Risk factors for incisional hernia repair after aortic reconstructive surgery in a nationwide study

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Objective: **Abdominal aortic aneurysm disease has been hypothesized as associated with the development of abdominal wall hernia. We evaluated the risk factors for incisional hernia repair after open elective aortic reconstructive surgery for aortoiliac occlusive disease and abdominal aortic aneurysm.**

Methods: **A retrospective analysis of prospectively recorded data in nationwide databases was carried out, with merged data from the Danish Vascular Registry (January 2006-January 2012), the Danish Ventral Hernia Database (January 2007-January 2012), and the Danish National Patient Register (January 2007-January 2012) to obtain 100% follow-up for incisional hernia repair in patients undergoing open elective aortic reconstructive surgery. The predefined risk factors of age, sex, American Association of Anesthesiologists score, body mass index, smoking status, type of aortic surgery, and type of incision were tested in a multivariate Cox regression model for the risk of incisional hernia repair.**

Results: **We identified 2597 patients, of whom 838 and 1759 underwent open elective surgery for an aortoiliac occlusive disease and abdominal aortic aneurysm, respectively. The median follow-up was 28.9 months (range, 0-71.6 months), and the cumulative risk of hernia repair after aortic reconstructive surgery was 10.4% after 6 years of follow-up. Body mass index >25.0 kg/m^2 (adjusted hazard ratio, 1.74; 95% confidence interval, 1.21-2.46) and abdominal aortic aneurysm repair (adjusted hazard ratio, 1.58; 95% confidence interval, 1.06-2.35) were significantly associated with incisional hernia repair.**

Conclusions: **High body mass index and abdominal aortic aneurysm repair were independent risk factors for a subsequent incisional hernia surgery in patients undergoing aortic reconstructive surgery. (J Vasc Surg 2013;57:1524-30.)**

Incisional hernia is a well-known complication of laparotomy, occurring in 7% to 26% of patients.[1-3] Known risk factors for incisional hernia formation are male sex, smoking, and postoperative wound complication.[3,4] Furthermore, to decrease the risk of incisional hernia formation, the fascia should be closed with slowly absorbable (total resorption >180 days) or nonabsorbable sutures and with a suture length at least four-times greater than the wound length.[5-7]

Several small-scale retrospective studies and a few prospective studies have suggested that patients undergoing surgery for abdominal aortic aneurysm (AAA) have a higher risk of developing an incisional hernia than patients undergoing surgery for aortoiliac occlusive disease (AOD).[8-16] It has been hypothesized that a systemically altered connective tissue metabolism may explain the pathogenesis of aneurysm and hernia development, although the mechanism is not fully understood.[17] The risk of incisional hernia repair after laparotomy for aortic reconstructive surgery has not been established in large-scale series from unselected centers, and surgical risk factors have not been identified. This large-scale study was undertaken to identify and evaluate the risk factors for incisional hernia repairs after open elective aortic reconstructive surgery.

METHODS

This study was approved by the Danish Data Protection Authorities (2009-41-3864).

Data source. A retrospective analysis of prospectively recorded data in nationwide databases was performed. Patients in Denmark undergoing vascular surgery are registered prospectively in the Danish Vascular Registry. Recorded data include sex, age, American Society of Anesthesiologists (ASA) score (ASA 1, no systemic disease; ASA 2, mild systemic disease; ASA 3, severe systemic disease), body mass index (BMI), smoking status (never, former, or current smoker), type of incision, type of surgery, and comorbidity. The Vascular Registry has a registration rate of 99%.[18] We included open elective aortic reconstructive surgeries approached transabdominally through a transverse or midline incision, defined as surgery for AOD comprising thromboendarterectomy, a bypass procedure, or AAA repair. These procedures are performed at eight different centers in Denmark. Prophylactic mesh insertion was not used routinely.

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This study was financially supported by the A.P. Møller and Wife Chastine Mc-Kinney Møller Foundation for Promotion of Medical Science, the Bispebjerg Hospital Foundation for Young Researchers, and the Frimodt Foundation.

Author conflict of interest: none.

