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REVIEW

Minimally invasive ventral herniorrhaphy: an analysis of 6,266 published cases

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Abstract
Background Over 300,000 ventral abdominal wall hernias are repaired each year in the United States; many of these operations are done with a minimally invasive approach. Despite these numbers, there are few controlled data that evaluate the minimally invasive method of ventral hernia repair.
Methods A review of over 6,000 published cases of minimally invasive ventral herniorrhaphy was performed in order to determine major outcome statistics for this procedure.
Results The mean follow-up period was 20 months. The operative mortality was 0.1%. The mean recurrence rate (weighted) was 2.7%, and the major complication rate (mostly bowel injury and infection) was 3%.
Conclusion The results from published cases of minimally invasive ventral herniorrhaphy appear to be competitive with the historical results of open ventral herniorrhaphy. The major caveats of this review are that most of the data are (1) retrospective/uncontrolled and (2) obtained from specialized centers.

Keywords Hernia · Herniorrhaphy · Ventral · Incisional · Laparoscopic · Minimally invasive

Abbreviations
BMI Body mass index
PTFE Polytetrafluoroethylene

Introduction

In the early 1990s laparoscopic cholecystectomy rapidly replaced open cholecystectomy as the treatment of choice for symptomatic cholelithiasis. This happened largely without the support of controlled data [1]. A similar transformation has been happening with ventral hernia repair, although not as rapidly as with cholecystectomy. There are some

Portions of this data were presented in a poster at the 2007 meeting of the American Hernia Society (Hollywood, FL, March 2007).

In the interval between the statistical analysis and the submission of this manuscript, at least four series [84–87] and three small randomized trials [2, 45, 66] were published that would have met our inclusion criteria; these papers would have increased the number of procedures in our review by ~650. We apologize to these authors for not including their data in our statistical analysis.

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randomized controlled trials in progress and completed that compare open versus laparoscopic ventral herniorrhaphy (described below) [2], yet the number of these trials is small relative to the large number of ventral herniorrhaphies performed—at least 300,000 in the United States alone in 2004 [not including procedures done in Veterans Administration (VA) hospitals; see Table 1]. So currently the best means we have to evaluate minimally invasive ventral hernia repair is a review of the uncontrolled series that have been published. In this manuscript we attempted to provide a statistical analysis of the complications and results of over 6,000 published cases of laparoscopic ventral hernia repair. Not surprisingly, we were limited in our analysis because of the variability of data reporting among the papers reviewed. Nevertheless, we determined what we believe to be reasonably accurate estimates of recurrence, mortality, and other outcomes, and offer an opinion regarding dogma about the operative approach to ventral hernia.

Methods

A PubMed search (http://www.ncbi.nlm.nih.gov/) was performed using the following Boolean strategy: (*laparoscopic* or *minimally invasive*) and (*abdominal* or *incisional* or *ventral*) and (*hernia* or *hernias* or *hernioplasty* or *hernioplasties* or *herniorrhaphy* or *herniorrhaphies*). In addition, the bibliographies of recent articles were examined to double-check the completeness of the Internet search. The search was completed on 26 April 2006. All papers containing data on >10 minimally invasive ventral herniorrhaphies were considered for the database. The types of ventral hernia repair included in this review were incisional, primary umbilical, recurrent, and other anterior abdominal wall hernias; there were no diaphragmatic, inguinal, or other hernias not involving the anterior abdominal wall. Articles were carefully screened to eliminate doubly published series under the same group of authors. In addition, it was common for a given group of authors to publish updates on their series of patients, or to re-analyze a subgroup of patients from their main series. In these cases, the one article from a group of authors that contained their latest update and/or their largest number of procedures was included in the database. In other words, care was taken to avoid counting any series of procedures more than once in the database. The database is available upon request from the first author. None of the manuscript authors were contacted regarding their data. The subsequent statistical analysis was performed using SAS software (PC version 9.1.3; http://www.sas.com).

Results

Manuscripts and journals

There were 60 articles [3–62] that met the inclusion criteria and were published through the first quarter of 2006. The articles appeared in 20 different journals: *Surgical Endoscopy* ($n = 20$ articles); *Hernia* (6); *Journal of Laparoendoscopic Advanced Surgical Techniques A* (5); *Journal of the Society of Laparoendoscopic Surgeons* (4); *Surgical Laparoscopy, Endoscopy and Percutaneous Techiques* (4); *American Journal of Surgery* (3); *American Surgery* (3), *International Surgery*, *Surgery*, and *Zentralblatt fuer Chirurgie* (all $n = 2$); and *Acta Chirurgica Belgica*, *American Journal of Transplation*, *Annals of Surgery*, *ANZ Journal of Surgery*, *European Journal of Surgery*, *Hong Kong Medical Journal*, *Journal of Gastrointestinal Surgery*, *Singapore Medical Journal*, and *Surgeon* (all $n = 1$).

Table 1 Number of ventral/incisional hernia repairs in the United States in 2004 per the National Hospital Discharge Survey, which is published by the National Center for Health Statistics (http://www.cdc.gov/nchs/), a division of the Centers for Disease Control and Prevention, which is within the United States Department of Health and Human Services

ICD-9-CM Procedure code	Description	Number
53.4	Repair of umbilical hernia	53,000
53.5	Repair of other hernia of anterior abdominal wall (without graft or prosthesis)	48,000
53.51	Repair of incisional hernia	31,000
53.59	Repair of other hernia of anterior abdominal wall	17,000
53.6	Repair of other hernia of anterior abdominal wall with graft or prosthesis	91,000
53.61	Incisional hernia repair with prosthesis	67,000
53.69	Repair of other hernia of anterior abdominal wall with prosthesis	23,000
Total		330,000

The Survey collects discharge diagnosis and procedure data from eligible nonfederal short-stay hospitals. In 2004, 476 hospitals met the survey's criteria, and 439 (92%) of these responded to the survey. (For more information, go the following web site: http://www.cdc.gov/nchs/about/major/hdasd/nhdsdes.htm)

Setting and study type

The manuscript setting included 32 academic centers, 27 clinics, and 1 multicenter study. Ten of the manuscripts could be described as prospective nonrandomized (i.e., uncontrolled) trials [5, 7, 14, 18, 19, 27, 39, 40, 45, 49]; the remainder could be classified as retrospective studies. There were two randomized controlled trials that were published during the period of our review [63, 64], but as the patients in these trials apparently were reported in later updates by the same authors [14, 64], the trials were not included in the database of this review.

Procedures per manuscript and publication year

A total of 6,266 procedures were described in 60 articles referred to above; the mean ± SD number of procedures per manuscript was 104 ± 131 (median = 65; mode = 100; range 11–850). The distribution of number of procedures per manuscript is shown in Fig. 1a, b. The vast majority (88%) of papers described a series of ≤200 procedures; 70% had ≤100 procedures, and 43% had ≤50 procedures. The distribution of publication year is shown in Fig. 1c. The interval from 2002 to 2004 appears to have been the peak period for publication of series on minimally invasive ventral herniorrhaphy (data are incomplete for 2006).

Age, sex, and BMI

Descriptive statistics of the patients are given in Table 2. The basic mean (i.e., mean of all the study averages) of the male:female ratios was 0.99, suggesting a nearly equal sex distribution (49.7% male and 50.3% female). The sex ratios of the individual studies, however, were widely variable, and the rough mean male:female ratio was 0.72. That is, out of the 5,223 procedures in which sex was reported, 3,031 of the patients (58%) were women. The mean of the average reported patient age was 55, but the average reported age ranged from 37 to 68. The mean of the average reported BMI was 32, but the range of the average BMI also was divergent. The wide ranges of these patient descriptors suggest (not surprisingly) that disparate patient populations were studied in the 60 manuscripts of this review, making comparison among these manuscripts difficult. So any conclusion derived from the present review will need to be considered in light of this reality.

