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Risk factors for incisional hernia according to different wound sites after open hepatectomy using combinations of vertical and horizontal incisions: A multicenter cohort study

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Abstract

Background: Although several risk factors for incisional hernia after hepatectomy have been reported, their relationship to different wound sites has not been investigated. Therefore, this study aimed to examine the risk factors for incisional hernia according to various wound sites after hepatectomy.

Methods: Patients from the Osaka Liver Surgery Study Group who underwent open hepatectomy using combinations of vertical and horizontal incisions (J-shaped incision, reversed L-shaped incision, reversed T-shaped incision, Mercedes incision) between January 2012 and December 2015 were included. Incisional hernia was defined as a hernia occurring within 3 y after surgery. Abdominal incisional hernia was classified into midline incisional hernia and transverse incisional hernia. The risk factors for each posthepatectomy incisional hernia type were identified.

Results: A total of 1057 patients met the inclusion criteria. The overall posthepatectomy incisional hernia incidence rate was 5.9% (62 patients). In the multivariate analysis, the presence of diabetes mellitus and albumin levels <3.5 g/dL were identified as independent risk factors. Moreover, incidence rates of midline and transverse incisional hernias were 2.4% (25 patients), and 2.3% (24 patients), respectively. In multivariate analysis, the independent risk factor for transverse incisional hernia was the occurrence of superficial or deep incisional surgical site infection, and interrupted suturing for midline incisional hernia.

Conclusions: Risk factors for incisional hernia after hepatectomy depend on the wound site. To prevent incisional hernia, running suture use might be better for midline wound closure. The prevention of postoperative wound infection is important for transverse wounds, under the presumption of preoperative nutrition and normoglycemia.

KEYWORDS
abdominal wound closure techniques, hepatectomy, incisional hernia, postoperative complications, suture techniques

1 | INTRODUCTION

Incisional hernia is a typical complication of abdominal surgery. Once it occurs, surgery is the only therapy, and patients are exposed not only to cosmetic problems, but also to a risk of death from incarceration. In addition, it causes symptoms, such as abdominal discomfort and pain.[1,2] The results of a questionnaire survey on postoperative wound closure indicated that the interrupted suture was used in ~75% of cases in Japan. The types of sutures included monofilament and braided sutures. Each type was used in ~50% of the cases. However, the fascia and subcutaneous tissue suture methods, as well as subcutaneous drain placement method and dressing materials, vary depending on the institution.[3] Meanwhile, running sutures are used in Europe and the United States.[4]

Abdominal incisional hernia occurrence is considered closely related to the hernia site, suture types, and wound closure methods. In a meta-analysis, the incidence rate of hernia after median incision was higher with fast absorbable sutures than with slowly absorbable sutures ($P < .009$) and nonabsorbable sutures ($P = .001$), whereas it was similar between slowly absorbable and nonabsorbable sutures, and between running and interrupted sutures.[5] In addition, median incisions have been associated with a higher incidence of hernia at incision sites than horizontal (relative risk = 1.77; 95% confidence interval [CI], 1.09–2.87) and paramedian incisions (relative risk = 3.41; 95% CI, 1.02–11.45).[6]

In reports on hernias occurring after hepatectomies, the risk factors included reverse T incision, refractory ascites, body mass index (BMI), repeated hepatectomy, steroid usage, running suture use, and the 7S domain of type IV collagen value.[7,8] Hernia risk factors following open hepatectomy for metastatic liver cancer included the duration of preoperative chemotherapy and bevacizumab administration.[9] However, currently available studies are limited to single institutions and did not elucidate the impact of the hernia site, type of suture material, and wound closure method on the occurrence of incisional hernia after hepatectomy. Moreover, the posthepatectomy wound is a combination of vertical and horizontal wounds with different injured tissues. Therefore, we hypothesized that examining the wounds separately would provide a clue to prevent incisional hernia after hepatectomy. Hence, this multicenter study aimed to investigate in detail the risk factors for abdominal incisional hernia according to different wound sites after hepatectomy.

2 | PATIENTS AND METHODS

Data of patients from eight university hospitals in the Kansai region were retrospectively reviewed. Our study group was called the Osaka Liver Surgery Study Group and has been conducting several clinical studies on hepatectomy.