Additional material for this article may be found online at www.jvascsurg.org.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214/$36.00

http://dx.doi.org/10.1016/j.jvs.2012.11.119

Table I. Aortic reconstructive surgery: list of procedures

Aortoiliac occlusive disease (n = 838)	*No. (%)*	*Abdominal aortic aneurysm (n = 1759)*	*No. (%)*
Bypass procedures		Bypass procedures	
Aortobifemoral	725 (86.5)	Aortobifemoral	200 (11.4)
Aortofemoral	14 (1.7)	Aortofemoral	11 (0.4)
Aortobiiliac	44 (5.3)	Aortobiiliac	440 (25.0)
Aortoiliac	3 (0.4)	Aortoiliac	33 (1.9)
Aortoiliac and femoral	19 (2.3)	Aortoiliac and femoral	94 (5.3)
Supraceliac and juxtarenal aorta	3 (0.4)	Supraceliac and juxtarenal aorta	32 (1.8)
Thromboendarterectomies		Tube graft	
Aortoiliac	15 (1.8)	Infrarenal	949 (54.0)
Infrarenal	15 (1.8)		

Patients undergoing an incisional hernia repair are registered prospectively in the Danish Hernia Database that includes perioperative data on the type of hernia and the selected surgical approach.[19] The Hernia Database has a registration rate of 79% for ventral hernias. In the Danish National Patient Register, all encounters with the health system that a patient may go through are registered using the International Classification of Diseases (ICD) codes and the Nordic Medical-Statistical Committee (NOMESCO) codes for surgical procedures.[20] Thus, a 100% follow-up for incisional hernia repair was obtained by electronic merging of the Hernia Database with the Danish National Patient Register from January 2007 to January 2012.[20]

Patients who underwent open elective surgery for AOD or AAA between January 2006 and January 2012 and subsequently required an open or laparoscopic incisional hernia repair were identified in a search using their unique Danish identification number. The medical files of all patients were checked for death or emigration. There is no free referral choice to undergo elective surgical treatment in the European Union. Exclusively Danish patients were included in this study.

The predefined potential risk factors for development of an incisional hernia registered during the primary reconstructive aortic surgery were sex, age, ASA score, BMI, smoking status, type of abdominal incision (transverse or midline), and indication for vascular surgery (AOD or AAA). The follow-up period was from the vascular operation to the incisional hernia repair, death, emigration, or the last follow-up date.

Statistical analysis. Patient demographics were compared with Mann-Whitney or χ^2 tests. Univariate analyses, which included sex, age in quartiles, ASA score, BMI, smoking status, type of incision, and type of vascular operation, were performed for evaluation of incisional hernia repair risk using the log-rank test with follow-up period as a time factor. Variables likely to be associated with incisional hernia repair ($P < .2$) were included in a multivariate Cox regression analysis. The numbers at risk and the cumulative risk of undergoing an incisional hernia repair were estimated using life-table analysis and are presented as hazard functions using 1 minus Kaplan-Meier analysis. Medians are presented with range and hazard ratios (HRs) with 95% confidence intervals (CIs). $P < .05$ was considered statistically significant. Statistical analyses were done using SPSS 20 software (SPSS Inc, Chicago, Ill).

RESULTS

In the Vascular Registry, 2597 patients were identified, of whom 1759 (67.7%) underwent elective surgery for AOD and 838 (32.3%) for AAA. During the study period, 6033 patients required an incisional hernia repair, of whom 148 (2.5%) had undergone previous aortic reconstructive surgery within the same observation period. Most patients in the AOD group underwent an aortobifemoral bypass procedure, whereas an infrarenal tube graft was the most common procedure performed in the AAA group (Table I). Follow-up was <1 month in 120 patients, of whom 94 (78.3%) died ≤30 days after surgery, and 26 (21.7%) underwent vascular surgery in December 2011.

Characteristics for AOD and AAA patients are listed in Table II. Patients operated on for AAA were older and were more frequently men, overweight, and never-smokers compared with patients operated on for AOD (Table II). The median follow-up was 31.4 months for AOD patients and 28.1 months for AAA patients ($P = .009$; Table II). The median time from the primary surgery to the incisional hernia repair was 14.8 months (range, 4.8-66.6 months) in AOD patients and 16.1 months (range, 4.8-65.0) in AAA patients ($P = .355$).

