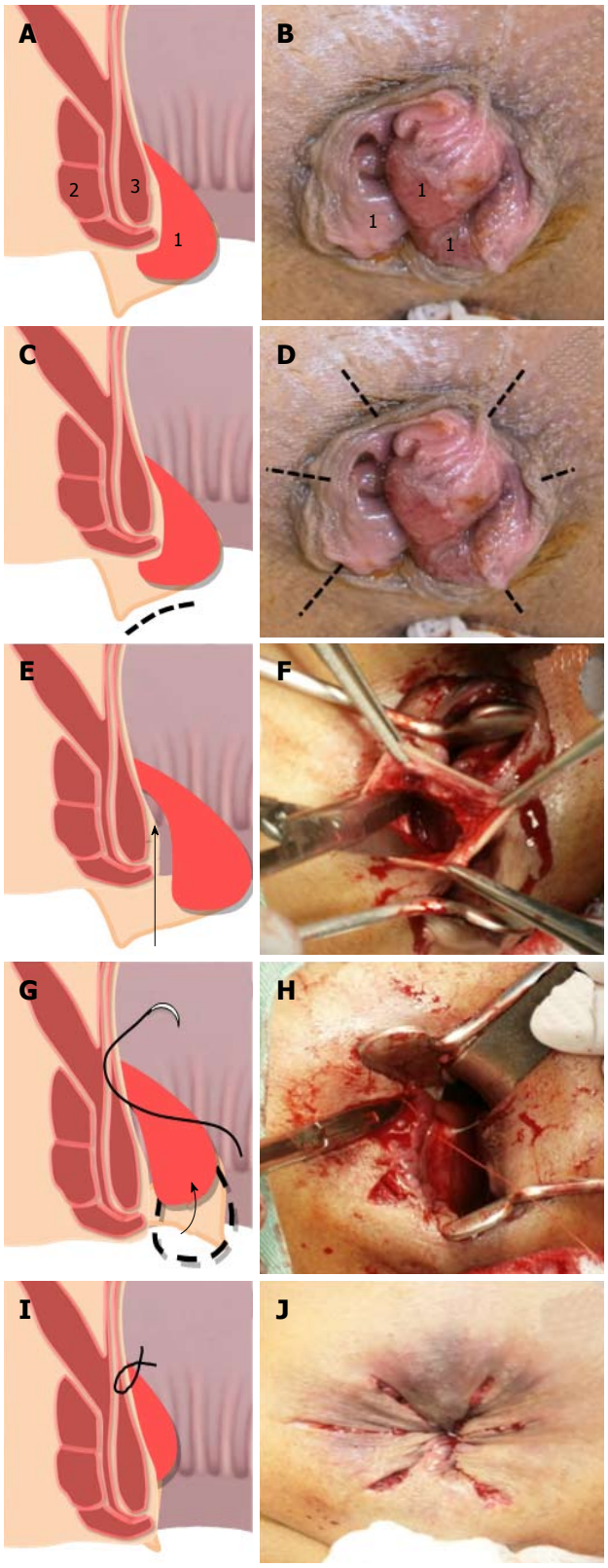

Figure 1 Sagittal diagrams (A, C, E, G and I) and intraoperative views (B, D, F, H and J) of the anus. Small incisions were made in the perianal skin (C), and several radial incisions were performed (D). The tissue between the internal sphincter muscle and anal cushion was dissected (E and F). The anal cushion was restored to its native position (G). The anal cushion was sutured from its middle portion to the cranial side using single stitches (G and H). All sutures were tied up circumferentially (I). The appearance of the anus after the completion of the ACL procedure (J). 1: Hemorrhoids; 2: External sphincter; 3: Internal sphincter. Dotted line: Incision; Arrow: Dissection.

which we named the ACL method. In the present study, the clinical outcomes of the ACL method; *i.e.*, its complications, the operative time, the number of postoperative analgesic injections required, the frequency of postoperative oral analgesic medication use, the duration of postoperative analgesic treatment, and the duration of the postoperative hospitalization period, were acceptable.

Classical hemorrhoidectomy and other surgical techniques for treating hemorrhoids basically involve the ligation of the feeding artery[1]. However, if the blood supply to the anoderm and perianal tissue is cut off due to arterial ligation then these tissues will become necrotic. On the other hand, the ACL method is based on the ligation of the superficial anal cushion and preserves the arterial supply. So, no necrosis occurs after surgery, and complete wound healing can be achieved. In addition, the importance of preserving the anoderm has been stressed in reports about various other techniques, and anoderm preservation has been reported to reduce the risk of anal stenosis and anal pain after surgery[13]. The ACL method does not involve any excision of the anoderm. Our only concern about the ACL method was whether the anal cushion would become congested after surgery, which could lead to a worsening of the patient's symptoms. However, the collateral venous plexus is preserved in the ACL method, so the anal cushion never becomes congested.