We performed open hepatectomy without biliary tract reconstruction and combined resection of adjacent organs for 1182 patients in eight institutions of the Osaka Liver Surgery Study Group between January 2012 and December 2015. Patients who underwent mini-laparotomy (small incision), single median incision, and thoracoabdominal incision were excluded. Finally, we investigated 1057 patients who underwent open hepatectomy using J-shaped, reversed L-shaped, reversed T-shaped, and Mercedes incisions (Figure 1).

Abdominal incisional hernia was defined as an explicit prolapse of an intra-abdominal organ at the incisional site on clinical examination within 3 y after the operation, and was classified into midline, central, transverse, and right edge categories, based on the hernia occurrence site (Figure 2) Transverse and right edge incisional hernias were further classified as transverse incisional hernias. The risk factors of midline and transverse (transverse and right edge) incisional hernias were investigated. We investigated the following background factors: age; sex; BMI before surgery; presence/absence of anemia; albumin, bilirubin, and creatinine levels; and indocyanine green retention rate at 15 min (ICGR15). Complications before surgery, presence/absence of diabetes mellitus and respiratory diseases, smoking history, steroid usage, and preoperative chemotherapy administration were examined. Anemia was defined as a hemoglobin level ≤13.0 g/dL in men and ≤12.0 g/dL in women. Respiratory diseases included asthma, chronic obstructive pulmonary disease, and interstitial pneumonia that required regular treatment with oral drugs or inhalants. Smoking history was defined as ≥400 cigarettes = cigarettes per day × number of years. Steroid usage was defined as receiving ≥5 mg/day prednisolone or its equivalent for ≥1 month before surgery. Chemotherapy was defined as the preoperative use of chemotherapeutic agents, including bevacizumab. General physical status was also assessed using the American Society of Anesthesiologists (ASA) classification.[10] Surgical factors, operative time, blood loss, need for blood transfusion, operative method, and need for repeat hepatectomy were examined. Operative methods were classified into anatomical resection, such as a subsegmentectomy or more extensive resection, and partial resection. In addition, the effects of using running and interrupted sutures and braided and monofilament sutures in the fascia suture were compared. A late absorbable suture was used in all institutions. The incidences of postoperative complications, including organ/space surgical site infection (SSI) and incisional SSI (superficial or deep), identified according to the Centers for Disease Control guidelines for the classification of SSIs, were analyzed.[11,12] For other complications, the Clavien–Dindo classification was used.[13,14] Refractory ascites was defined as postoperative ascites ≥1 L persisting for 7 d after surgery and requiring abdominal drainage. Based on these factors, the independent risk factors for postoperative transverse and midline incisional hernia were examined by univariate and multivariate analyses.

2.1 | Statistical analysis

The cutoff values of the continuous variables were selected using receiver-operating characteristic curve analysis. In addition, we decided on the cutoff values that were close to the most significant

difference and clinically useful. For example, a cutoff albumin level of 3.5 g/dL is also used in the Child–Pugh classification. A logistic regression analysis was used for multivariate analysis using factors with $P \leq .1$ in the univariate analysis. All statistical analyses were performed using R v. 3.5.3 (R Foundation for Statistical Computing; https://cran.r-project.org/bin/macosx/).

3 | RESULTS

The overall incidence of incisional hernias was 62/1057, with 3.5%, 5.4%, and 5.9% in the first, second, and third years, respectively.

The incisional hernia sites are shown in Figure 2. The most frequent site was the midline (25/62), accounting for 40.3% of all cases, followed by the transverse (15/62, 24.2%), central (13/62, 21.0%), and right edge (9/62, 14.5%) sites.

The cumulative incidence rate of each incisional hernia site is shown in Figure 3. The midline site was associated with a significantly higher incidence of incisional hernia compared to the right edge site ($P = .006$). The comparison among other sites showed no significant difference in the incidence of incisional hernia (Figure 3).

The univariate analysis revealed that the overall incidence of abdominal incisional hernias was significantly higher at ages ≥65 y (incisional hernia group, 80.6% vs nonincisional hernia group, 67.7%; $P = .035$). Diabetic patients accounted for 38.7% of patients in the incisional hernia group as compared with 24.5% in the nonincisional hernia group ($P = .016$). No significant differences were demonstrated in sex, BMI (<25 kg/m^2 vs ≥ 25 kg/m^2), ASA physical status ($<$class 3 vs $\geq$class 3), smoking history, use of steroids, primary disease (hepatocellular carcinoma vs others), preoperative chemotherapy, and repeat hepatectomy. For blood tests, the proportion of patients with albumin levels <3.5 g/dL was significantly greater in the incisional hernia group (incisional hernia group, 30.6% vs nonincisional hernia group, 17.9%; $P = .038$). No significant differences were found in bilirubin levels (<1.0 mg/dL vs ≥1.0 mg/dL), creatinine levels (<1.0 mg/dL vs ≥1.0 mg/dL), and ICGR15 (<15% vs ≥15%). Among the surgical factors, the operative method (partial vs anatomical), blood loss (<1000 mL vs ≥1000 mL), operative time (<360 min vs ≥360 min), and transfusion were similar between the two groups. No significant

