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Long-term Recurrence and Complications Associated With Elective Incisional Hernia Repair

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IMPORTANCE Prosthetic mesh is frequently used to reinforce the repair of abdominal wall incisional hernias. The benefits of mesh for reducing the risk of hernia recurrence or the long-term risks of mesh-related complications are not known.

OBJECTIVE To investigate the risks of long-term recurrence and mesh-related complications following elective abdominal wall hernia repair in a population with complete follow-up.

DESIGN, SETTING, AND PARTICIPANTS Registry-based nationwide cohort study including all elective incisional hernia repairs in Denmark from January 1, 2007, to December 31, 2010. A total of 3242 patients with incisional repair were included. Follow-up until November 1, 2014, was obtained by merging data with prospective registrations from the Danish National Patient Registry supplemented with a retrospective manual review of patient records. A 100% follow-up rate was obtained.

EXPOSURES Hernia repair using mesh performed by either open or laparoscopic techniques vs open repair without use of mesh.

MAIN OUTCOMES AND MEASURES Five-year risk of reoperation for recurrence and 5-year risk of all mesh-related complications requiring subsequent surgery.

RESULTS Among the 3242 patients (mean age, 58.5 [SD, 13.5] years; 1720 women [53.1%]), 1119 underwent open mesh repair (34.5%), 366 had open nonmesh repair (11.3%), and 1757 had laparoscopic mesh repair (54.2%). The median follow-up after open mesh repair was 59 (interquartile range [IQR], 44-80) months, after nonmesh open repair was 62 (IQR, 44-79) months, and after laparoscopic mesh repair was 61 (IQR, 48-78) months. The risk of the need for repair for recurrent hernia following these initial hernia operations was lower for patients with open mesh repair (12.3% [95% CI, 10.4%-14.3%]; risk difference, −4.8% [95% CI, −9.1% to −0.5%]) and for patients with laparoscopic mesh repair (10.6% [95% CI, 9.2%-12.1%]; risk difference, −6.5% [95% CI, −10.6% to −2.4%]) compared with nonmesh repair (17.1% [95% CI, 13.2%-20.9%]). For the entirety of the follow-up duration, there was a progressively increasing number of mesh-related complications for both open and laparoscopic procedures. At 5 years of follow-up, the cumulative incidence of mesh-related complications was 5.6% (95% CI, 4.2%-6.9%) for patients who underwent open mesh hernia repair and 3.7% (95% CI, 2.8%-4.6%) for patients who underwent laparoscopic mesh repair. The long-term repair-related complication rate for patients with an initial nonmesh repair was 0.8% (open nonmesh repair vs open mesh repair: risk difference, 5.3% [95% CI, 4.4%-6.2%]; open nonmesh repair vs laparoscopic mesh repair: risk difference, 3.4% [95% CI, 2.7%-4.1%]).

CONCLUSIONS AND RELEVANCE Among patients undergoing incisional repair, sutured repair was associated with a higher risk of reoperation for recurrence over 5 years compared with open mesh and laparoscopic mesh repair. With long-term follow-up, the benefits attributable to mesh are offset in part by mesh-related complications.

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Supplemental content

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Elective incisional hernia repair is one of the most commonly performed general surgical operations.[1,2] In the United States alone, there were about 190 000 inpatient abdominal wall hernia repairs performed in 2012.[3] Because it is believed to reduce the risk of hernia recurrence, mesh is commonly placed as an adjunct to hernia repair and mesh placement is done in at least half of the abdominal wall hernia repairs performed in the United States.[3,4] However, the long-term complications related to mesh placement are not known. There are few randomized trials assessing the effectiveness of mesh, and observational trials investigating these questions are limited by incomplete long-term follow-up and relatively small numbers of patients.[4-6] Although mesh reduces recurrences, it is a foreign material and may cause a host of complications.[7,8] These range from mild skin problems such as skin infections, nonhealing wounds, and seroma formation to severe chronic pain, life-threatening bowel obstruction, and chronic fistula development that may be caused by chronic mesh infection.