The univariate analysis found the risk of incisional hernia repairs was significantly higher for patients with a BMI ≥25.0 kg/m^2 than for patients with a BMI <25.0 kg/m^2 (Table III; Fig 1), whereas no significant difference was found between patients undergoing repair for AOD and AAA (Fig 2). The risk factors of age, ASA score, and indication for vascular surgery were associated with incisional hernia repair ($P < .2$) and were retained in the multivariate analysis together with BMI (Supplementary Figs 1 and 2). Sex, smoking, and type of incision were not significantly associated with incisional hernia repair and were not included in the multivariate analysis (Supplementary Figs 3-5).

In the multivariate analysis, incisional hernia repair had a HR of 1.74 (95% CI, 1.21-2.46; $P = .002$) for patients

Table II. Patient characteristics

Variable[a]	*AOD (n = 838)*	*AAA (n = 1759)*	P
Male sex	421 (50.2)	1415 (80.4)	.0005
Age, years	63.2 (25-89)	71.3 (35-89)	.0005
ASA score			
1	153 (18.3)	298 (16.9)	.523
2	493 (58.8)	1075 (61.1)	
3	192 (22.9)	386 (21.9)	
BMI, kg/m^2			
<25.0	464 (55.4)	745 (42.4)	.0005
≥25.0	374 (44.6)	1014 (57.6)	
Smoking			
Never smoker	42 (5.1)	281 (16.1)	.0005
Former smoker	294 (35.5)	722 (41.4)	
Current smoker	493 (59.5)	741 (42.5)	
Surgical approach			
Transverse incision	531 (63.4)	1111 (63.2)	.92
Midline incision	307 (36.6)	648 (36.8)	
Incisional hernia repair	40 (4.7)	108 (6.1)	.16
Follow-up time, months	31.4 (0.0-71.7)	28.1 (0.0-71.7)	.009
Death during follow-up	106 (12.7)	265 (15.1)	.107

AAA, Abdominal aortic aneurysm; *AOD,* aortic occlusive disease; *ASA,* American Society of Anesthesiologists; *BMI,* body mass index.
[a]Categoric data are shown as number (%) and continuous data as median (range).

Table III. Univariate analysis of variables associated with incisional hernia repair using log-rank test

Variables	*All patients (n = 2597)*	*Incisional hernia repairs (n =148), No. (%)*	P
Sex			
Female	761	38 (5)	.255
Male	1836	110 (6)	
Age quartiles, years			
25-63	657	45 (6.8)	.008
64-69	683	46 (6.7)	
70-74	619	40 (6.5)	
75-88	638	17 (2.7)	
ASA score			
1	451	37 (8.2)	.137
2	1568	88 (5.6)	
3	578	23 (4)	
Body mass index, kg/m^2			
<25.0	1209	48 (4)	.0005
≥25.0	1388	100 (7.2)	
Smoking			
Never smoker	323	20 (6.2)	.782
Former smoker	1016	58 (5.7)	
Current smoker	1234	70 (5.7)	
Indication for vascular surgery			
Aortoiliac occlusive disease	838	40 (4.8)	.083
Abdominal aortic aneurysm	1759	108 (6.1)	
Surgical approach			
Transverse incision	1642	82 (5)	.322
Midline incision	955	66 (6.9)	

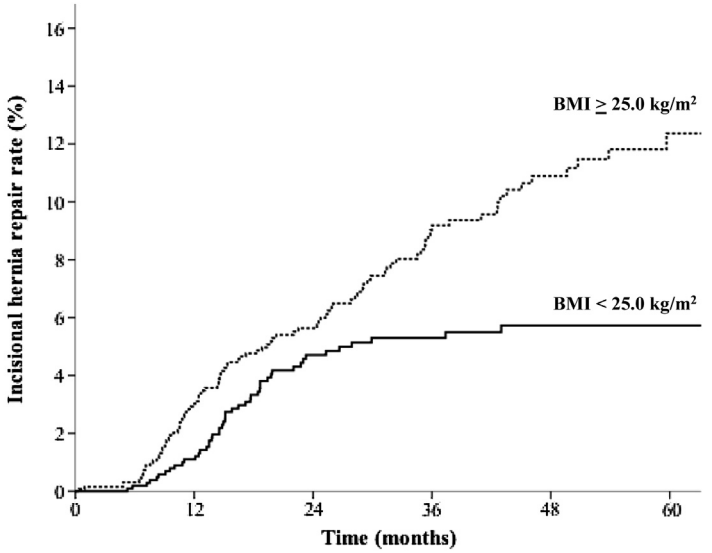
ASA, American Society of Anesthesiologists.