differences were found in superficial or deep incisional SSI (incisional hernia group vs nonincisional hernia group: 11.3% vs 5.6%, $P = .089$), organ/space SSI (9.7% vs 11.1%, $P > .999$), and other complications (6.5% vs 3.2%). In terms of refractory ascites occurrence, no significant difference was found between the two groups.

We performed a multivariate analysis using factors with $P \leq .1$ in the univariate analysis. The results indicated that the presence of diabetes mellitus (risk ratio, 1.74; 95% CI, 1.00–3.00) and albumin levels <3.5 g/dL (risk ratio, 1.82; 95% CI, 1.01–3.03) were independent risk factors of incisional hernia occurrence (Table 1).
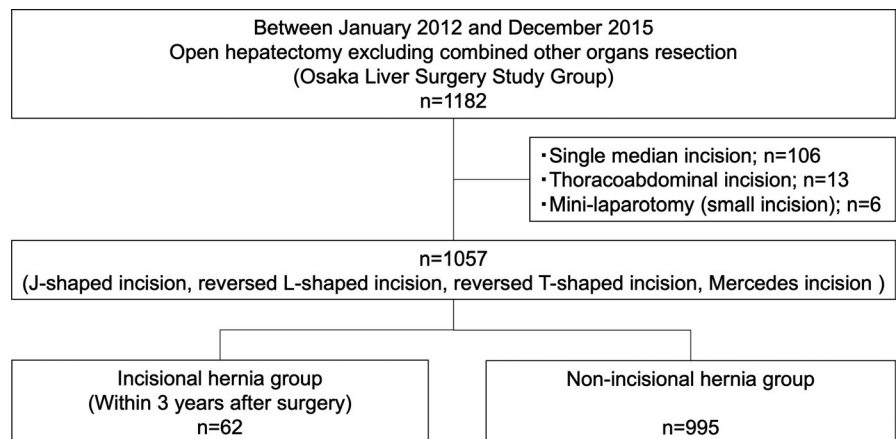
Based on the structure of the fascia under the incision site, we defined hernias in the midline site as midline incisional hernias (n = 25) and hernias in the transverse and right edge sites as transverse incisional hernias (n = 24; Figure 2). The wound crossing area of the central site was excluded from the investigation.

First, the risk factors for transverse incisional hernia were investigated. In the univariate analysis, the transverse incisional hernia group had a significantly higher proportion of elderly patients (≥65 y) and those with high ICGR15 values (≥15%). Moreover, 16.7% and 5.7% of patients in the transverse incisional hernia and nontransverse incisional hernia groups, respectively, had postoperative superficial or deep incisional SSI ($P = .049$). We assessed the types of suture and closing methods used in the posterior and anterior fascia. For the posterior fascia, the use of interrupted and running sutures was similar between the transverse incisional hernia and nontransverse incisional hernia groups. Meanwhile, the rate of closing with monofilament suture was higher than that with braided suture in the transverse incisional hernia group ($P = .094$).

Factors with $P \leq .1$ were included in the multivariate analysis. As a result, the independent risk factor for transverse incisional hernia was the occurrence of superficial or deep incisional SSI (risk ratio, 4.00; 95% CI, 1.27–12.60; Table 2).

Thereafter, the risk factors for midline incisional hernia were assessed. Univariate and multivariate analyses revealed that the incidence of midline incisional hernia was significantly higher only in patients whose wounds were closed with interrupted sutures (midline incisional hernia group vs nonmidline incisional hernia group, 68.2% vs 88.0%; $P = .047$) with risk ratio of 0.29 (95% CI, 0.09–0.93; Table 3).