Recently, a similar technique, the Z-shaped ligation method for anal hemorrhoids, was reported by Gemici *et al*[14]. Their concept is derived from sclerotherapy, which aims to treat vascular structures alone. The difference between our ACL method and the Z-shaped ligation method is that we dissected the tissue between the anal cushion and internal sphincter muscle and they did not. Both procedures involve similar ligation sites and exhibited similar complications rates. Our ACL method might be more painful than the Z-shaped ligation method as it requires incisions and dissection. However, small radial incisions do not cause severe anal pain, and dissection itself does not cause anal pain. The recurrence rate of the ACL method seems to be lower than that of the Z-shaped ligation method, which is reasonable. As *en-bloc* ligation of the anal cushion can only be achieved after the dissection of the tissue, both methods prove that ligation of the anal cushion is sufficient for managing hemorrhoids.

The anal pain experienced after the LE method is considered to be caused by the anal duct being subjected to excessive tension after surgery[8]. Excision of the anoderm and perianal epithelium itself can also cause postoperative anal pain[13]. On the other hand, the ACL method causes minimal postoperative anal pain, as it does not involve the application of tension to the anal duct. In addition, the total length of the incisions made during the ACL method is shorter than the total length of the incisions made during classical methods. Furthermore, the better blood supply provided by the

Table 3 Perioperative and postoperative findings of conventional hemorrhoidectomy methods

Ref.	Bikhchandani *et al*[15]	Shalaby *et al*[10]	Bulus *et al*[16]	Correa-Rovelo *et al*[9]
Method	MM	MM	Ferguson	Ferguson
No. of patients	42	100	71	42
Operative time (min) (mean ± SD)	45.2 ± 5.4	19.7 ± 4.7	25.5 ± 7.7	38.1 ± 12.9
Complications (%)				
Bleeding	2.4	2.0	4.2	0
External tags	2.4	1.0	-	4.9
Anal stenosis	0	5.0	1.4	2.4
Infection	0	-	1.4	-
Urinary retention	16.7	14.0	28.2	7.1
Recurrence	5.0	2.0	8.5	0

MM: Milligan-Morgan.

ACL method helps to prevent persistent pain after surgery. In fact, the patients that underwent the ACL method did not have to stay in hospital for as long and were able to return to normal life faster than those that underwent the classical method. Also, the patients who underwent the ACL method required fewer analgesic injections, took analgesic medications less often and for shorter periods, and experienced less pain than those that underwent the LE method.

As we have shown, the ACL method is a very simple technique that does not cause significant bleeding. The classical surgical methods for hemorrhoids are based on the excision of the anoderm and ligation of the feeding artery[2,3]. In such procedures, the incisions have to be meticulously planned in order to prevent skin tags. However, the ACL method involves simple dissection of the tissue between the anal cushion and the inner sphincter muscle followed by the ligation of the anal cushion. Therefore, in the present study the total operation time for the ACL method was shorter than that for the LE method.

The most important aspect of the classical technique is the extent of the excision. In cases involving significant anal prolapse, a large amount of skin has to be excised to achieve good anal esthetics. However, the risk of postoperative stenosis is increased if the excision is too extensive. On the other hand, the ACL method is not affected by such concerns. The clinical outcomes of two excision methods, the MM and Ferguson methods, are summarized in Table 3. In the present study, the ACL method exhibited a lower complications rate than the abovementioned excision methods. Interestingly, all of the patients' anal cushions eventually shrank after the ACL method. This makes sense as the ACL method preserves collateral venous vessels, which facilitates anal cushion shrinkage and the restoration of normal function.

We consider that the ACL method might be better than all other current methods for managing hemorrhoids, including the Z-shaped ligation method. However, we could not prove that the ACL method has definitive clinical advantages in the present study. Therefore, a large prospective study should be designed to confirm the clinical advantages of the ACL method over other methods.

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COMMENTS

Background

Hemorrhoidectomy is still the gold standard surgical procedure for hemorrhoids, and various hemorrhoidectomy procedures, such as the ligation and excision method, *etc*., have been proposed. All of the classical surgical techniques for hemorrhoids are based on resecting the hemorrhoids together with the anoderm and the perianal epithelium, which occasionally causes anal stenosis and persistent anal pain. The authors present a novel surgical approach, in which the prolapsed anal cushion is restored to its native position that does not cause postoperative stenosis or persistent anal pain.

Research frontiers

Classical hemorrhoidectomy and other surgical techniques for treating hemorrhoids cause postoperative stenosis or persistent anal pain. On the other hand, the anal cushion lifting (ACL) method is based on the ligation of the superficial anal cushion and preserves the arterial supply. So, no necrosis occurs after surgery, and complete wound healing can be achieved.

Innovations and breakthroughs

The ACL method is an original novel surgical technique which causes no anal stenosis and persistent pain after surgery.

Applications

The ACL method might take place classical technique for surgical management of the hemorrhoids in future.