with a BMI ≥25.0 kg/m^2 compared with patients with a BMI <25.0 kg/m^2 after adjustment for age, ASA score, and type of vascular surgery (Table IV). Incisional repair had a HR of 1.58 (95% CI, 1.06-2.35; $P = .024$) for patients operated on for AAA compared with AOD patients after adjustment for age, ASA score, and BMI (Table IV). The cumulative risk of undergoing an incisional hernia repair was 11% for AAA patients (Fig 2).

DISCUSSION

This is the first large-scale nationwide study to evaluate the association between aortic reconstructive surgery and the risk of incisional hernia repair in a multivariate model. Risk factors independently associated with incisional hernia repair were AAA repair and BMI ≥25.0 kg/m^2.

Previous studies have evaluated the frequency of incisional hernias in patients operated on for AOD and



BMI < 25.0 kg/m²						
Numbers at risk	1,073	830	605	413	240	79
Standard error	0.00	0.01	0.01	0.01	0.01	0.01
BMI ≥ 25.0 kg/m²						
Numbers at risk	1,237	933	677	441	248	81
Standard error	0.00	0.01	0.01	0.01	0.01	0.02

Fig 1. Hazard function of the risk of undergoing an incisional hernia repair rate is shown in patients with a body mass index (*BMI*) <25.0 kg/m^2 (n = 1209) and with a BMI ≥25.0 kg/m^2 (n = 1388). $P = .0005$, log-rank test.

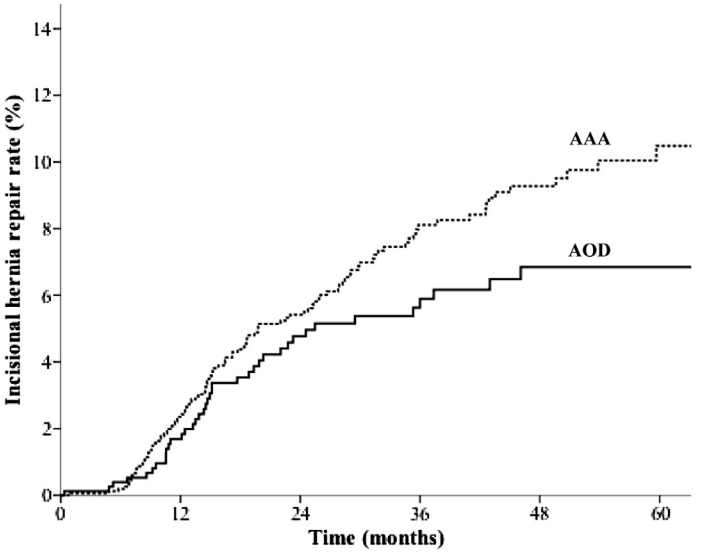
AAA and have found an incisional hernia frequency of 11% to 42% in AAA patients compared with 2% to 12% in AOD patients.[8-16] Most of these studies were retrospective reviews from selected centers with a maximum of 200 medical files.[8-13] Three of the studies[14-16] conducted a prospective follow-up of the patients; however, the number of patients was still <300. Furthermore, these studies only included vascular surgeries approaching the aorta through the midline. Two recent meta-analyses assembled the data from these studies and concluded that the risk of developing an incisional hernia after aortic reconstructive surgery through a midline incision was 2.8-fold higher for AAA patients than for AOD patients.[17,21] However, there was substantial heterogeneity in trial designs, and the overall number of patients was small.