FIGURE 1 Study design and flow chart. Open hepatectomy without combined resection of other organs was performed in 1182 patients between January 2012 and December 2015. Patients who underwent single median incision (n = 106), thoracoabdominal incision (n = 13), and mini-laparotomy (n = 6) were excluded. Finally, 1057 patients were followed for 3 y after surgery and divided into the incisional hernia group (n = 62) and the nonincisional hernia group (n = 995)

Between January 2012 and December 2015
Open hepatectomy excluding combined other organs resection
(Osaka Liver Surgery Study Group)
n=1182

· Single median incision; n=106
· Thoracoabdominal incision; n=13
· Mini-laparotomy (small incision); n=6

n=1057
(J-shaped incision, reversed L-shaped incision, reversed T-shaped incision, Mercedes incision)

Incisional hernia group
(Within 3 years after surgery)
n=62
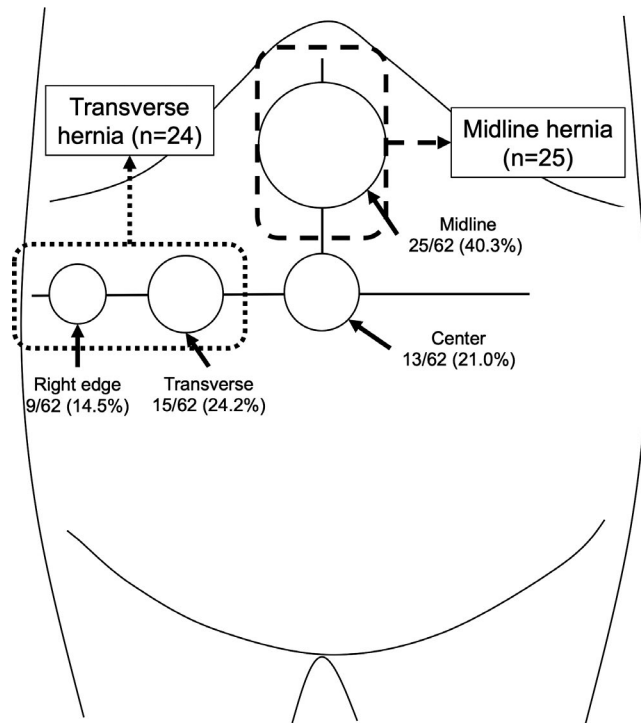
Non-incisional hernia group

n=995

FIGURE 2 Classification of incisional hernia sites. Incisional hernias accounted for 40.3%, 21.0%, 24.2%, and 14.5% of midline, central, transverse, and right edge sites, respectively. Hernias in the midline sites were classified as a midline incisional hernia (n = 25) and hernias in the transverse and right edge sites as transverse incisional hernias (n = 24)

4 | DISCUSSION

This multicenter study clearly showed that the risk factors of all kinds of abdominal incisional hernias after open hepatectomy were low albumin levels and diabetes mellitus history, as these impart a low wound-healing ability. Interestingly, the risk factors for abdominal incisional hernias differed according to the wound site, with wound infection primarily contributing to the development of transverse incisional hernias, and interrupted suture use being the most important factor in the development of midline abdominal incisional hernias.

Incisional hernia is a typical complication of abdominal surgery; many studies have been hitherto published regarding this topic. In their meta-analysis, Kossler et al reported incidence rates of abdominal incisional hernia of 10.1% and 4.5% in open and laparoscopic surgeries, respectively.[15] Based on the operative method, the frequencies of incisional hernia after open colorectal surgery, bariatric surgery, and liver transplantation are reported to be 7.8–10%[16-18], 4–10% [19], and 6–15.1%,[20,21] respectively. These surgical operations have high risks for incisional hernias, due to contamination by intestinal bacteria in colorectal surgery, high intra-abdominal pressure in bariatric surgery, and immunosuppressive drug administration in liver transplantation. Our results demonstrated that the incidence of incisional hernia after open hepatectomy was 5.9%. Therefore, incisional hernia occurrence rate after open hepatectomy is lower

than that after high-risk surgery; however, it is slightly higher than that after normal aseptic surgery.