Table 2 Summary of average sex, age, and BMI for manuscripts on minimally invasive incisional herniorrhaphy

Variable	Basic mean[a]	Median	Range of study averages	No. manuscripts reporting
M/F ratio	0.99	0.716	0–13.5	50
Age	55.2	56	37.0–68.0	53
BMI	32.0	31.7	27.4–37.9	27

[a] The basic mean is the mean of all of the individual study averages

Mortality and recurrence

Two of the most important numbers that can be drawn from this review are the mortality and recurrence rate (see Table 3). Operative mortality (generally defined as death within 30 days of the procedure) was 0.14%. This is a rough mean (also known as raw rate), equal to the total number of events divided by the total number of procedures. Specifically, there were eight deaths; the causes included perforation ($n = 6$), myocardial infarction ($n = 1$), and end-stage liver disease ($n = 1$). The rough mean for hernia recurrence was 3.61%. The distribution of individual rates was negatively skewed for both mortality and recurrence (see Fig. 2a), but in real terms the median rate for both outcomes (0 and 3.6%, respectively) did not differ much from the rough mean. A more accurate measure of operative mortality than the rough mean probably is not feasible, since the number of deaths in this review was quite low, and most (86%) of the studies did not have an

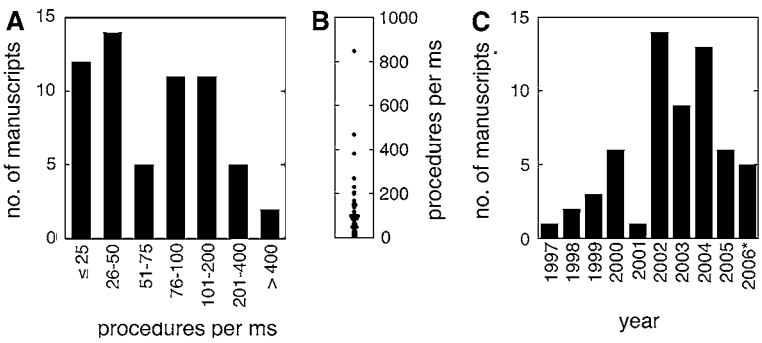

Fig. 1a–c Classification of manuscripts by procedure number and publication year. **a** Histogram of manuscripts sorted by number of procedures per manuscript (ms). For example, there were five manuscripts with a total procedure number in the 51–75 range. **b** Scattergram of procedure number; each *open circle* represents the number of procedures in an individual manuscript. **c** Histogram of manuscripts sorted by publication year. For example, there were six manuscripts published in 2000. *Asterisk* Data incomplete for 2006

Table 3 Summary of major outcome data

Value	Mortality	Conversion	Recurrence	Perforation/leak/fistula	Mesh infection	Reoperation
Rough mean[a] (%)	0.14	3.33	3.61	2.05	0.78	3.14
Total procedures	5,566	5,411	5,624	5,797	5,797	5,163
Total events	8	180	203	119	45	162

[a] The rough mean is the total number of events divided by the total number of procedures (data on all outcomes were not available in all of the manuscripts)

operative mortality. In essence, about one in every 1,000 patients died after a minimally invasive incisional herniorrhaphy.

Further statistical manipulation is possible with the recurrence data, since this event was more frequent than operative mortality. In addition to the rough mean, another simple statistic is the basic mean, which is calculated by first determining the recurrence rate for each study, and then taking the average of all these recurrence rates. This process yielded a basic recurrence rate of 4.3%. The basic mean, however, does not account for the relative weight of each study average secondary to its procedure number or other factors, e.g., a series of 12 patients with two recurrences would skew the basic mean. Likewise, the rough mean described in the previous paragraph is problematic because it makes the bold assumption that there is no variability among the studies, e.g., a series of 100 patients with an incisional hernia after hepatic transplantation might be expected to heal after an incisional herniorrhaphy differently than a series of 100 incisional hernia patients not on immunosuppressive medication.

In order to obtain a more accurate estimate of the recurrence rate, a weighted mean recurrence rate was calculated using the inverse of the variance as the weight. The variance was calculated using the formula $(r)(1-r)/(n)$, where r is the recurrence rate and n is the number of procedures. For studies that had a recurrence rate of 0, the variance cannot be calculated. Therefore, the recurrence rate was recalculated using 0.5 divided by the number of procedures. This allowed an estimate of the variance and also accounted for sample size in that a study with fewer procedures had a larger variance estimate, resulting in a lower weight. The weighted mean recurrence rate was 2.7% (with a 95% confidence interval of 2.25–3.10), which was somewhat lower than both the rough and basic means. Roughly speaking, there were about three hernia recurrences for every 100 herniorrhaphies in this review.

Correlation of recurrence with other variables

In an attempt to identify factors associated with the development of recurrence after minimally invasive ventral herniorrhaphy, we performed univariate analysis on each of the putative risk factors listed in Table 4 (descriptive data on these variables appear below). Although there was a mild association with male sex or duration of follow-up (not reaching significance), none of the variables examined were significantly associated with recurrence. Amount of operative experience often is associated with better outcome; one measure of experience that was available was the number of procedures performed per manuscript. This variable was plotted against recurrence in Fig. 2b. As Table 4 indicates, there was no obvious linear correlation between recurrence and procedure number. A casual glance at the scattergram in Fig. 2b might suggest a power curve fit of the type $y = kx^n$, particularly if the data points with a recurrence rate of zero are eliminated from the analysis. Eliminating these produced a power curve fit with $R = 0.22$, only modestly better than the linear curve fit. Other curve fits (polynomial, exponential, logarithmic) of the recurrence rate versus procedure number data were not better than the power curve fit (data not shown).

Another possible measure of experience that was available was the manuscript publication year. Use of the publication year as a risk factor assumes that later publication equates to more experience, which is a nonscientific assumption, at best. Irrespective of this, the publication year was plotted against the recurrence rate in Fig. 2c. Similar to the case with procedure number, there was no obvious linear correlation between recurrence and publication year. If the mean recurrence rate of each year's publications is plotted (inset of Fig. 2c), then there does appear to be a slight trend downward in recurrence rate, but this also produces a poor correlation coefficient. So the bottom line is that this review of minimally invasive ventral hernia repairs was not able to confirm any of the previously hypothesized recurrence risk factors for which data could be collected.

Conversion, perforation, mesh infection, and reoperation

Summary statistics on other major outcomes—conversion, perforation, mesh infection, and reoperation—are also given in Table 3. Conversion is relatively unambiguous event, and usually has the same meaning from one manuscript to another. Perforation, as utilized in this review, clumps together all events in which there is inadvertent escape of intestinal contents into the surrounding area. This includes an obvious intestinal rent made during the