The Danish Hernia Database was established to monitor and improve outcomes of hernia repair.[9] Previous reports from the database were on short-term outcomes (readmissions, patient reported outcomes, complications) and hernia recurrence risks.[8,10,11] None of these prior studies exceeded a median follow-up of 41 months. We now report long-term (≥5 years), complete follow-up of our patients. We hypothesized that mesh reinforcement in incisional hernia repair decreases hernia recurrence but may be associated with a high risk of complications. The objective of the study was to analyze the long-term consequences of mesh reinforcement in elective incisional hernia repair.

Key Points

Question What are the long-term consequences in patients undergoing incisional hernia repair?

Findings In this registry-based nationwide cohort study including 3242 patients, mesh repair was associated with a lower risk of reoperation for recurrence compared with nonmesh repair over a 5-year follow-up period. However, a risk of long-term mesh-related complications for open and laparoscopic mesh repairs partially offset these benefits.

Meaning The overall benefits of mesh utilization for the repair of abdominal wall hernias are uncertain.

Methods

Patients and Data Sources

The present study extends our previously reported data on 30-day postoperative complications and recurrence.[8] Consecutive patients undergoing elective incisional hernia repair from January 1, 2007, to December 31, 2010, were analyzed. Patients were identified from the Danish Hernia Database. The study was approved by the Danish Data Protection Agency and the National Board of Health. Because the study is a registry-based study, participant consent and institutional review board approval are not required in accordance with Danish national ethical standards.

An index repair was defined as a patient's first incisional hernia repair in the Danish Hernia Database. The number of patients included in the study corresponded to the number of hernia repairs. Categorization of patient demographics such as age and hernia size was consistent with a previous study making comparison possible.[8] Open sutured repairs without mesh were categorized as nonmesh repairs. Information about reoperations was obtained by merging data from the Danish Hernia Database with that from the Danish National Patient Registry using a patient's unique Danish social security number as a patient identifier. Additional information about patients was obtained by manual review of patient records for those who underwent subsequent abdominal reoperation. One investigator (D.K.) performed the patient record reviews and assessed if the reoperations were related to the original mesh hernia repair. When there was uncertainty regarding the relationship between the original hernia operation and the need for any subsequent surgical care, the records were discussed with a second investigator (F.H.) and a consensus opinion was made. Chart reviewers were not blinded to the study hypothesis nor to what a patient's initial operation was. The follow-up period extended from the time of the index hernia repair until reoperation for recurrence, death, emigration, mesh removal, or the end of the study period (November 1, 2014). A 100% follow-up rate was obtained.

The Danish Hernia Database covers 80% to 90% of all ventral hernia repairs in Denmark.[9,12] The database is dependent on surgeons' registration of their individual hernia repairs, and this registration is mandatory. The actual registration rate is approximately 90%. The Danish Hernia Database contains information about intraoperative technical details of the hernia operation as detailed previously.[8,9] There is substantial concordance between information in the Danish Hernia Database and patient records.[9,12] The Danish National Patient Registry is a national administrative database based on prospective registration of diagnosis- and procedure-related code classifications (*International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* diagnosis codes and NOMESCO Classification of Surgical Procedures[13] procedure codes). The Danish National Patient Registry has not been specifically validated for hernia repairs but has been for other surgical procedures such as cholecystectomies and operations for gynecological malignancies. More than 90% of the surgical procedures were registered.[14,15] The National Patient Registry has information on all patient encounters within the Danish hospital system (public and private) and has information on all procedures performed during hospital admissions and in ambulatory settings.[16,17] Because Denmark has minimal emigration, the database represents an essentially closed cohort.[16] Before commencing the study, a decision was made to supplement follow-up data available from the Danish National Patient Registry with a manual review of patient records from patients who underwent abdominal reoperations, including operations done for abdominal infection or bleeding, diagnostic laparoscopies, and diagnostic laparotomies. Operations not related to the abdominal wall or abdominal cavity were not reviewed.