Many patients developed abdominal incisional hernia within 6 mo to 3 y after surgery; the frequency was higher, especially when a midline incision was used. The risk factors of abdominal incisional hernia vary widely and can be classified as cytotoxic factors, such as SSI and inflammation of the wound site; external factors, such as obesity, ascites, and ileus; and healing factors, such as blood flow, nutritional disorder, and steroid use.[22-27]

In the comparison of the impact of suture types on the occurrence of abdominal incisional hernia, several meta-analyses found similar incidences for absorbable and nonabsorbable sutures. However, it was reported that the incidence of abdominal incisional hernia was higher for fast absorbable sutures than for slowly absorbable sutures.[28,29] Therefore, slowly absorbable sutures are currently the most commonly used sutures for wound closure. For suturing, small bites <10 mm from the wound edges have been recommended, and a suture length-to-wound length ratio of 4:1 is considered safe and applicable.[30] Compared with braided sutures, monofilament sutures are noncapillary and do not spread bacteria, which is favorable for infection prevention. Therefore, the braided suture is considered not suitable for wound infection prevention because it can easily worsen the infection due to the attached bacteria between the suture tissues. Meanwhile, the braided suture is flexible and easier to tie, and the knot is difficult to break because of a large coefficient of friction. Studies that reviewed the types of suture showed the usefulness in infection prevention of the monofilament suture. A high-quality randomized controlled trial (RCT) comparing monofilament and braided sutures for occurrence of incisional hernias would be required in the future.[31]

Almost all laparotomy of hepatectomies were generally performed using combinations of vertical and horizontal incisions. Therefore, we separately investigated midline and transverse

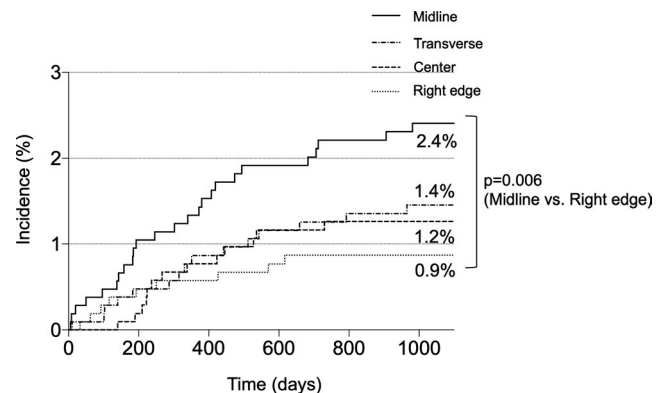**FIGURE 3** Cumulative incidence rate of each incisional hernia site. The incidences of incisional hernias were 2.4%, 1.4%, 1.2%, and 0.9% in midline, transverse, central, and right edge sites, respectively. The midline site had a significantly higher incidence of incisional hernia than the right edge site (P = .006). Comparison among other sites showed no significant difference in the incidence of incisional hernia

incisions in this study. The methods of incision were J-shaped, reversed L-shaped, reversed T-shaped, and Mercedes incisions. We excluded other incision methods.

Anatomically, the midline line incision was made through the stiff fascia called the linea alba (white line) in between the left and right rectus abdominis muscles. The linea alba is the part where the fascia

TABLE 1 Risk factors of all kinds of incisional hernia after hepatectomy

		Univariate analysis			Multivariate analysis	
		Non-incisional hernia (n = 995)	Incisional hernia (n = 62)	P-value	Odds ratio	P-value
Age	<65 y	321 (32.3)	12 (19.4)	.035	1.61 (0.83–3.11)	.16
	≥65 y	674 (67.7)	50 (80.6)			
Sex	Men	707 (71.1)	47 (75.8)	.472		
	Women	288 (28.9)	15 (24.2)			
Body mass index	<25 kg/m^2	773 (77.7)	45 (72.6)	.35		
	≥25 kg/m^2	222 (22.3)	17 (27.4)			
ASA physical status	<class 3	885 (88.9)	56 (90.3)	>.999		
	≥class 3	110 (11.1)	6 (9.7)			
Diabetes mellitus		244 (24.5)	24 (38.7)	.016	1.74 (1.00–3.00)	.048
Smoking history		423 (42.5)	30 (48.4)	.428		
Steroid usage		13 (1.3)	1 (1.6)	.573		
Respiratory diseases		42 (4.2)	1 (1.6)	.509		
Primary disease	HCC	535 (53.8)	41 (66.1)	.066	1.46 (0.83–2.55)	.19
	Others	460 (46.2)	21 (33.9)			
Preoperative chemotherapy		174 (17.5)	10 (16.1)	.865		
Repeat hepatectomy		188 (18.9)	12 (19.4)	.869		
Anemia		481 (48.3)	31 (50.0)	.896		
Albumin	<3.5 g/dL	178 (17.9)	19 (30.6)	.018	1.82 (1.02–3.23)	.041
	≥3.5 g/dL	817 (82.1)	43 (69.4)			
Total bilirubin	<1.0 mg/dL	809 (81.3)	48 (77.4)	.503		
	≥1.0 mg/dL	186 (18.7)	14 (22.6)			
Creatinine	<1.0 mg/dL	836 (84.0)	55 (88.7)	.374		
	≥1.0 mg/dL	159 (16.0)	7 (11.3)			
ICGR15	<15%	657 (66.0)	40 (64.5)	.784		
	≥15%	338 (34.0)	22 (35.5)			
Operative method	Partial	371 (37.3)	18 (29.0)	.222		
	Anatomic	624 (62.7)	44 (71.0)			
Blood loss	<1000 mL	686 (68.9)	44 (71.0)	.779		
	≥1000 mL	309 (31.1)	18 (29.0)			
Operative time	<360 min	593 (59.6)	37 (59.7)	.655		
	≥360 min	402 (40.4)	25 (40.3)			
Transfusion		254 (25.5)	14 (22.6)	.086		
Superficial or deep incisional SSI		56 (5.6)	7 (11.3)	.089	2.13 (0.91–4.96)	.081
Organ/space SSI		110 (11.1)	6 (9.7)	>.999		
Other complications (≥Clavien–Dindo grade III)		32 (3.2)	4 (6.5)	.155		
Refractory ascites		65 (6.5)	5 (8.1)	.597		