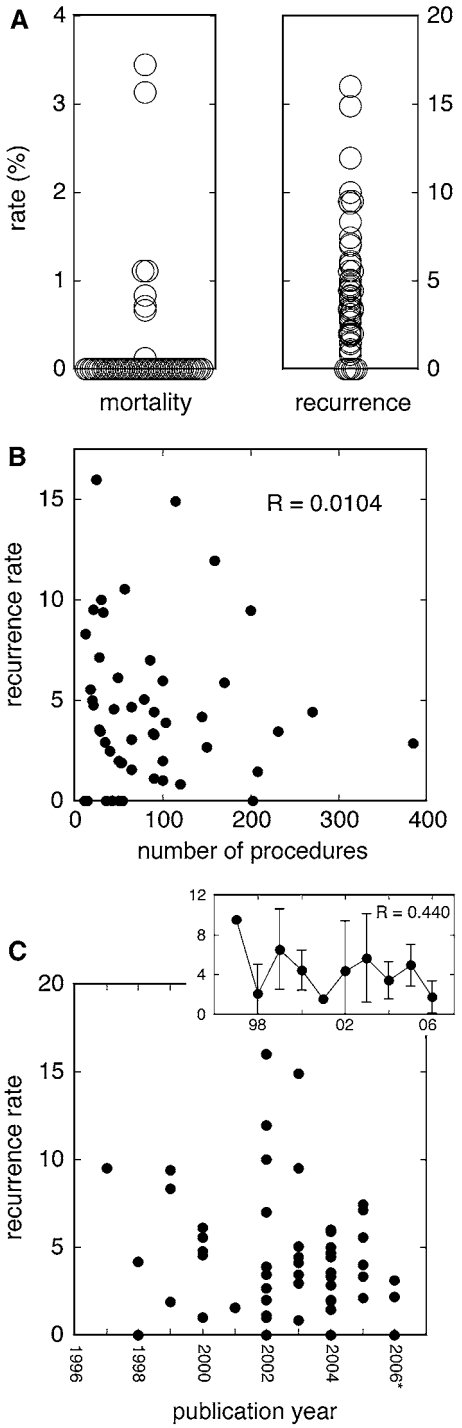

Fig. 2a–c Mortality and recurrence data. **a** Scattergrams of mortality and recurrence rates. Each *circle* represents the rate from one study. Data are summarized in Table 3. Note that the vast majority of studies did not have mortality. **b** Scattergram of recurrence rate versus procedure number (i.e., the denominator from which the rate was calculated). One data point (procedure number = 850, recurrence rate = 4.1%) is not shown in the plot but was included in the analysis. **c** Scattergram of recurrence rate versus year of publication. *Asterisk* indicates data are incomplete for 2006. *Inset* "Mean" recurrence rate plotted against the publication year. Each data point is the mean of all the rates reported during that year ± SD. *R* Correlation coefficient for a linear curve fit

Table 4 Correlation of putative risk factors with recurrence rate

Risk factor	*n*	Test	*P* value[a]
Follow-up duration	50	Spearman	0.12
Male sex	46	Spearman	0.12
Mesh[b]	59	Wilcoxon	0.42
Fixation[c]	54	Wilcoxon	0.43
BMI	24	Spearman	0.54
Publication year	55	Spearman	0.64
Mesh overlap (cm)	50	Spearman	0.72
Procedure number	55	Spearman	0.87

n Number of manuscripts in which the data were available

[a] Null hypothesis for the statistical test was that there was no relationship between the risk factor and recurrence rate

[b] For the mesh risk factor, use of PTFE was compared with the use of non-PTFE mesh

[c] For the fixation risk factor, fixation with the combination of sutures + tacks was compared with other fixation types

operation, a leak or fistula that develops in the early postoperative period, or the formation of an intraabdominal abscess (an extremely probable manifestation of intestinal injury). Mesh infection typically is not a subtle event (e.g., mesh floating in a pus-filled cavity), but these details sometimes were not available in the reviewed manuscripts. In certain manuscripts an interpretation had to be made (by the review authors) on whether a mesh infection actually had occurred or not. Reoperation also was an event subject to interpretation. Some reoperations were obvious; for example, bowel herniation above the mesh in the early postoperative period. For the purpose of quantifying reoperations, the authors counted any reoperative event that was related to the herniorrhaphy which occurred at any point (no time limit) in the postoperative period. Again, this type of data was not carefully documented in some manuscripts, so it is likely that the rough mean reoperative rate quoted in Table 3 underestimates the true reoperative rate. The causes for reoperation are detailed in Table 5; recurrence, bowel leak, mesh infection, and obstruction were the most common indications, in descending order.

Defect and mesh size, duration, and blood loss

Summary statistics on the defect and mesh size, operative duration, and blood loss are given in Table 6; other procedural details will be described below. The mean operative time was about 2 h, and the blood loss (when reported) was minimal. The mean hernia defect size was about 100 cm^2, which is equivalent to a circle about 11.3 cm in diameter. The mean mesh size used was about 300 cm^2, which is equivalent to a square about 17.3 cm on edge. For comparison, an oval 19 × 15 cm Gore-Tex DualMesh (W. L. Gore

Table 5 Indications for reoperation after minimally invasive incisional herniorrhaphy from 40 manuscripts in which reoperative data were available

Reoperation indication	Number of reoperations	Total (%)
Recurrence	64	39.0
Leak/fistula	29	17.7
Mesh infection	28	17.1
Small bowel obstruction	16	9.8
Negative exploration	7	4.3
Hematoma and/or seroma	5	3.0
Pain	4	2.4
Soft tissue necrosis	3	1.8
Trocar hernia	3	1.8
Mesh erosion	1	0.6
Bladder injury	1	0.6
Suture sinus	1	0.6
Mesh intolerance	1	0.6
Bowel ischemia	1	0.6
Total	164	100.0

& Associates) has an area of about 235 cm^2. In terms of extremes, the largest defect repaired in the papers of this review was 1,600 cm^2 (equivalent to a circle about 45 cm in diameter); the smallest defect was 1 cm^2. Incidentally, the use of a circle to describe a hernia defect is an oversimplification, as many incisional hernias have irregular shapes and/or consist of multiple, separate defects.

Operative technique

Some aspects of the operative technique were nearly universal. Intraperitoneal sublay of prosthetic mesh without excision of the hernia sac was the technique used in >95% of the minimally invasive incisional herniorrhaphies in the 60 manuscripts of this review. The surgical technique differed in the type of mesh used, the extent that the mesh overlapped the defect, and the method of mesh fixation to the abdominal wall (see Table 7). Some type of PTFE mesh was used in nearly four-fifths of the cases, with polypropylene mesh being a distant second favorite. For the purpose of this review, "mesh overlap" will be defined as the distance that the mesh extends beyond the edge of the defect in a single radius. So if the defect was 5 cm in diameter, and 4 cm of mesh overlap was utilized, then the mesh would be 13 cm in diameter (5 + 4 + 4). A minimum mesh overlap of 3 cm was quoted by the majority of authors; mesh overlap is defined by the radial distance between the edge of the defect and the edge of the mesh. Nearly two-thirds of the surgeons preferred mesh fixation with a combination of full-thickness abdominal wall sutures and laparoscopic tacks.

Table 7 Type of mesh used, amount of mesh overlap of the defect, and type of mesh fixation

Mesh type	No. of manuscripts which used	Percentage[a] (%)
PTFE	46	78.0
PPE	10	16.9
PPE/PTFE	7	11.9
Coated polyester	7	11.9
Acellular collagen matrix	1	1.7
Minimum mesh overlap (cm)	**No. of manuscripts which used**	**Percentage (%)**
2.0	4	7.4
2.5	3	5.6
3.0	31	57.4
4.0	9	16.7
5.0	7	13.0
Mesh fixation	**No. of manuscripts which used**	**Percentage (%)**
Sutures + tacks	35	64.8
Tacks only	16	29.6
Sutures only	3	5.6

PTFE Polytetrafluoroethylene, *PPE* polypropylene

[a] Of the 59 manuscripts in which mesh type was described, some reported the use of more than one type, so the percentages do not add up to 100%. Data were available on mesh overlap and fixation in 54 manuscripts

Table 6 Summary of operative details

Statistic	Hernia defect size (cm^2)			Mesh size (cm^2)			Operative time (min)			Mean EBL (ml)
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	
Basic mean	10.4	452	96.8	89.1	976	296	43	252	110	41
Standard deviation	13.4	354	7.4[a]	16.5	672	20.8[a]	17	115	5[a]	5[a]
N	30	30	36	17	17	23	39	39	53	8

The basic mean for each measurement was calculated by first determining the mean value for each study, and then averaging all of these mean values

EBL Estimated blood loss, *N* number of manuscripts in which the data were reported

[a] Value actually is the standard error of the mean (SEM), because the basic mean is the average of the mean from the group of reporting manuscripts

Cause of conversion

The reason for conversion to an open repair was reported in 50 manuscripts (describing 157 conversions) and, for the purpose of this review, was classified as extensive adhesions (75 out of 157, or 48%), intraoperative complication (29%), surgeon "comfort" (22%), or equipment failure (1%). Causes for conversion are subject to interpretation, especially when a retrospective analysis is performed. One could argue that the cause for conversion in the vast majority of such incidents (for any type of minimally invasive procedure) is surgeon comfort in proceeding with the minimally invasive approach, whether dealing with dense adhesions, hemorrhage, poor exposure, and so on. On a positive note, equipment failure rarely was reported as the sole cause of conversion.