Independent Variables

Information about the size and type of hernia and position and fixation of the mesh material was prospectively collected in

the Danish Hernia Database. The hernia defect size was defined as the largest diameter of the fascia defect (length or width) as measured by the surgeon during the operation.[8] Mesh types included polypropylene (PPL), coated PPL, expanded polytetrafluoroethylene (ePTFE), PPL plus ePTFE, coated polyester, or other types (biological mesh, completely absorbable synthetic mesh, and not specified). For open repairs, the mesh position was onlay, sublay, intraperitoneal, or other position (inlay, plug). All laparoscopic repairs were performed by intraperitoneal placement of mesh. The techniques of mesh fixation included tacking (absorbable and nonabsorbable), suture, and other fixation techniques (glue, clips, and unspecified fixation). Tacks are mesh fixation devices made of titanium (nonabsorbable) or polymers (absorbable). The distinction between absorbable and nonabsorbable tack fixation for hernia repair was systematically recorded in the Danish Hernia Database after 2008. A combination of tack and suture fixation was classified as tack fixation because in this circumstance, suture is usually used to position the mesh prior to placing the tacks.

Outcomes

The 2 outcomes were risk of reoperation for recurrence and risk of mesh-related complications. The definitions and methods applied for assessing recurrence repair were the same as used in our prior analyses, and a recurrence repair was defined as a repair of an incisional hernia in the same scar as the previous hernia repair.[8] We a priori defined long-term complications as those occurring 30 days after the index hernia operation and requiring surgical intervention in either an inpatient or outpatient setting. Similar to our previous work, surgical complications were graded into major and clinically important complications.[10] Major complications were defined as acutely life-threatening and requiring emergency surgery. Clinically important complications, such as late abscesses and fistulas, were defined as all clinically significant complications not requiring emergency surgery. We a priori defined complications as surgical site infection, presence of a chronic sinus tract, late-onset intra-abdominal abscess, enterocutaneous fistula, seroma, hematoma, nonhealing wound, bowel obstruction, bowel perforation, bleeding, and need for diagnostic laparoscopy or laparotomy because of severe abdominal pain. Complications were stratified by one of the investigators as definitely, potentially, or unlikely to be related to the previous repair based on hospital records and operative reports regarding anatomical conditions, etc.[8,10] Surgical complications classified as "definitely related to the hernia repair" and "possibly related to the hernia repair" were included in the analyses. When doubt existed about the relatedness of the complication to the index hernia operation, consensus was obtained between 2 investigators. Only 1 operation for a complication per patient (the most severe) was assessed, although more than 1 operation per patient may have occurred.[18] Prior to commencing the study and because of the risk of selection bias, we decided not to make a statistical comparison of outcomes between open mesh repair and laparoscopic mesh repair.[10] The 30-day mesh-related mortality rate was defined as death within the first 30 days after surgical intervention due to mesh-related complications.

Statistical Analysis

The distribution of continuous data was assessed by visual inspection of histograms. Age was calculated as mean with standard deviation. Hernia size, mesh size, and follow-up time were calculated as medians with interquartile ranges (IQRs). The risk of reoperation for recurrence and the risk of mesh-related complications were analyzed in accordance with the competing risk method[19] and presented as cause-specific cumulative incidences.[20] To analyze independent risk factors for recurrence after open repair, we performed bivariable analyses screening clinically relevant risk factors including age, sex, primary (vs recurrent) repair, mesh position, and hernia size. For laparoscopic repair, bivariable analyses were performed for age, sex, primary (vs recurrent) repair, hernia size, and mesh fixation. Bivariables expressing a $P < .20$ and clinically relevant covariates were entered simultaneously into a Cox regression model to follow methods from a previous study.[8] The analysis was performed separately for open repairs (mesh) and for laparoscopic repairs. To analyze the independent risk factors for long-term mesh-related complications, clinically important characteristics such as age, sex, mesh size, mesh type, mesh positioning, and technique for mesh fixation were entered into a Cox regression model for open and laparoscopic mesh repair separately. Hernia size was not entered as a variable in the regression model for mesh-related complications because mesh size, from a clinical standpoint, can act as a surrogate measure of hernia size. Relevant interaction analyses were chosen based on clinical relevance (for open repairs: hernia size, mesh size, mesh position, mesh fixation, and mesh type; for laparoscopic repairs: hernia size, mesh size, and mesh type). Results are presented as hazard ratios (HRs) with 95% confidence intervals. Furthermore, a separate Cox analysis including type of tacks (data from 2008-2010) and the above-mentioned variables was performed for laparoscopic repair. The proportional hazard assumption was tested by visual inspection of log-minus-log survival curves, and this assumption was not violated. Testing was 2-sided and $P<.05$ was considered statistically significant. The statistical analyses were performed using the IBM statistical software package SPSS, version 22, module Statistics Base, Advanced Statistics, and Regression. Cumulative incidence was analyzed in R, version 3.0.2, with the cmprsk package.