A previous large retrospective cohort study evaluated the frequency of all types of abdominal wall hernias in 4404 vascular surgery patients by extracting diagnosis codes from an electronic medical record system.[22] The frequency of abdominal wall hernias was significantly higher in AAA patients, reaching an incidence of 16.7% compared with 9.9% in patients with peripheral arterial disease.[22] Unfortunately, the frequency of incisional hernias was not presented separately.

The cumulative risk of incisional hernia repair in our study was 11% for AAA patients, leading to a 1.6-fold higher risk of incisional hernia repair for AAA patients compared with AOD patients after adjustment for age, ASA score, and BMI. For the first 2 years after surgery for AOD or AAA, the cumulative risks of incisional hernia repair were nearly the same, probably suggesting that early hernias arose because of technical failures or wound dehiscence (Fig 2). The cumulative risk of incisional hernia repair is lower than the findings of previous studies exclusively reporting on the substantially higher incidence of clinically detectable hernia.[8-16]

The current study found being overweight or obese was significantly associated with a subsequent incisional hernia repair. Two of the previous studies evaluating incisional hernia formation after AOD and AAA repair also identified overweight and obese status as independent risk factors for incisional hernia formation.[11,13] Larger studies have also reported that obesity is associated with incisional hernia formation after laparotomy[1,23,24] and that the risk of incisional hernia recurrence is higher in obese patients.[25] Apart from surgical site infection, obese patients are at higher risk of wound dehiscence predisposing to incisional hernia formation.[26] Abdominal aponeuroses or the linea alba may also be technically more difficult to suture in obese patients.[27]

The type of incision was evaluated as a risk factor for incisional hernia formation in vascular patients for the first time in a large patient cohort. Results of a meta-analysis[28] and a Cochrane systematic review[29] suggest that a midline incision causes incisional hernias more frequently than transverse incisions; however, the studies included in the analyses were small and with a short follow-up period.



AOD patients						
Numbers at risk	755	593	435	299	174	58
Standard error	0.00	0.01	0.01	0.01	0.01	0.02
AAA patients						
Numbers at risk	1,555	1,170	846	556	314	102
Standard error	0.00	0.01	0.01	0.01	0.01	0.01

Fig 2. Hazard function of the risk of undergoing an incisional hernia repair rate is shown in patients operated on for aortoiliac occlusive disease (*AOD*) (n = 838) and in patients operated on for abdominal aortic aneurysm (*AAA*) (n = 1759). $P = .083$, log-rank test.

Another study evaluated risk factors for development of a subsequent incisional hernia in 69 patients undergoing AAA repair and found that a midline incision was the only risk factor significantly associated with incisional hernia formation compared with transverse incision after a mean follow-up of 4.4 years.[30] The incisional hernia repair rate in the present study was not significantly different between patients who had a transverse or midline incision. The follow-up period of this study was longer than the follow-up period in most of the studies included in the meta-analysis and Cochrane systematic review. However, this study evaluated hernia repairs and not clinical hernias, and our findings may not be comparable to previous studies.[31]

Patients operated on for AAA were more frequently men and significantly older than AOD patients, corresponding to findings in the literature.[21] Male sex is a known risk factor for incisional hernia formation in patients undergoing open gastrointestinal surgery.[3] In the current study, male sex was not significantly associated with incisional hernia repair in the univariate analysis. In the Hernia Database, 60% of patients operated on for incisional hernia are women. It is possible that women are more likely to undergo repair of an incisional hernia than men. In the multivariate analysis, patients aged >75 years underwent hernia repair more infrequently, perhaps indicating that older patients may not be referred for hernia repair due to higher risk of comorbidity. Thus, repair for incisional hernia may not truly reflect the clinical hernia incidence, and the incisional hernia repair rate is probably an underestimate of the true hernia prevalence.[31]

Smoking status was significantly different between AOD and AAA patients; however, it was not a statistically significant risk factor for incisional hernia repair in this study. Most of the vascular patients were smokers or former smokers, which may explain the lack of differences between the groups when considering smoking status.