Perioperative complications

Summary statistics on perioperative complications are given in Table 8. Unlike straightforward outcomes such as 30-day mortality, most of the perioperative complications listed in this table are subject to observer bias, and event reporting depends on the observer's definition of a perioperative event as a complication. Needless to say, there were no standard perioperative complication definitions in use by the 60 manuscripts under review. For example, seroma is an ill-defined event, typically involving a collection of fluid above and/or below the mesh. Not surprisingly, the range of incidence for this event as shown in Table 8 was huge. Postoperative ileus also is a subjective diagnosis; the rates reported in the table likely reflect patients who had an overt disruption of gastrointestinal motility, and do not necessarily reflect patients who had mild to moderate ileus. Other major complications not listed in Table 8 include 15 cardiac events (e.g., myocardial infarction, congestive heart failure, arrhythmia) for an incidence of 0.26%; seven episodes of *Clostridium difficile* colitis (incidence = 0.1%); and two episodes of mesh "reaction" (or rejection/intolerance) involving PTFE (incidence = 0.03%).

Length of stay and follow-up

Data on hospitalization time and follow-up duration are shown in Table 9. For both length of stay and follow-up, each study typically reported a mean, a maximum, and a minimum; for example, a mean follow-up period of 13 months (range 2–31 months). From these data, an array of summary statistics was calculated; in essence, the average length of stay in this review was 3 days (median 2.3) and the average follow-up period was 21 months (median 19).

Discussion

A procedure as common as ventral/incisional herniorrhaphy produces a large and (unfortunately) diverse clinical experience. Not surprisingly, varied opinions have emerged regarding the optimum approach to minimally invasive ventral herniorrhaphy. At this point in time, precious few of these opinions are supported by controlled data. While the existence of controlled data usually has not been a requirement for the adoption of a new therapy that is obviously better than an old therapy, history has suggested that such data might smoothen the transition from the old to the new. For example, better collection of controlled data during the development of laparoscopic cholecystectomy might have ameliorated the subsequent epidemic of common bile duct

Table 8 Summary of perioperative complications

Value	Seroma	Ileus	Pain	Hematoma	Wound infection	Urinary	Pulmonary	Serosal tear	SBO	FUO	Trocar hernia
Rough rate[a] (%)	9.7	2.2	2.0	1.3	1.2	0.83	0.72	0.52	0.35	0.33	0.29
Median rate (%)	7.1	1.3	0	0.35	0	0	0	0	0	0	0
Range (%)	0–92.7	0–26.7	0–18.2	0–36.4	0–9.1	0–6.9	0–7.7	0–10.0	0–5.6	0–5.2	0–2.7

[a] The rough rate is the total number of events divided by the total number of procedures (=5,797, from a reporting group of 59 manuscripts)

SBO Small bowel obstruction, *FUO* fever of unknown origin

Table 9 Summary of length of stay (LOS) and follow-up (F/U) times

	Minimum LOS (days)	Maximum LOS (days)	Mean LOS (days)	Minimum F/U (months)	Maximum F/U (months)	Mean F/U (months)
Basic mean[a]	1.0	15.8	3.0	5.0	46.7	20.6
Median	1.0	11.5	2.3	4.0	39.5	19.0
Range	0–4	3–64	0.1–9.5	0–16.0	1–141	2.5–49.0

[a] The basic mean is the average of all the study means

injury. General surgery has been witnessing a similar transformation in ventral hernia repair.

A problem with basing clinical practice on retrospective experience, however, is the development of diverse dogmas—and this is a playground for medicolegal opportunists in the field of malpractice litigation. With a broad array of expert opinions to choose from, both plaintiff and defense counsel can pick and choose their "weapons," tailoring arguments from the available dogmas to suit their own purpose. Of course, this is not a problem limited to laparoscopic cholecystectomy or herniorrhaphy. In the following discussion, we will address some common issues in minimally invasive ventral herniorrhaphy, but all the while taking a relative stance and avoiding absolutisms.

Indications and contraindications

Currently it is not clear whether the shift to the minimally invasive approach for ventral/incisional herniorrhaphy has broadened the indication for repair of a ventral or incisional hernia. According to data from the National Center for Health Statistics, the number of ventral/incisional hernia repairs performed in the United States has increased gradually since 1996 (see Fig. 3). The cause of this increase is difficult to know. Academically speaking, the advent of the minimally invasive approach probably should not have changed the indication for ventral/incisional hernia repair. Since the indication for such a repair is somewhat relative, however, it may be that patients with less symptomatic hernias and/or in relative poor health are now choosing laparoscopic hernia repair. Perhaps the assumption made by these patients is that the laparoscopic operation will have less physiologic impact, and therefore will be more desirable. Although difficult to document, a similar scenario likely

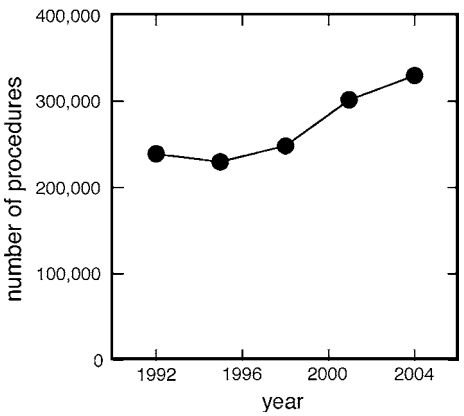

Fig. 3 Approximate annual number of ventral/incisional herniorrhaphies performed in nonfederal hospitals in the United States. Data are from the National Center for Health Statistics (see Table 1). "*No. procedures*" refers to the sum of procedures for ICD-9-CM codes 53.4, 53.5, 53.51, 53.59, 53.6, 53.61, and 53.69

was at play when laparoscopy was implemented for cholecystectomy and antireflux procedures.

One aspect of minimally invasive ventral/incisional herniorrhaphy that often comes up for discussion is the "minimum defect size" required for the laparoscopic approach. This has not been studied well. The data of this review indicate that in some centers very small defects have been undergoing laparoscopic repair. Whether it is advisable to place ports into the abdominal cavity to repair such a small defect is not clear; guidelines published online by the SSAT [65] state that defects <3 cm in diameter can be repaired with primary tissue approximation (which would obviate the need for laparoscopy). This particular guideline is not supported by controlled data, though. In actuality, such small defects typically occur with umbilical hernia; with incisional hernia, however, small defects can occur in clusters along the incision ("Swiss cheese"), and not in isolation. Unfortunately, a Swiss cheese abdomen is not always clinically evident, so that repair of an apparently small incisional hernia with tissue approximation may not address the entire problem. Experience with open hernias has suggested that in these cases the entire incision should be repaired.

The progress of minimally invasive surgery has seen more written about new techniques and approaches and less about contraindications. In general, it would be difficult to name an absolute contraindication to laparoscopic ventral/incisional herniorrhaphy with mesh implantation, which would not also apply to open repair with mesh implantation. Contraindications to minimally invasive repair with mesh implantation are increasingly relative, and generally should be individualized. For example, most surgeons of minimally invasive repair would not view multiple previous abdominal operations, morbid obesity, or giant hernia as a contraindication to a laparoscopic procedure, herniorrhaphy or otherwise. On the other hand, intraoperative bowel perforation presents a more controversial set of circumstances; this particular scenario will be discussed below.

Approach: open versus laparoscopic

This review has made no effort to address the controversy about which approach (open vs. laparoscopic) is better for ventral hernia. The randomized controlled trials that have been published [2, 45, 63, 64, 66] have small subject numbers, but nevertheless suggest that acute complications and recovery time are decreased with the laparoscopic approach. Long-term direct comparative results (especially with respect to recurrence) have not yet been published, but more trials have been planned or are in progress [67, 68]. "Meta-analytic" type comparisons of retrospective data from open versus laparoscopic ventral/incisional herniorrhaphy also have suggested that the laparoscopic approach has a

decreased rate of acute complications, recovery time, and recurrence [69–71]. It has not been uncommon, however, to observe that major treatment differences that were touted by retrospective/preliminary studies become less prominent and/or more vague after the performance of a carefully designed trial. One issue with estimating the recurrence rate of laparoscopic ventral hernia data is that follow-up periods of 10 years or more are needed to obtain a true incidence of hernia recurrence [72–74], and none of the articles in this review have anything close to that duration as a minimum. So it may be premature to conclude that laparoscopic ventral herniorrhaphy has a lower recurrence rate than open repair (one merely has to remember the debate on laparoscopic vs. open inguinal hernia in this regard [75]). With regard to surgical wound or mesh infection, it is the authors' opinion that minimally invasive ventral hernia repair has a lower infection rate than the open procedure, but adequate controlled data at this point are not available.