Propensity Score Adjustment

Because this was an observational study, direct comparison between patients treated with open surgery and laparoscopic surgery could be influenced by selection bias. Propensity-adjusted analysis was performed in an effort to minimize the influence of selection bias on the analysis. A score reflective of the propensity to have mesh placed was calculated in a logistic regression model that included clinical information that might predict the use of mesh: hernia size and primary vs recurrent repair.[21] Propensity-adjusted Cox regression analysis was performed for mesh complications and included all patients with a mesh repair. The Cox regression analysis entered the following variables: propensity score, operation type (open mesh or laparoscopic mesh), age, sex, mesh size, mesh type, mesh positioning, and technique for mesh fixation.

Table 1. Patient Demographics and Mesh Characteristics for Patients Undergoing Incisional Hernia Repair[a]

Characteristics	Open Repair		Laparoscopic Mesh Repair (n = 1757)
	Mesh (n = 1119)	Nonmesh (n = 366)	
Sex			
Male	547 (48.9)	170 (46.4)	805 (45.8)
Female	572 (51.1)	196 (53.6)	952 (54.2)
Age, y			
18-50	267 (23.9)	128 (35.0)	462 (26.3)
51-60	324 (29.0)	93 (25.4)	498 (28.3)
61-70	301 (26.9)	63 (17.2)	456 (26.0)
>70	227 (20.3)	82 (22.4)	341 (19.4)
Hernia defect, cm			
0-2	166 (14.8)	210 (57.4)	101 (5.7)
3-7	463 (41.4)	108 (29.5)	676 (38.5)
8-15	311 (27.8)	33 (9.0)	692 (39.4)
16-20	133 (11.9)	11 (3.0)	209 (11.9)
>20	46 (4.1)	4 (1.1)	79 (4.5)
Primary vs recurrent repair			
Primary	921 (82.3)	320 (87.4)	1560 (88.8)
Recurrent	198 (17.7)	46 (12.6)	197 (11.2)
Mesh size, median (interquartile range), cm^2	180 (66-400)	NR	324 (225-500)
Mesh type			
PLL	597 (53.4)	NR	23 (1.3)
Coated PPL	123 (11.0)	NR	843 (48.0)
PPL plus ePTFE	230 (20.6)	NR	617 (35.1)
ePTFE	48 (4.3)	NR	79 (4.5)
Coated polyester	26 (2.3)	NR	176 (10.0)
Other[b]	95 (8.4)	NR	19 (1.1)
Mesh position			
Sublay	322 (28.8)	NR	NR
Onlay	451 (40.3)	NR	NR
Intraperitoneal	255 (22.8)	NR	1757
Other[c]	91 (8.1)	NR	NR
Mesh fixation technique			
Tack	226 (20.2)	NR	1719 (97.9)
Suture	823 (73.5)	NR	4 (0.2)
Other[d]	70 (6.3)	NR	34 (1.9)
Tack type			
Absorbable	17 (14.5)	NR	241 (24.9)
Nonabsorbable	100 (85.5)	NR	727 (75.1)

Abbreviations: ePTFE, expanded polytetrafluoroethylene; NR, not relevant; PPL, polypropylene.

[a] Data are expressed as No. (%) of patients unless otherwise indicated. Tacks were mesh fixation devices made of titanium (nonabsorbable) or polymers (absorbable).

[b] Biologic (n = 4); completely absorbable synthetic (n = 3); not specified (n = 107).

[c] Inlay or plug.

[d] Glue, clips, or not specified.