Abbreviations: ASA, American Society of Anesthesiologists; ICGR15, indocyanine green retention rate at 15 min; SSI, surgical site infection.

TABLE 2 Risk factors of transverse incisional hernia

		Univariate analysis			Multivariate analysis	
		Non-transverse incisional hernia (n = 1033)	Transverse incisional hernia (n = 24)	P-value	Odds ratio	P-value
Age	<65 y	330 (31.9)	3 (12.5)	.046	2.41 (0.69–8.38)	.17
	≥65 y	703 (68.1)	21 (87.5)			
Sex	Men	736 (71.2)	18 (75.0)	.821		
	Women	297 (28.8)	6 (25.0)			
Body mass index	<25 kg/m^2	803 (77.7)	15 (62.5)	.086	1.93 (0.81–4.62)	.14
	≥25 kg/m^2	230 (22.3)	9 (37.5)			
ASA physical status	<class 3	921 (89.2)	20 (83.3)	.324		
	≥class 3	112 (10.8)	4 (16.7)			
Diabetes mellitus		258 (25.0)	10 (41.7)	.093	1.60 (0.68–3.77)	.28
Smoking history		439 (42.5)	14 (58.3)	.145		
Steroid usage		13 (1.3)	1 (4.2)	.276		
Respiratory diseases		43 (4.2)	0 (0.0)	.62		
Primary disease	HCC	558 (54.0)	18 (75.0)	.06	1.88 (0.71–4.99)	.2
	Others	475 (46.0)	6 (25.0)			
Preoperative chemotherapy		179 (17.3)	5 (20.8)	.592		
Repeat hepatectomy		195 (18.9)	5 (20.8)	.793		
Anemia		502 (48.6)	10 (41.7)	.541		
Albumin	<3.5 g/dL	189 (18.3)	8 (33.3)	.105		
	≥3.5 g/dL	844 (81.7)	16 (66.7)			
Total bilirubin	<1.0 mg/dL	840 (81.3)	17 (70.8)	.192		
	≥1.0 mg/dL	193 (18.7)	7 (29.2)			
Creatinine	<1.0 mg/dL	868 (84.0)	23 (95.8)	.156		
	≥1.0 mg/dL	165 (16.0)	1 (4.2)			
ICGR15	<15%	686 (66.4)	11 (45.8)	.048	1.74 (0.75–4.05)	.2
	≥15%	347 (33.6)	13 (54.2)			
Operative method	Partial	383 (37.1)	6 (25.0)	.286		
	Anatomic	650 (62.9)	18 (75.0)			
Blood loss	<1000 mL	712 (68.9)	18 (75.0)	.657		
	≥1000 mL	321 (31.1)	6 (25.0)			
Operative time	<360 min	619 (59.9)	11 (45.8)	.207		
	≥360 min	414 (40.1)	13 (54.2)			
Transfusion		265 (25.7)	3 (12.5)	.162		
Posterior fascia suture type	Monofilament	585 (56.6)	18 (75.0)	.094	0.47 (0.18–1.21)	.12
	Braid	448 (43.4)	6 (25.0)			
Posterior fascia closure method	Interrupted	513 (49.7)	8 (33.3)	.148		
	Running	520 (50.3)	16 (66.7)			
Anterior fascia suture type	Monofilament	583 (56.4)	10 (41.7)	.211		
	Braid	450 (43.6)	14 (58.3)			
Anterior fascia closure method	Interrupted	662 (64.1)	19 (79.2)	.194		
	Running	370 (35.9)	5 (20.8)			
Superficial or deep incisional SSI		59 (5.7)	4 (16.7)	.049	4.00 (1.27–12.6)	.018