Optimal closing of the fascia with nonabsorbable or slowly absorbable sutures in a suture-wound length ratio exceeding 4:1 decreases the risk of incisional hernia.[5] Despite an optimal closing technique, incisional hernias still develop in a number of patients. The use of prophylactic meshes inserted during primary laparotomy to avoid subsequent incisional hernia formation has been evaluated in high-risk groups such as patients undergoing bariatric surgery, stoma formation, and high-risk gastrointestinal surgery.[32-34] A recent randomized controlled trial evaluated the use of prophylactic mesh insertion vs sutured fascial closure with nonabsorbable suture in a 4:1 ratio in 85 patients undergoing open elective AAA repair.[35] The incisional hernia rate was significantly decreased in the mesh group, with no increase in the wound infection rate.[35]

Table IV. Multivariate Cox regression analysis evaluating risk factors for incisional hernia repair after aortic reconstructive surgery

Variables	*All patients (n = 2597)*	*Incisional hernia (n = 148)*		
		No.	*HR (95% CI)*	P
Age quartiles, years				
25-63	657	45	1 (Ref)	.819
64-69	683	46	0.95 (0.62-1.46)	.693
70-74	619	40	0.91 (0.58-1.44)	.001
75-88	638	17	0.38 (0.21-0.68)	
ASA score				
1	451	36	1 (Ref)	.167
2	1568	91	0.76 (0.52-1.12)	.088
3	578	25	0.64 (0.38-1.07)	
Body mass index, kg/m^2				
<25.0	1209	48	1 (Ref)	.002
≥25.0	1388	100	1.74 (1.21-2.46)	
Indication for vascular surgery				
Aortoiliac occlusive disease	838	40	1 (Ref)	.024
Abdominal aortic aneurysm	1759	108	1.58 (1.06-2.35)	

ASA, American Society of Anesthesiologists; *CI,* confidence interval; *HR,* hazard ratio.

A genetic predisposition to weakened connective tissue causing the aorta to expand and a subsequent hernia to develop is hypothesized as a common pathophysiologic entity of the two diseases.[17] Several biomarkers have been suggested as markers for aneurysm growth[36]; however, none of these are useful for both aneurysm and hernia disease.[37] Further research is still needed to clarify the exact pathogenesis of both diseases.

The present study has some limitations. The suture type (quickly absorbable, slowly absorbable, or nonabsorbable), suturing method, and length of incision were not registered in the Vascular Registry. Furthermore, the rate of postoperative wound dehiscence and previous abdominal operations was not known. The presence of connective tissue disorders, the use of immunosuppressive medicine, or other comorbidity would have been interesting to evaluate as possible risk factors for incisional hernia repair; however, these data were not available from the Vascular Registry. The incisional hernia repair rate was evaluated, which is probably an underestimate of the true hernia prevalence.[31] It may, however, serve as a more appropriate outcome for clinically significant incisional hernia in patients fit for surgery.

Selection bias is a possible confounder because hernia repair in older patients with severe comorbidity is often avoided. We included patients from the Vascular Registry from 2006 to include as many patients as possible; however, the Danish Hernia Database started registration in 2007. A minority of the vascular patients might possibly have undergone a hernia repair in 2006 that might have been missed. Furthermore, the follow-up time of the patients undergoing vascular surgery in 2012 is very short, probably underestimating the hernia repair rate. AOD surgery served as a control group for AAA surgery, as in previous studies,[8-16] because the operations have similarities in surgical approach, incision length, and length of surgery. However, the AOD and AAA patients differ demographically with respect to disease pathophysiology.

CONCLUSIONS

A high BMI and AAA are independent risk factors for incisional hernia repair in patients undergoing open elective aortic reconstructive surgery. Patients with a high BMI have a 1.7-fold higher risk of a subsequent incisional hernia repair compared with normal-weight patients. Patients undergoing AAA repair have a 1.6-fold higher risk of a subsequent hernia repair than patients undergoing AOD repair.

We thank Dr. Leif Panduro Jensen for data extraction from the Danish Vascular Registry.

AUTHOR CONTRIBUTIONS

Conception and design: NH, FH, KV, LJ, TB
Analysis and interpretation: NH, LJ, TB
Data collection: NH, FH, KV, TB
Writing the article: NH, LJ, TB
Critical revision of the article: NH, FH, KV, LJ, TB
Final approval of the article: NH, FH, KV, LJ, TB
Statistical analysis: NH, LJ
Obtained funding: NH
Overall responsibility: NH

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Submitted Sep 4, 2012; accepted Nov 27, 2012.