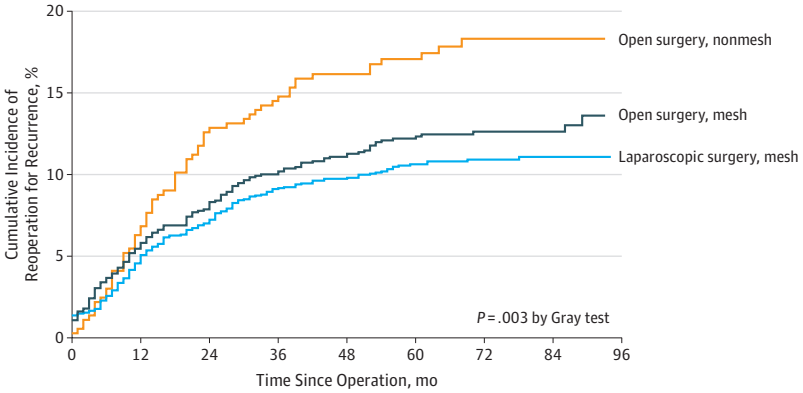
Results

In total, 3242 patients (mean age, 58.5 [SD, 13.5] years; 1720 women [53.1%]) were included in the analysis: 1119 patients (34.5%) with open mesh repair, 366 patients (11.3%) with nonmesh repair, and 1757 patients (54.2%) with laparoscopic mesh repair (eFigure in the Supplement). Median follow-up after open mesh repair was 59 (IQR, 44-80) months, after nonmesh repair was 62 (IQR, 44-79) months, and after laparoscopic mesh repair was 61 (IQR, 48-78) months. For mesh repairs, only 4 patients (0.1%) underwent repair with a biological mesh, with the remainder undergoing a repair using a synthetic mesh. Patient and mesh characteristics are presented in **Table 1**.

Reoperation for Recurrence (Open and Laparoscopic Repair)

Four hundred twelve patients (12.7%) underwent a repair for recurrence. The overall recurrence rate in the open mesh group was 13.2% (n = 148), in the laparoscopic mesh group was 11.2% (n = 197), and in the nonmesh group was 18.3% (n = 67). The cumulative risk of reoperation for recurrence increased throughout the study period. The cumulative risk of reoperation for recurrence at 5 years was lower for patients with open mesh repair (12.3% [95% CI, 10.4%-14.3%); risk difference, −4.8% [95% CI, -9.1% to -0.5%]) and laparoscopic mesh repair (10.6% [95% CI, 9.2%-12.1%]; risk difference, −6.5% [95% CI, -10.6% to -2.4%]) compared with nonmesh repair (17.1% [95% CI, 13.2%-20.9%]) (**Figure 1**).

Figure 1. Risk of Reoperation for Hernia Recurrence After Index Incisional Hernia Repair

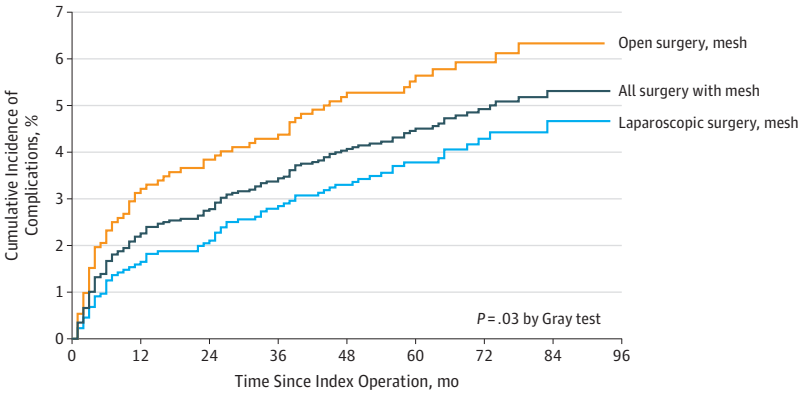


No. at risk

Open nonmesh	366	329	294	283	260	201	125	56
Laparoscopic mesh	1757	1620	1532	1455	1332	942	578	260
Open mesh	1119	1000	942	880	790	556	370	211

Cumulative incidence of reoperation for recurrence after index repair for patients treated with open nonmesh repair, laparoscopic mesh repair, and open mesh repair. Median follow-up: nonmesh, 62 (interquartile range [IQR], 44-79) months; laparoscopic mesh, 61 (IQR, 48-78) months; open mesh, 59 (IQR, 44-80) months.