Prophylaxis of infection

The available data and expert opinion mostly support the use of antibiotic prophylaxis for the insertion of a foreign body, especially in orthopedics [76]. With respect to mesh insertion for inguinal hernia repair, the data are more conflicting [77]; and with respect to mesh insertion for ventral herniorrhaphy, the data for open procedures are insufficient. Whether antibiotic prophylaxis for insertion of mesh during minimally invasive ventral herniorrhaphy is necessary is not clear. Since mesh infection can be a catastrophic complication, however, it would seem reasonable to utilize antibiotic prophylaxis for the laparoscopic approach in the absence of controlled data. The reporting of antibiotic prophylaxis by the papers of this review was not consistent enough to warrant a summary. In addition to properly performed antibiotic prophylaxis [78], there are other practices that might decrease the risk for infection, including (1) the use of an alcohol-based skin preparation, (2) the use of an iodine-impregnated or similar antibacterial adhesive drape to cover the exposed skin of the patient, (3) the use of an antibiotic-impregnated mesh, (4) avoidance of mesh contact with the patient's skin (this would include not dragging the mesh through a port incision, (5) changing surgical gloves just prior to handling the mesh, and (6) postponing the procedure if the patient has evidence of a bacterial infection. The evidence supporting these practices is only expert opinion, and enthusiasm for each technique varies from expert to expert.

Establishment of pneumoperitoneum

The establishment of pneumoperitoneum in a previously operated abdomen can be fraught with difficulty. The techniques in common use for this include (1) insufflation with a Veress needle followed by trocar insertion, (2) "open" insertion with a Hasson cannula or similar device, and (3) direct insertion with an optical/viewing trocar or similar device. While each of these techniques has its proponents, all of these insertion methods have a learning curve and all are prone to misadventure. There are some controlled data (not reviewed here) that compare these insertion techniques, but as the subject numbers in these studies have been too small, definitive answers are not available. In spite of this situation, there are some common sense maneuvers one can employ to decrease the risk of complication associated with pneumoperitoneum establishment, including (1) placing the Veress needle/optical trocar as far as possible from previous incisions, (2) aiming the Veress needle/optical trocar away from major vascular or solid organ structures, (3) placing the Hasson where the subcutaneous fat is the thinnest (typically in the midline, especially just inferior to the umbilicus—if this area was not involved with a previous incision), (4) exercising extreme caution if the Hasson has to be placed through a previous incision, and (5) carefully observing the patient during insufflation. Despite these precautions, complications of pneumoperitoneum establishment can occur even in the most experienced of hands.

Another acute complication related to trocar insertion is abdominal wall hematoma secondary to laceration of an abdominal wall vessel. In our own clinical practices, we have adopted the technique of abdominal wall transillumination with an intraabdominal laparoscope prior to trocar insertion. The surgeon simply presses the laparoscope (with the light intensity at maximum) into the peritoneal side of the abdominal wall where the surgeon intends to insert a trocar, and (if the patient is not too obese) a map of vessels is illuminated and visible from the outside. While this technique obviously is not possible for the very first device inserted into the abdomen, it can prevent abdominal wall hematoma caused by subsequent trocar insertion by defining the path of larger vessels as they traverse the abdominal wall. This technique has not been substantiated by any controlled data and is not useful in patients with thick abdominal walls.

General technique of repair

When operating on an incisional hernia, most operators have advocated complete exposure of the previous incision (i.e., dissection of all adhesions away from the old scar) and the entirety of the anterior abdominal wall. This is done in order to avoid missing one or more abdominal wall defects. The laparoscopic repair of ventral hernia with sublay of mesh essentially is the same technique described by Stoppa for open repair of inguinal hernias [79] and by Rives and Flament for open repair of incisional hernias [80]. The

differences are that the minimally invasive technique employs smaller incisions, and also uses intraperitoneal mesh placement instead of a retromuscular/preperitoneal position. The mechanical result is similar; in both the open and minimally invasive approaches, the mesh is underneath the fascia, and there is a substantial amount of mesh overlap (or underlap, depending on one's perspective) with respect to the fascia. The utilization of mesh has been an increasingly popular trend with incisional hernia repair; there now is a wealth of both controlled and uncontrolled data supporting this trend (not reviewed here). The bottom line appears to be that the use of mesh for incisional hernia repair decreases the risk of recurrence. The dogma that arises from this clinical experience regards the details of the operative technique: where the mesh should be placed in relation to the abdominal wall layers, what kind of mesh should be used, how large the mesh should be relative to the hernia defect, etc. So if the question regarding an incisional hernia is repair with mesh or repair without mesh, then the answer, in general, would be: repair with mesh. Beyond this, there is controversy.

Mesh type and positioning

Intraperitoneal placement of mesh without sac excision seems to be the near-universal method of mesh positioning in the manuscripts of this review. A vast amount of retrospective data, including that in this review, has confirmed the safety of this approach. The greater majority of these intraperitoneal prosthetics utilized in the reviewed manuscripts were PTFE or PTFE composites. It seems that most surgeons believe that PFTE has a very low risk of visceral erosion. Another material commonly used for abdominal wall hernia repair, polypropylene, is believed to have an unacceptable risk of visceral erosion. This risk probably has been exaggerated based on publicity over small but prominent reports [81, 82]. Upon close inspection, however, it is apparent that most reported cases of polypropylene erosion into the bowel occurred in wounds that had excessive and ongoing inflammation. Nevertheless, anecdotal experience with erosive complications of polypropylene mesh is common, so intraperitoneal placement of this type of mesh is infrequent. Interestingly, there is a new generation of lightweight polypropylene materials now widely available that may be safer for intraperitoneal placement during minimally invasive ventral herniorrhaphy. There is as yet no controlled data that examine this issue.

Mesh size in relation to the defect ("overlap") and mesh fixation

In minimally invasive ventral herniorrhaphy, the extent of mesh overlap of the defect and the method of mesh fixation may be primary determinants of two critical outcomes measures: (1) hernia recurrence and (2) abdominal wall pain. Overlap (see definition under "Operative technique" in "Results") is an often-discussed topic that is supported with scant data, i.e., that which was summarized in "Results." Overlap of the defect by the mesh appears necessary to prevent recurrence, but how much? Is more always better? And if the mesh is large enough, will it need less fixation (similar to the groin hernia repair of Stoppa)? The answers to these questions are unknown. Likewise, the technique of mesh fixation also appears important to prevent recurrence, but fixation may be a culprit in another debilitating long-term complication: abdominal wall pain. This problem is uncommon, but aggravating to both patient and surgeon. The statistics of this review indicate that fixation sutures with tacks are the preferred method to secure the mesh; however, there was no standardization of these fixation techniques. Not surprisingly, we could not detect any differences in their outcomes. It also may be of no surprise that the senior authors (MAC and CTF) of this review differ in their approach to mesh fixation, yet both report salutary results. So optimum mesh overlap and fixation technique in minimally ventral hernia repair are guided almost exclusively by expert opinion.

Management of untoward perioperative events

Aside from the long-term complications of hernia recurrence and abdominal wall pain, there are four bothersome perioperative events specific to minimally invasive ventral herniorrhaphy that we will discuss here, since their management is controversial.