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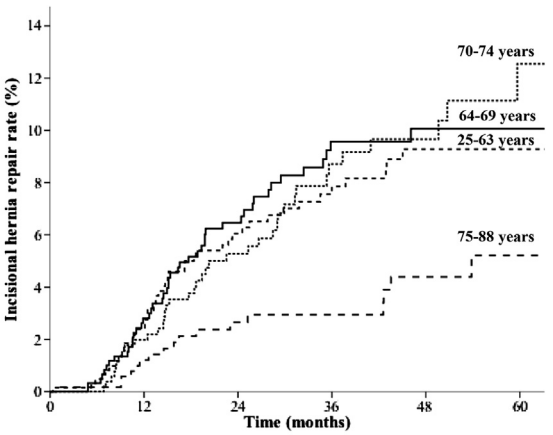
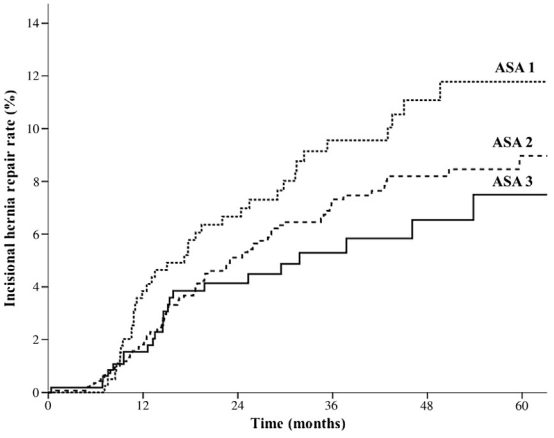


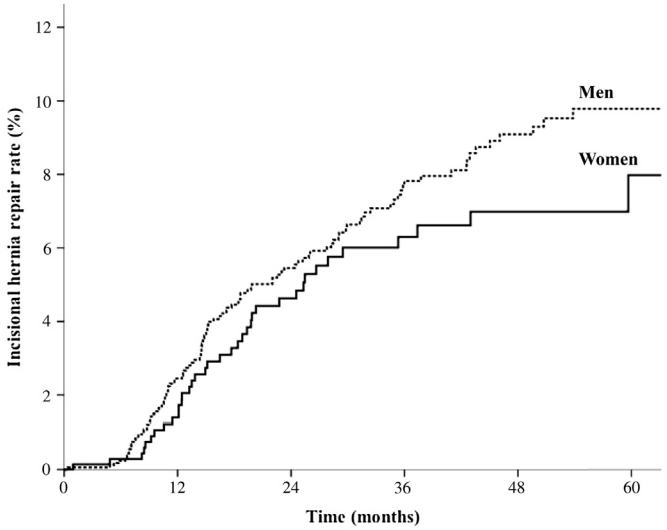
25-63 years						
Numbers at risk	604	488	369	257	150	52
Standard error	0.01	0.01	0.01	0.01	0.01	0.02
64-69 years						
Numbers at risk	611	465	337	219	121	39
Standard error	0.01	0.01	0.01	0.01	0.01	0.01
70-74 years						
Numbers at risk	544	406	281	175	100	32
Standard error	0.01	0.01	0.01	0.02	0.02	0.03
75-88 years						
Numbers at risk	551	405	296	204	118	37
Standard error	0.00	0.01	0.01	0.01	0.01	0.01

Supplementary Fig 1 (online only). Hazard function of the risk of undergoing an incisional hernia repair rate is shown in patients aged 25 to 63 years (n = 657), 64 to 69 years (n = 683), 70 to 74 years (n = 619), and 75 to 88 years (n = 638). $P = .137$, log-rank test.