(Continues)

TABLE 2 (Continued)

	Univariate analysis			Multivariate analysis	
	Non-transverse incisional hernia (n = 1033)	Transverse incisional hernia (n = 24)	P-value	Odds ratio	P-value
Organ/space SSI	112 (10.8)	4 (16.7)	.324		
Other complications (≥Clavien–Dindo grade III)	35 (3.4)	1 (4.2)	.569		
Refractory ascites	68 (6.6)	2 (8.3)	.67		

Abbreviations: ASA, American Society of Anesthesiologists; ICGR15, indocyanine green retention rate at 15 min; SSI, surgical site infection.

of the rectus abdominis muscles are folded and united. Generally, when an incision is made on the linea alba, the rectus abdominis muscle is not incised.

In contrast, the left and right rectus abdominis fibers have a vertical orientation; thus, a horizontal incision always reaches the rectus abdominis muscle. In addition, the external oblique, internal oblique, and transverse abdominis muscles overlap on the lateral side of the rectus abdominis muscle. Horizontal incisions usually also extend to these muscles.

Therefore, in the closure of the midline incision, two layers, the linea alba and the skin, are closed; however, the horizontal incision would require a three-layer closure because of the need to close the anterior and posterior fascias of the rectus abdominis muscles. Similarly, the lateral side of the rectus abdominis, including the external oblique, internal oblique, and transverse abdominis muscles, also require separate closures of the anterior and posterior fascias.

In summary, the difference between a midline and a transverse incision is based on whether or not the muscle is incised and the number of layers of fascia to be sutured. Therefore, this difference explains the different risk factors for abdominal incisional hernia at different sites. We confirmed that a three-layer closure was performed for the horizontal incision and a two-layer closure was performed for the vertical incision in all institutes.

As a result, superficial and deep incisional SSIs, which indicate the occurrence of wound infection, were found to be risk factors for horizontal incisional hernias, whereas closure methods and suture types were not. Contrariwise, for the midline hernias, the closure method (interrupted suture) was identified as the main risk factor.

Regarding the impact of running and interrupted sutures on the occurrence of midline incisional hernias, some studies showed no difference, whereas others reported that running sutures were associated with better outcomes.[4,32-36] Diener et al[14] stated that the incidence of abdominal incisional hernia was lower with running sutures than with interrupted sutures for midline wounds was used in 14 RCTs in their systematic review (odds ratio: 0.59; P < .001). For this reason, they reported that the running suture tended to evenly distribute the pressure on the whole wound, thus reducing the risk of amputation of the fascia by the suture.[37,38] In addition, a running suture requires fewer knots than the interrupted suture, thus reducing the incidence if SSI, since bacteria mainly attach to the knots. On the other hand, the interrupted suture was reportedly associated with better drainage of ascites from the gaps between the sutures; thus, the interrupted suture not only improves wound healing, but also reduces the accumulation of fluid and pus in the abdominal cavity.[39] Whichever way, the problem-solving process has not been concluded, and an RCT (CONTINT Study) on the impact of interrupted and running sutures on midline incisions is ongoing.[39]

In this study we conducted separate investigations for midline and transverse incision sites. As the posterior and anterior parts of the fascia were separately closed in the transverse incision site, the suture type or method was not a risk factor, but rather wound infection. However, the closure method was a risk factor for midline incision sites. Certainly, nutrition and healing factors are generally important for abdominal incisional hernia prevention. Therefore, the closure of the midline incision might require a running suture, and preventive strategies for incisional SSI should be applied for transverse incisional sites, while maintaining preoperative nutrition and diabetes mellitus control.