Recognized intraoperative bowel perforation

Most patients undergoing minimally invasive ventral herniorrhaphy have had a previous laparotomy with the expected formation of intraabdominal adhesions. In some cases the intraabdominal adhesiolysis required for an incisional hernia repair can be extremely difficult and time consuming. For this reason we do not necessarily consider an enterotomy incurred and recognized during an adhesiolysis as a complication. Bowel injury also can occur secondary to a penetrating instrument, such as a Veress needle, a trocar, or a suture-passing device. Strategies for management of a bowel perforation that is recognized intraoperatively include (1) open conversion with repair of the injury, (2) laparoscopic repair of the injury with delayed hernia repair, (3) laparoscopic repair of the injury with concomitant hernia repair using permanent mesh, or (4) laparoscopic repair of the injury with concomitant hernia repair using a biological or absorbable mesh. The first option is becoming less common as operators are

becoming more comfortable with repairing these injuries laparoscopically. Regarding the repair itself, simple closure perforation usually is sufficient; resection may be necessary if a segment of bowel has been devascularized or sufficiently shredded by a penetrating trocar, for example. Colostomy typically should not be necessary, although it would be rash to say that colostomy absolutely never would be indicated. In most cases of recognized intraoperative bowel perforation in which there is minimal/nil spillage, the real decision has become whether to insert a piece of mesh at the first operation after the injury has been repaired, or whether to wait days to months for a second attempt under "cleaner" conditions. Formerly it might have been considered surgical "heresy" to insert a prosthetic sheet in the presence of a bowel injury, but there are now a number of anecdotal reports of surgeons actually doing this in minimally invasive herniorrhaphy (using PTFE). We do not necessarily advocate this practice, but we acknowledge that it has been done, and that it obviously can work. The difficulty arises in each individual decision of whether a patient with a bowel injury should be managed with immediate or delayed hernia repair. Since the incidence of this complication is quite low, it will be difficult to produce controlled data with sufficient numbers to study the management of recognized intraoperative bowel perforation. As it stands currently, expert opinion can support both delayed and immediate hernia repair after a recognized intraoperative bowel injury with minimal/nil spillage. With regard to use of a biological mesh (e.g., acellular dermal matrix, or Alloderm) in this scenario, there are insufficient data to make a statement.

Delayed intraabdominal sepsis

Although only eight deaths occurred in this collection of over 6,000 cases of minimally invasive ventral herniorrhaphy, six of these deaths were from bowel perforation not recognized intraoperatively (i.e., a delayed diagnosis). Without a doubt, this is the most feared complication of this procedure. A patient with an unrecognized bowel injury may be asymptomatic for days prior to getting sick, and then have a fulminate course. The management of these cases again follows expert opinion; reoperation with closure/resection of the injury in conjunction with mesh explantation typically is necessary. If the patient develops a fistula but is otherwise not sick, then operation need not be emergent, but still is virtually inevitable because of the presence of mesh. Creation of a colostomy to safely manage a colon injury may be required depending on the time elapsed since the injury, patient stability and comorbidities, and the degree of intraabdominal contamination and inflammation. These management options all are relative, and should be individualized to each patient.

Mesh infection

Wound sepsis occurring after minimally invasive ventral herniorrhaphy can have a range of expression, from mild cellulitis of a port site to drainage of purulence from the port(s) with systemic sepsis. In fact, a quantitative definition of mesh infection does not exist. Cellulitis around a port site does not necessarily imply a mesh infection or the need for mesh explantation. Similarly, the presence of fluid around the mesh (as seen on a CT scan), even months after the original procedure, does not necessarily imply a mesh infection. Sometimes a mesh infection can be easy to diagnose; for example, in association with a delayed bowel perforation. On the other hand, a patient who has a little redness over a trocar site, some fever, an elevated white blood cell count, and some peri-mesh fluid on CT scan, can present a diagnostic difficulty. Explantation of mesh in such a patient may be found, in retrospect, to have been unnecessary. Alternatively, a patient with soft signs and symptoms suggesting a mesh infection may be better managed with close clinical follow-up and carefully planned diagnostic studies. The risks and benefits of aspirating any fluid collection should be considered carefully because such an aspiration can seed a sterile collection. If the diagnosis of mesh infection becomes probable, then mesh explantation likely will be required. It is unlikely that mesh (particularly PTFE) that becomes infected after minimally invasive ventral hernia repair can be salvaged with medical (i.e., antibiotic) therapy.

Seroma

Careful study of patients who have undergone minimally invasive ventral herniorrhaphy likely would reveal a peri-mesh fluid collection, or seroma, in 100% of the cases. Not surprisingly, we regard a seroma as an expected outcome of this operation and not a complication. In the vast majority of the cases, a seroma will re-absorb without any specific intervention. The surgeon does not need to tap or drain a seroma simply because it exists. As part of our postoperative clinical pathway for minimally invasive ventral herniorrhaphy, we have each patient wear an abdominal binder in order to counter the tendency for seroma formation. We know of no controlled data, however, that demonstrate that a binder reduces this tendency. The point at which a seroma becomes a complication is relative, and depends primarily on symptomatology. In a tiny fraction of cases, aspiration or drainage of the seroma may be necessary. The integrity of the mesh should be respected, though, especially if one is preparing to tap into the seroma.

Risk factors for recurrence

The surgical literature on abdominal wound closure contains numerous manuscripts that describe "risk factors" for primary or secondary failure of an incision. Some individuals in surgery believe that the main risk factor for wound failure, whether in a primary incision or in a subsequent hernia repair, is surgical technique or the inadequacy thereof. While this philosophical stance may cause anxiety and discomfort among some operators, the data supporting this stance for minimally invasive ventral herniorrhaphy actually would not stand up to scrutiny. We personally feel that good results in this operation primarily depend on the "proper" utilization of mesh. We know which technique works for each of us (and the technique does differ between the senior authors); yet there are other techniques that work equally well for other surgeons. So we are in no position to be dogmatic about technique, other than to make a vague statement such as "technique is important to prevent hernia recurrence." Having said that, were there any nontechnique risk factors for recurrence within the data of this review? Not really. Male sex and increasing length of follow-up approached but did not reach significance; these factors have been associated with recurrence after open ventral hernia repair [74, 83].

Conclusion

This article is not a meta-analysis, since very few of the articles available for review actually compared treatments. There were not enough appropriate articles on minimally invasive ventral hernia repair to construct a meaningful meta-analysis. In the near future, however, the results of some well-designed trials [67] should be available that may examine some questions related to open and minimally invasive ventral hernia repair. Until then, the best measure we have of this operation is to look at the results so far, as we have attempted in this review. However, it should be emphasized that the results reported in this review are primarily from referral centers, i.e., from "expert" hernia surgeons. In general, the operative results reported in retrospective series authored by "expert surgeons," whether on hernia or some other pathology, are better than those reported in the general community or in controlled trials. So the data summarized in this review need to be interpreted in that context. In addition, there were no standards of patient selection, operative technique, data reporting, and so on that were followed by the manuscripts collected for this review. So the following concluding statement needs to be interpreted in light of the above caveats: minimally invasive hernia repair has an operative mortality of approximately 0.1%, a major complication (mainly bowel injury and infection) rate of approximately 3%, and a recurrence rate of just under 3%.

Summary

A comprehensive review of 60 articles on minimally invasive ventral herniorrhaphy constituting 6,266 procedures found an overall mortality rate of 0.14% and a recurrence rate of 2.7%. No risk factors were identified that significantly correlated with recurrence. The overall conversion rate was 3.3%, and the incidence of perforation/leak/fistula was 2%. The average defect size was 97 cm^2, and the average area of the mesh used to repair the defect was 296 cm^2. The most commonly stated length of mesh "overlap" was 3 cm (57% of the manuscripts). Intraperitoneal sublay of mesh was the near-universal method of mesh placement. PTFE was the mesh of choice in 78% of the manuscripts; the remainder utilized polypropylene or a composite. Mesh fixation was done with sutures plus tacks in 65% of the manuscripts; the remainder used sutures or tacks only. The median length of hospital stay was 2.3 days, and the median follow-up period was 19 months.