Figure 2. Cumulative Incidence of Mesh-Related Complications Treated by Surgical Intervention After Index Incisional Hernia Repair



No. at risk

Laparoscopic mesh	1757	1620	1532	1455	1332	942	578	260
Open mesh	1119	1000	942	880	790	556	370	211
All mesh	2876	2620	2474	2335	2122	1498	948	471

Cumulative risk of long-term complications after index repair for all incisional hernias with mesh and according to surgical technique for hernia repair (laparoscopic mesh or open mesh). $P = .03$. Complications included are those requiring surgical intervention. Median follow-up: laparoscopic mesh repair, 61 (interquartile range [IQR], 48-78) months; open mesh repair, 59 (IQR, 44-80) months.

Risk Factors for Reoperation for Recurrence

Open Repair

Risk factors for reoperation for recurrence are presented in eTable 1 in the Supplement. In a multivariable analysis, larger hernia size was associated with increased risk of reoperation for recurrence (eTable 1). Older age at the time of the index operation was associated with reduced risk of reoperation for recurrence (eTable 1). Mesh position (onlay, sublay, etc) was not significantly associated with risk of reoperation for recurrence.

Laparoscopic Repair

Risk factors for reoperation for recurrence are presented in eTable 1. In a multivariable analysis, increasing age was associated with reduced risk of reoperation for recurrence. Furthermore, hernia size greater than 20 cm compared with 0 to 2 cm and nontack mesh fixation compared with tack fixation were independent risk factors for hernia recurrence requiring repair (eTable 1).

Surgical Complications

Open and Laparoscopic Mesh Repair

During the study period, the risk of mesh-related complications increased continuously with time (**Figure 2**). Overall, 1050 patients (30% of the entire cohort) underwent subsequent abdominal surgery, and these patient records were examined. For 7 patients (0.2% of the entire cohort), hospital records could not be found. A total of 142 patients (4.9%; open mesh repair, n = 68 [6.1%]; laparoscopic mesh repair, n = 74 [4.2%]) required subsequent operations for mesh-related complications. The cumulative incidence of a mesh-related complication requiring surgical treatment was 4.5% at 5 years (open mesh repair, 5.6% [95% CI, 4.2%-7.0%]; laparoscopic mesh repair, 3.7% [95% CI, 2.8%-4.6%]) (Figure 2 and **Table 2**). Compared with laparoscopic mesh hernia repair, open mesh hernia repair was an independent risk factor for long-term complications in a propensity-adjusted analysis (HR, 2.36; 95% CI, 1.28-4.36; $P = .01$) (eTable 2 in the Supplement). The median time to a mesh-related surgical complication

Table 2. Long-term Repair-Related Complications Treated by Surgical Intervention After Index Incisional Hernia Repair

Complications	No. (%) of Patients			
	Mesh Repair			
	Open (n = 1119)	Laparoscopic (n = 1757)	Total (n = 2876)	Open Nonmesh Repair (n = 366)
Major	10 (0.9)	31 (1.8)	41 (1.4)	0
Bowel obstruction	9 (0.8)	28 (1.6)	37 (1.3)	0
Bowel perforation	1 (0.1)	2 (0.1)	3 (0.1)	0
Bleeding	0	1 (0.1)	1 (0.1)	0
Clinically important	58 (5.2)	43 (2.4)	101 (3.5)	3 (0.8)
Chronic surgical site infection and/or sinus tract	24 (2.1)	2 (0.1)	26 (0.9)	1 (0.3)
Late intra-abdominal abscess	8 (0.7)	5 (0.3)	13 (0.5)	0
Enterocutaneous fistula	7 (0.6)	6 (0.3)	13 (0.5)	0
Seroma	7 (0.6)	8 (0.5)	15 (0.5)	0
Hematoma	2 (0.2)	1 (0.1)	3 (0.1)	0
Nonhealing wound	4 (0.4)	3 (0.2)	7 (0.2)	1 (0.3)
Diagnostic surgery due to pain[a]	6 (0.5)	18 (1.0)	24 (0.8)	1 (0.3)
Total	68 (6.1)	74 (4.2)	142 (4.9)	3 (0.8)

[a] Both diagnostic laparoscopies and open procedures. Only 1 complication per patient (the first) was reported.