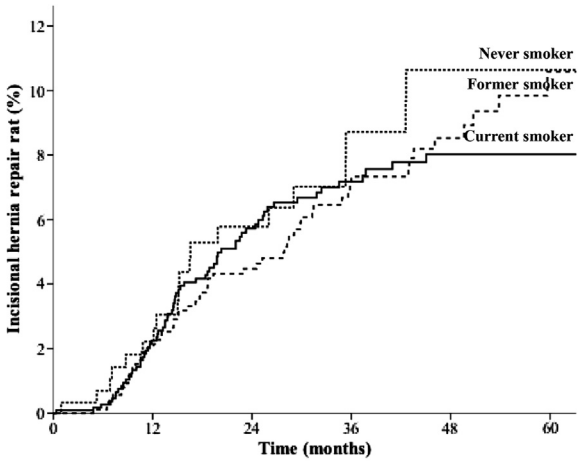
ASA 1						
Numbers at risk	415	334	261	181	103	33
Standard error	0.01	0.01	0.02	0.02	0.02	0.02
ASA 2						
Numbers at risk	1,405	1,080	780	520	291	93
Standard error	0.00	0.01	0.01	0.01	0.01	0.02
ASA 3						
Numbers at risk	491	349	240	154	94	34
Standard error	0.01	0.01	0.01	0.01	0.02	0.02

Supplementary Fig 2 (online only). Hazard function of the risk of undergoing an incisional hernia repair rate is shown in American Society of Anesthesiologists (*ASA*) 1 patients (n = 451), ASA 2 patients (n = 1568), and ASA 3 patients (n = 578). $P = .0005$, log-rank test.



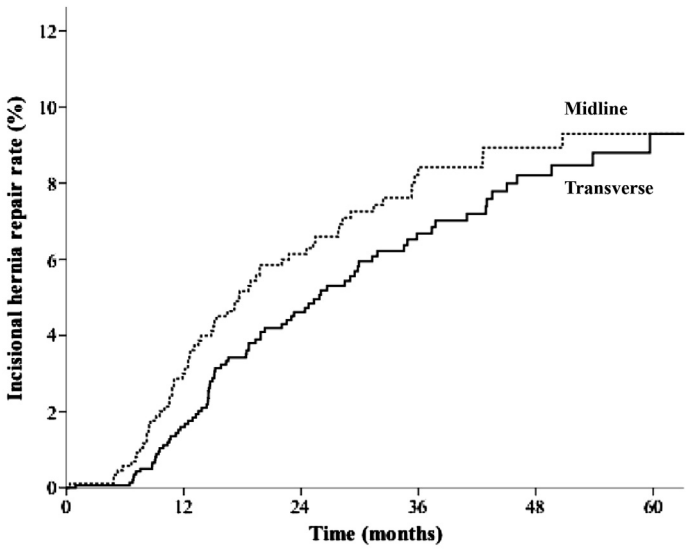
Women						
Numbers at risk	684	531	383	255	144	47
Standard error	0.00	0.01	0.01	0.01	0.01	0.02
Men						
Numbers at risk	1,626	1,231	898	600	344	113
Standard error	0.00	0.01	0.01	0.01	0.01	0.01

Supplementary Fig 3 (online only). Hazard function of the risk of undergoing an incisional hernia repair rate is shown in women (n = 761) and men (n = 1836). $P = .255$, log-rank test.



Never smokers						
Numbers at risk	282	207	141	92	55	18
Standard error	0.01	0.02	0.02	0.02	0.02	0.02
Former smokers						
Numbers at risk	903	691	513	335	184	60
Standard error	0.00	0.01	0.01	0.01	0.02	0.02
Current smokers						
Numbers at risk	1,106	855	620	422	246	81
Standard error	0.00	0.01	0.01	0.01	0.01	0.02

Supplementary Fig 4 (online only). Hazard function of the risk of undergoing an incisional hernia repair rate is shown in never smokers, (n = 323), former smokers (n = 1016), and current smokers (n = 1234). $P = .782$, log-rank test.



Transverse incision						
Numbers at risk	1,430	1,048	736	488	281	90
Standard error	0.00	0.01	0.01	0.01	0.01	0.01
Midline incision						
Numbers at risk	880	715	545	366	207	69
Standard error	0.01	0.01	0.01	0.01	0.01	0.02

Supplementary Fig 5 (online only). Hazard function of the risk of undergoing an incisional hernia repair rate is shown in patients operated on through a transverse incision (n = 1642) or a midline incision (n = 955). $P = .322$, log-rank test.