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References

1. Shea JA, Healey MJ, Berlin JA et al (1996) Mortality and complications associated with laparoscopic cholecystectomy. A meta-analysis. Ann Surg 224:609–620
2. Barbaros U, Asoglu O, Seven R et al (2007) The comparison of laparoscopic and open ventral hernia repairs: a prospective randomized study. Hernia 11:51–56
3. Andreoni KA, Lightfoot H Jr, Gerber DA et al (2002) Laparoscopic incisional hernia repair in liver transplant and other immunosuppressed patients. Am J Transplant 2:349–354
4. Angele MK, Lohe F, Dietz J et al (2005) Laparoscopic incisional hernia repair—an alternative to the conventional procedure? (German). Zentralbl Chir 130:255–259
5. Aura T, Habib E, Mekkaoui M et al (2002) Laparoscopic tension-free repair of anterior abdominal wall incisional and ventral hernias with an intraperitoneal Gore-Tex mesh: prospective study and review of the literature. J Laparoendosc Adv Surg Tech A 12:263–267
6. Bageacu S, Blanc P, Breton C et al (2002) Laparoscopic repair of incisional hernia: a retrospective study of 159 patients. Surg Endosc 16:345–348
7. Bamehriz F, Birch DW (2004) The feasibility of adopting laparoscopic incisional hernia repair in general surgery practice: early outcomes in an unselected series of patients. Surg Laparosc Endosc Percutan Tech 14:207–209
8. Beldi G, Ipaktchi R, Wagner M et al (2006) Laparoscopic ventral hernia repair is safe and cost effective. Surg Endosc 20:92–95
9. Ben-Haim M, Kuriansky J, Tal R et al (2002) Pitfalls and complications with laparoscopic intraperitoneal expanded polytetrafluoroethylene patch repair of postoperative ventral hernia. Surg Endosc 16:785–788

10. Bencini L, Sanchez LJ (2004) Learning curve for laparoscopic ventral hernia repair. Am J Surg 187:378–382
11. Berger D, Bientzle M, Muller A (2002) Postoperative complications after laparoscopic incisional hernia repair. Incidence and treatment. Surg Endosc 16:1720–1723
12. Birgisson G, Park AE, Mastrangelo MJ Jr et al (2001) Obesity and laparoscopic repair of ventral hernias. Surg Endosc 15:1419–1422
13. Bower CE, Reade CC, Kirby LW, Roth JS (2004) Complications of laparoscopic incisional-ventral hernia repair: the experience of a single institution. Surg Endosc 18:672–675
14. Carbajo MA, Martp del Olmo JC, Blanco JI et al (2003) Laparoscopic approach to incisional hernia. Surg Endosc 17:118–122
15. Chari R, Chari V, Eisenstat M, Chung R (2000) A case controlled study of laparoscopic incisional hernia repair. Surg Endosc 14:117–119
16. Chelala E, Gaede F, Douillez V et al (2003) The suturing concept for laparoscopic mesh fixation in ventral and incisional hernias: preliminary results. Hernia 7:191–196
17. Chowbey PK, Sharma A, Khullar R et al (2000) Laparoscopic ventral hernia repair. J Laparoendosc Adv Surg Tech A 10:79–84
18. Chowbey PK, Sharma A, Khullar R et al (2003) Laparoscopic ventral hernia repair with extraperitoneal mesh: surgical technique and early results. Surg Laparosc Endosc Percutan Tech 13:101–105
19. DeMaria EJ, Moss JM, Sugerman HJ (2000) Laparoscopic intraperitoneal polytetrafluoroethylene (PTFE) prosthetic patch repair of ventral hernia. Prospective comparison to open prefascial polypropylene mesh repair. Surg Endosc 14:326–329
20. Earle D, Seymour N, Fellinger E, Perez A (2006) Laparoscopic versus open incisional hernia repair: a single-institution analysis of hospital resource utilization for 884 consecutive cases. Surg Endosc 20:71–75
21. Eid GM, Prince JM, Mattar SG et al (2003) Medium-term follow-up confirms the safety and durability of laparoscopic ventral hernia repair with PTFE. Surgery 134:599–603; discussion 603–604
22. Farrakha M (2000) Laparoscopic treatment of ventral hernia. A bilayer repair. Surg Endosc 14:1156-1158
23. Farrakha M (2006) Laparoscopic ventral hernia repair using expanded polytetrafluoroethylene-polyester mesh compound. Surg Endosc 20:820–823
24. Franklin ME Jr, Gonzalez JJ Jr, Glass JL, Manjarrez A (2004) Laparoscopic ventral and incisional hernia repair: an 11-year experience. Hernia 8:23–27
25. Frantzides CT, Carlson MA, Zografakis JG et al (2004) Minimally invasive incisional herniorrhaphy: a review of 208 cases. Surg Endosc 18:1488–1491
26. Gal I, Balint A, Szabo L (2004) Results of laparoscopic repair of abdominal wall hernias using an ePTFE-polypropylene composite mesh (German). Zentralbl Chir 129:92–95
27. Gillian GK, Geis WP, Grover G (2002) Laparoscopic incisional and ventral hernia repair (LIVH): an evolving outpatient technique. JSLS 6:315–322
28. Golash V (2006) Laparoscopic geometrical repair of ventral hernia. Surgeon 4:33–38, 62
29. Heniford BT, Park A, Ramshaw BJ, Voeller G (2003) Laparoscopic repair of ventral hernias: nine years' experience with 850 consecutive hernias. Ann Surg 238:391–399; discussion 399–400
30. Holzman MD, Purut CM, Reintgen K et al (1997) Laparoscopic ventral and incisional hernioplasty. Surg Endosc 11:32–35
31. Johna S (2005) Laparoscopic incisional hernia repair in obese patients. JSLS 9:47–50
32. Kannan K, Ng C, Ravintharan T (2004) Laparoscopic ventral hernia repair: local experience. Singapore Med J 45:271–275
33. Kirshtein B, Lantsberg L, Avinoach E et al (2002) Laparoscopic repair of large incisional hernias. Surg Endosc 16:1717–1719
34. Koehler RH, Voeller G (1999) Recurrences in laparoscopic incisional hernia repairs: a personal series and review of the literature. JSLS 3:293–304
35. Kua KB, Coleman M, Martin I, O'Rourke N (2002) Laparoscopic repair of ventral incisional hernia. ANZ J Surg 72:296–299
36. Kyzer S, Alis M, Aloni Y, Charuzi I (1999) Laparoscopic repair of postoperation ventral hernia. Early postoperation results. Surg Endosc 13:928–931
37. Lau H, Patil NG, Yuen WK, Lee F (2002) Laparoscopic incisional hernioplasty utilising onlay expanded polytetrafluoroethylene DualMesh: prospective study. Hong Kong Med J 8:413–417
38. LeBlanc KA, Whitaker JM, Bellanger DE, Rhynes VK (2003) Laparoscopic incisional and ventral hernioplasty: lessons learned from 200 patients. Hernia 7:118–124
39. McGreevy JM, Goodney PP, Birkmeyer CM et al (2003) A prospective study comparing the complication rates between laparoscopic and open ventral hernia repairs. Surg Endosc 17:1778–1780
40. McKinlay RD, Park A (2004) Laparoscopic ventral incisional hernia repair: a more effective alternative to conventional repair of recurrent incisional hernia. J Gastrointest Surg 8:670–674
41. Mizrahi S, Lantsberg L, Kirshtein B et al (2003) The experience with a modified technique for laparoscopic ventral hernia repair. J Laparoendosc Adv Surg Tech A 13:305–307
42. Morales-Conde S, Cadet H, Cano A et al (2005) Laparoscopic ventral hernia repair without sutures–double crown technique: our experience after 140 cases with a mean follow-up of 40 months. Int Surg 90:S56–S62
43. Moreno-Egea A, Torralba JA, Girela E et al (2004) Immediate, early, and late morbidity with laparoscopic ventral hernia repair and tolerance to composite mesh. Surg Laparosc Endosc Percutan Tech 14:130–135
44. Muysoms F, Daeter E, Vander Mijnsbrugge G, Claeys D (2004) Laparoscopic intraperitoneal repair of incisional and ventral hernias. Acta Chir Belg 104:705–708
45. Olmi S, Magnone S, Erba L et al (2005) Results of laparoscopic versus open abdominal and incisional hernia repair. JSLS 9:189–195
46. Parker HH 3rd, Nottingham JM, Bynoe RP, Yost MJ (2002) Laparoscopic repair of large incisional hernias. Am Surg 68:530–533; discussion 533–534
47. Perrone JM, Soper NJ, Eagon JC et al (2005) Perioperative outcomes and complications of laparoscopic ventral hernia repair. Surgery 138:708–715; discussion 715–716
48. Raftopoulos I, Vanuno D, Khorsand J et al (2002) Outcome of laparoscopic ventral hernia repair in correlation with obesity, type of hernia, and hernia size. J Laparoendosc Adv Surg Tech A 12:425–429
49. Reitter DR, Paulsen JK, Debord JR, Estes NC (2000) Five-year experience with the "four-before" laparoscopic ventral hernia repair. Am Surg 66:465–468; discussion 468–469
50. Rosen M, Brody F, Ponsky J et al (2003) Recurrence after laparoscopic ventral hernia repair. Surg Endosc 17:123–128
51. Salameh JR, Sweeney JF, Graviss EA et al (2002) Laparoscopic ventral hernia repair during the learning curve. Hernia 6:182–187
52. Sanchez LJ, Bencini L, Moretti R (2004) Recurrences after laparoscopic ventral hernia repair: results and critical review. Hernia 8:138–143
53. Sanders LM, Flint LM, Ferrara JJ (1999) Initial experience with laparoscopic repair of incisional hernias. Am J Surg 177:227–231
54. Szymanski J, Voitk A, Joffe J et al (2000) Technique and early results of outpatient laparoscopic mesh onlay repair of ventral hernias. Surg Endosc 14:582–584
55. Tessier DJ, Swain JM, Harold KL (2006) Safety of laparoscopic ventral hernia repair in older adults. Hernia 10:53–57
56. Toy FK, Bailey RW, Carey S et al (1998) Prospective, multicenter study of laparoscopic ventral hernioplasty. Preliminary results. Surg Endosc 12:955–959