after the index hernia repair was 11 (IQR, 4-38) months after open mesh repair and 24 (IQR, 6-43) months after laparoscopic mesh repair. The cumulative rates of major and clinically significant complications were 1.4% and 3.5%, respectively. Life-threatening complications occurred in 0.9% of patients with open mesh repair and 1.8% of patients with laparoscopic mesh repair. In 2 patients, a diagnostic procedure was performed to investigate severe pain; no significant pathologic findings were present. These patients continued to have pain until the end of the study period (information obtained from hospital records). In total, 6 patients (0.2%) underwent surgery for bowel obstruction due to intra-abdominal bowel adhesions; there were no descriptions of adhesions to the mesh and therefore the obstructions were considered related to the patient' prior abdominal surgery rather than to the mesh itself. Mesh removal was performed in 46 patients (1.6%). The mesh removal rates after open and laparoscopic mesh repair were 2.6% and 1.0%, respectively. The reasons for mesh removal were infection (n = 29 [63.0%]), pain (n = 9 [19.6%]), bowel obstruction (n = 4 [8.7%]), bowel perforation (n = 1 [2.2%]), and adhesions (n = 3 [6.5%]).

In total, 342 patients (11.9%) died during the follow-up period and 3 (0.1%) died because of a mesh-related complication after laparoscopic repair (bleeding due to tearing of a vessel by a nonabsorbable tack, n = 1; bowel perforation due to mesh migration into the bowel, n = 1; bowel obstruction, n = 1). No patients emigrated during the follow-up period.

Nonmesh Repair

The long-term repair-related complication rate for patients with an initial nonmesh repair was 0.8% (open nonmesh repair vs open mesh repair, risk difference, 5.3% [95% CI, 4.4%-6.2%]; open nonmesh repair vs laparoscopic mesh repair, risk difference, 3.4% [95% CI, 2.7%-4.1%]) (Table 2). Patients with a nonmesh repair had no major complications but did have some clinically significant complications. Seven patients (1.9%) with an index operation of nonmesh hernia repair required abdominal exploration for intra-abdominal adhesions. All operations for bowel obstruction were thought to be related to patients' prior abdominal surgery. In total, 45 patients (12.3%) in the nonmesh group died during the follow-up period. No patients died in relation to a surgery for a long-term repair-related complication. No patients emigrated out of Denmark during follow-up.

Risk Factors for Mesh-Related Complications

Open Mesh Repair

The larger the mesh used, the higher the risk of mesh-related complications (HR, 1.02; 95% CI, 1.01-1.03; $P < .001$). Coated polypropylene had fewer complications than did uncoated polypropylene (HR, 1.20; 95% CI, 0.04-0.90; $P = .04$) (eTable 3 in the Supplement). There were no statistically significant interactions between the various mesh positions and mesh fixation methods, mesh position and hernia size, mesh positions and mesh types, or mesh size and mesh types (all $P > .05$ for interaction).

Laparoscopic Mesh Repair

As found for open mesh repair, the larger the mesh, the higher the risk of laparoscopic mesh-related complications (HR, 1.02; 95% CI, 1.01-1.02; $P < .001$) (eTable 3). We found no statistically significant interaction between mesh size and mesh type ($P > .05$ for interaction).

Discussion

In this Danish nationwide analysis of long-term complications following elective incisional hernia repair, the use of mesh to reinforce the repair was associated with a lower risk of recurrence compared with when mesh was not used. In the long term, there was a progressively increasing rate of serious mesh-related complications partially offsetting the recurrence benefits of the mesh material. Given the continuously increasing incidence of mesh-related complications with time, it is expected that with even longer follow-up than the 5 years observed in this study, mesh-related complications continue to accrue.

With 5-year follow-up, there was a 6.5% lower hernia recurrence rate requiring reoperation attributable to laparoscopic hernia repair compared with open, nonmesh hernia repair. Mesh reinforcement was associated with a 4.8% reduced risk of recurrence for open repairs. However, with long-term follow-up, 1.4% of patients required reoperation for bowel obstruction, bowel perforation, or bleeding that was not required for patients who did not get mesh. There was a need for subsequent operations in 2.7% more patients receiving mesh than those not receiving mesh for other complications, such as the development of enterocutaneous fistula, late abscess, etc. Thus, mesh implantation prevented the need for subsequent reoperation in relatively few patients, suggesting that the benefits associated with the use of mesh are partially offset by long-term complications associated with its use. This observation, however, should be interpreted with caution because of the risk of selection bias. Larger, more complicated hernias are likely to be repaired with mesh, and small, simple hernias with little likelihood of long-term problems tend to be repaired without mesh.[8]