Terminology

Hemorrhoidectomy, *e.g.*, the ligation and excision method, is still the gold standard surgical technique for hemorrhoids. The ACL method is novel surgical technique for hemorrhoids.

Peer-review

The authors have presented interesting results on the development of a new surgical method for the management of hemorrhoid which shows superiority to the current surgical techniques in terms of operation time, post-operative pain and recovery.

REFERENCES

1 **Altomare DF**, Giuratrabocchetta S. Conservative and surgical treatment of haemorrhoids. *Nat Rev Gastroenterol Hepatol* 2013; **10**: 513-521 [PMID: 23752820 DOI: 10.1038/nrgastro.2013.91]

2 **Lohsiriwat V**. Approach to hemorrhoids. *Curr Gastroenterol Rep* 2013; **15**: 332 [PMID: 23715885 DOI: 10.1007/s11894-013-0332-6]

3 **Madoff RD**, Fleshman JW. American Gastroenterological Association technical review on the diagnosis and treatment of hemorrhoids. *Gastroenterology* 2004; **126**: 1463-1473 [PMID: 15131807 DOI: 10.1053/j.gastro.2004.03.008]

4 **Milligan ETC**, Morgan CN, Jones LE. Surgical anatomy of the anal canal and operative treatment of haemorrhoids. *Lancet* 1937; **1**: 1119-1124 [DOI: 10.1016/S0140-6736(00)88465-2]

5 **Riss S**, Weiser FA, Schwameis K, Riss T, Mittlböck M, Steiner G, Stift A. The prevalence of hemorrhoids in adults. *Int J Colorectal Dis* 2012; **27**: 215-220 [PMID: 21932016 DOI: 10.1007/s00384-011-1316-3]

6 **Haas PA**. The prevalence of confusion in the definition of hemorrhoids. *Dis Colon Rectum* 1992; **35**: 290-291 [PMID: 1740081 DOI: 10.1007/BF02051030]

7 **Lehur PA**, Pierres C, Dert C. Haemorrhoids: 21st-century management. *Colorectal Dis* 2013; **15**: 501 [PMID: 23107439 DOI: 10.1111/codi.12075]

8 **Katdare MV**, Ricciardi R. Anal stenosis. *Surg Clin North Am* 2010; **90**: 137-145, Table of Contents [PMID: 20109638 DOI: 10.1016/j.suc.2009.10.002]

9 **Correa-Rovelo JM**, Tellez O, Obregón L, Miranda-Gomez A, Moran S. Stapled rectal mucosectomy vs. closed hemorrhoidectomy: a randomized, clinical trial. *Dis Colon Rectum* 2002; **45**: 1367-1374; discussion 1374-1375 [PMID: 12394436 DOI: 10.1007/s10350-004-6426-3]

10 **Shalaby R**, Desoky A. Randomized clinical trial of stapled versus Milligan-Morgan haemorrhoidectomy. *Br J Surg* 2001; **88**: 1049-1053 [PMID: 11488788 DOI: 10.1046/j.0007-1323.2001.01830.x]

11 **Gravié JF**, Lehur PA, Huten N, Papillon M, Fantoli M, Descottes B, Pessaux P, Arnaud JP. Stapled hemorrhoidopexy versus milligan-morgan hemorrhoidectomy: a prospective, randomized, multicenter trial with 2-year postoperative follow up. *Ann Surg* 2005; **242**: 29-35 [PMID: 15973098 DOI: 10.1097/01.sla.0000169570.64579.31]

12 **Clinical Practice Committee**, American Gastroenterological Association. American Gastroenterological Association medical position statement: Diagnosis and treatment of hemorrhoids. *Gastroenterology* 2004; **126**: 1461-1462 [PMID: 15131806 DOI: 10.1053/j.gastro.2004.03.001]

13 **Theodoropoulos GE**, Michalopoulos NV, Linardoutsos D, Flessas I, Tsamis D, Zografos G. Submucosal anoderm-preserving hemorrhoidectomy revisited: a modified technique for the surgical management of hemorrhoidal crisis. *Am Surg* 2013; **79**: 1191-1195 [PMID: 24165256]

14 **Gemici K**, Okuş A, Ay S. Vascular Z-shaped ligation technique in surgical treatment of haemorrhoid. *World J Gastrointest Surg* 2015; **7**: 10-14 [PMID: 25625005 DOI: 10.4240/wjgs.v7.i1.10]

15 **Bikhchandani J**, Agarwal PN, Kant R, Malik VK. Randomized controlled trial to compare the early and mid-term results of stapled versus open hemorrhoidectomy. *Am J Surg* 2005; **189**: 56-60 [PMID: 15701493 DOI: 10.1016/j.amjsurg.2004.03.014]

16 **Bulus H**, Tas A, Coskun A, Kucukazman M. Evaluation of two hemorrhoidectomy techniques: harmonic scalpel and Ferguson's with electrocautery. *Asian J Surg* 2014; **37**: 20-23 [PMID: 23726831 DOI: 10.1016/j.asjsur.2013.01.002]

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