57. Tsimoyiannis EC, Tassis A, Glantzounis G et al (1998) Laparoscopic intraperitoneal onlay mesh repair of incisional hernia. Surg Laparosc Endosc 8:360–362
58. Ujiki MB, Weinberger J, Varghese TK et al (2004) One hundred consecutive laparoscopic ventral hernia repairs. Am J Surg 188:593–597
59. van't Riet M, Vrijland WW, Lange JF et al (2002) Mesh repair of incisional hernia: comparison of laparoscopic and open repair. Eur J Surg 168:684–689
60. Verbo A, Petito L, Pedretti G et al (2004) Use of a new type of PTFE mesh in laparoscopic incisional hernia repair: the continuing evolution of technique and surgical expertise. Int Surg 89:27–31
61. Wright BE, Niskanen BD, Peterson DJ et al (2002) Laparoscopic ventral hernia repair: are there comparative advantages over traditional methods of repair? Am Surg 68:291–295; discussion 295–296
62. Yavuz N, Ipek T, As A et al (2005) Laparoscopic repair of ventral and incisional hernias: our experience in 150 patients. J Laparoendosc Adv Surg Tech A 15:601–605
63. Carbajo MA, Martin del Olmo JC, Blanco JI et al (1999) Laparoscopic treatment vs open surgery in the solution of major incisional and abdominal wall hernias with mesh. Surg Endosc 13:250–252
64. Moreno-Egea A, Carrasco L, Girela E et al (2002) Open vs laparoscopic repair of spigelian hernia: a prospective randomized trial. Arch Surg 137:1266–1268
65. SSAT Patient Care Committee (2007) SSAT Patient Care Guidelines: Surgical Repair of Incisional Hernias. Society for Surgery of the Alimentary Tract. http://www.ssat.com/cgi-bin/incisionalhernia.cgi. Accessed 9 July 2007
66. Misra MC, Bansal VK, Kulkarni MP, Pawar DK (2006) Comparison of laparoscopic and open repair of incisional and primary ventral hernia: results of a prospective randomized study. Surg Endosc 20:1839–1845
67. Itani KM, Neumayer L, Reda D et al (2004) Repair of ventral incisional hernia: the design of a randomized trial to compare open and laparoscopic surgical techniques. Am J Surg 188:22S–29S
68. Weber G, Horvath OP (2002) Results of ventral hernia repair: comparison of suture repair with mesh implantation (onlay vs sublay) using open and laparoscopic approach–prospective, randomized, multicenter study (Hungarian). Magy Seb 55:285–289
69. Sains PS, Tilney HS, Purkayastha S et al (2006) Outcomes following laparoscopic versus open repair of incisional hernia. World J Surg 30:2056–2064
70. Pierce RA, Spitler JA, Frisella MM et al (2007) Pooled data analysis of laparoscopic vs. open ventral hernia repair:14 years of patient data accrual. Surg Endosc 21:378–386
71. Goodney PP, Birkmeyer CM, Birkmeyer JD (2002) Short-term outcomes of laparoscopic and open ventral hernia repair: a meta-analysis. Arch Surg 137:1161–1165
72. Burger JW, Luijendijk RW, Hop WC et al (2004) Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 240:578–583; discussion 583–585
73. Flum DR, Horvath K, Koepsell T (2003) Have outcomes of incisional hernia repair improved with time? A population-based analysis. Ann Surg 237:129–135
74. Mudge M, Hughes LE (1985) Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 72:70–71
75. Neumayer L, Giobbie-Hurder A, Jonasson O et al (2004) Open mesh versus laparoscopic mesh repair of inguinal hernia. N Engl J Med 350:1819–1827
76. van Kasteren ME, Mannien J, Ott A et al (2007) Antibiotic prophylaxis and the risk of surgical site infections following total hip arthroplasty: timely administration is the most important factor. Clin Infect Dis 44:921–927
77. Aufenacker TJ, Koelemay MJ, Gouma DJ, Simons MP (2006) Systematic review and meta-analysis of the effectiveness of antibiotic prophylaxis in prevention of wound infection after mesh repair of abdominal wall hernia. Br J Surg 93:5–10
78. Ludwig KA, Carlson MA, Condon RE (1993) Prophylactic antibiotics in surgery. Annu Rev Med 44:385–393
79. Stoppa R, Petit J, Abourachid H et al (1973) Original procedure of groin hernia repair: interposition without fixation of Dacron tulle prosthesis by subperitoneal median approach (French). Chirurgie 99:119–123
80. Rives J, Pire JC, Flament JB, Convers G (1977) Treatment of large eventrations (apropos of 133 cases) (French). Minerva Chir 32:749–756
81. Fansler RF, Taheri P, Cullinane C et al (1995) Polypropylene mesh closure of the complicated abdominal wound. Am J Surg 170:15–18
82. Voyles CR, Richardson JD, Bland KI et al (1981) Emergency abdominal wall reconstruction with polypropylene mesh: short-term benefits versus long-term complications. Ann Surg 194:219–223
83. Bucknall TE, Cox PJ, Ellis H (1982) Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. Br Med J (Clin Res Ed) 284:931–933
84. Johanet H, Coelio C (2004) Laparoscopic treatment of incisional hernia by reinforced Parietex composite mesh: prospective multicenter study (French). Ann Chir 129(3):6–8
85. Engledow AH, Sengupta N, Akhras F et al (2007) Day case laparoscopic incisional hernia repair is feasible, acceptable, and cost effective. Surg Endosc 21:84–86
86. Lomanto D, Iyer SG, Shabbir A, Cheah WK (2006) Laparoscopic versus open ventral hernia mesh repair: a prospective study. Surg Endosc 20:1030–1035
87. Motson RW, Engledow AH, Medhurst C et al (2006) Laparoscopic incisional hernia repair with a self-centring suture. Br J Surg 93:1549–1553