Mesh-related complications have previously been reported in case series,[22] small retrospective studies,[5,6] and a single randomized clinical trial.[4] Most of these studies had relatively few (<200) patients, and follow-up was incomplete and between 34 and 81 months. Only a single study of 29 patients evaluated long-term complications following laparoscopic mesh repair.[5] These studies found an approximately 6% to 20% complication rate attributable to mesh.[4-6] These complications included bowel obstruction, enterocutaneous fistulas, and development of chronic sinus tracts. We found that bowel obstruction[4,5] and sinus tract[6] were the most commonly occurring long-term mesh-related complications. The lower complication rate in the current study relative to prior reports is explained by our focus on clinically serious complications that required subsequent operations, and we excluded analysis of medically related complications. Our finding that the incidence of complications progressively increases with time may be explained by a prior observation that inflammation associated with mesh persists for up to 8 years following implantation.[23]

Another reason our results may differ from prior reports is the complete, long-term follow-up we have for the patient followed in the Danish Hernia Database. Loss to follow-up is common in clinical studies and seriously limits conclusions that can be made regarding the efficacy of various treatments. In general, it is optimal to have greater than 80% follow-up in any cohort to make meaningful conclusions, a degree of follow-up rarely achieved in published studies.[24,25]

Mesh size was an independent risk factor for mesh-related complications for both open and laparoscopic hernia repair. Mesh size is closely related to hernia size (4- to 5-cm overlap is generally recommended),[26] and this finding substantiates that larger hernias are associated with higher risk of postoperative complications.[8,27] Coated mesh appeared to reduce the long-term complications associated with mesh. This might be because of less long-term inflammation associated with hernia mesh.[28-31] However, inflammation increases fibrosis, which results in a more secure repair. Less fibrosis can, in theory, increase the risk of recurrences. Information on the type of mesh coating was not available in the present study.

There are several limitations to this study. These results were not based on randomized data, so selection bias and imbalance between the groups at baseline cannot be fully controlled for. We did prospectively collect data from detailed registries maintained in 2 national databases that we supplemented with retrospective data collected from individual patient records. There is only a single randomized clinical trial of the use of mesh reporting long-term outcomes[4] and, given limitations in that study's inclusion and exclusion criteria, the results cannot be generalized to all patients with hernia. Also, the study was small, including only 126 patients, limiting the ability to fully understand the true spectrum of long-term complications and how they influence outcomes. Our study had the benefit of reflecting the real-world experience of an entire nation and all surgeons performing hernia repair, with complete follow-up for all patients. Thus, our results more closely reflect experience that might be expected for hernia repair in actual practice than has been suggested by prior studies.

Defining recurrence complications by the need for reoperation may underestimate the overall recurrence by a factor of 4 to 5.[32] This conservative definition emphasizes recurrences that have the most substantial clinical consequences. Another limitation to our analysis is that our registry did not include other factors such as body mass index and smoking habits, which are known to influence the risk of complications from hernia repair.[33] Although we tried to balance the groups we compared by propensity adjustment,[34] the influence of selection bias on the outcomes of observational trials can never be completely overcome by statistical adjustment.[35]

The present study highlights the need to assess the long-term safety of interventions before making definitive conclusions about their benefits. Demonstration of long-term safety is required for drugs in the United States[36] but not for some devices, such as hernia meshes, which are not subject to similarly strict documentation.[37] In the United States, most hernia mesh is approved for use by the 510(k) mechanism. This requires only that these materials have similarity to existing products on the market without the need for clinical trials to demonstrate safety or efficacy.[3] Thus, the complete spectrum for the risks and benefits of mesh used to reinforce hernia repair is not known because there are very few clinical trial data reporting hernia outcomes as they pertain to mesh utilization. This highlights the need for more long-term studies of mesh repair using high-quality registries such as the one in Denmark.[38,39]

Conclusions

Among patients undergoing incisional repair, sutured repair was associated with a higher risk of reoperation for recurrence over 5 years compared with open mesh and laparoscopic mesh repair. With long-term follow-up, the benefits attributable to mesh are offset in part by mesh-related complications.

ARTICLE INFORMATION

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