Furthermore, 13 (21%) of the 62 patients with incisional hernia underwent surgical repair: open primary closure, open mesh repair, and laparoscopic mesh repair in three (23.1%), four (30.8%), and six (46.1%) patients, respectively.

his study had certain limitations. First, it had a retrospective design. Moreover, the diagnosis of abdominal incisional hernia was based on clinical symptoms, not on imaging evaluations such as computed tomography. Therefore, asymptomatic patients with abdominal incisional hernia might have been excluded from this study. Second, this study was a multicenter retrospective study; hence, perioperative management including enhanced recovery after surgery, nutritional support, and infection control were different at each institution. However, since all participating institutions were board-certified training institutions for expert surgeons of the Japanese Society of Hepato-Biliary-Pancreatic Surgery, the quality of surgical skills including suturing techniques during hepatectomy was guaranteed.

5 | CONCLUSION

The risk factors for abdominal incisional hernia after open hepatectomy depend on the wound site. For transverse incisions, wound infection may primarily contribute to the development of abdominal

TABLE 3 Risk factors of midline incisional hernia

		Univariate analysis			Multivariate analysis	
		Non-midline incisional hernia (n = 1032)	Midline incisional hernia (n = 25)	P-value	Odds ratio	P-value
Age	<65 y	329 (31.9)	4 (16.0)	.126		
	≥65 y	703 (68.1)	21 (84.0)			
Sex	Men	734 (71.1)	20 (80.0)	.381		
	Women	298 (28.9)	5 (20.0)			
Body mass index	<25 kg/m^2	798 (77.3)	20 (80.0)	>.999		
	≥25 kg/m^2	234 (22.7)	5 (20.0)			
ASA physical status	<class 3	918 (89.0)	23 (92.0)	>.999		
	≥class 3	114 (11.0)	2 (8.0)			
Diabetes mellitus		261 (25.3)	7 (28.0)	.816		
Smoking history		439 (42.5)	14 (56.0)	.22		
Steroid usage		14 (1.4)	0 (0.0)	>.999		
Respiratory diseases		43 (4.2)	0 (0.0)	.62		
Primary disease	HCC	562 (54.5)	14 (56.0)	>.999		
	Others	470 (45.5)	11 (44.0)			
Preoperative chemotherapy		182 (17.6)	2 (8.0)	.289		
Repeat hepatectomy		195 (18.9)	5 (20.0)	.8		
Anemia		498 (48.3)	14 (56.0)	.545		
Albumin	<3.5 g/dL	191 (18.5)	6 (24.0)	.443		
	≥3.5 g/dL	841 (81.5)	19 (76.0)			
Total bilirubin	<1.0 mg/dL	838 (81.2)	19 (76.0)	.449		
	≥1.0 mg/dL	194 (18.8)	6 (24.0)			
Creatinine	<1.0 mg/dL	871 (84.4)	20 (80.0)	.575		
	≥1.0 mg/dL	161 (15.6)	5 (20.0)			
ICGR15	<15%	678 (65.7)	19 (76.0)	.393		
	≥15%	354 (34.3)	6 (24.0)			
Operative method	Partial	381 (36.9)	8 (32.0)	.68		
	Anatomic	651 (63.1)	17 (68.0)			
Blood loss	<1000 mL	712 (69.0)	18 (72.0)	.83		
	≥1000 mL	320 (31.0)	7 (28.0)			
Operative time	<360 min	611 (59.2)	19 (76.0)	.102		
	≥360 min	421 (40.8)	6 (24.0)			
Transfusion		262 (25.4)	6 (24.0)	>.999		
Fascia suture type	Monofilament	584 (56.6)	18 (72.0)	.153		
	Braid	448 (43.4)	7 (28.0)			
Fascia closure method	Interrupted	704 (68.2)	22 (88.0)	.047	0.29 (0.09–0.99)	0.047
	Running	328 (31.8)	3 (12.0)			
Superficial or deep incisional SSI		60 (5.8)	3 (12.0)	.183		
Organ/space SSI		115 (11.1)	1 (4.0)	.511		
Other complications (≥Clavien–Dindo grade III)		34 (3.3)	2 (8.0)	.208		
Refractory ascites		68 (6.6)	2 (8.0)	.679		

Abbreviations: ASA, American Society of Anesthesiologists; ICGR15, indocyanine green retention rate at 15 min; SSI, surgical site infection.

incisional hernias. However, the suture method may be the most important factor in the development of midline abdominal incisional hernias. We recommend the implementation of systemic nutrition and blood glucose monitoring.

ETHICAL STATEMENT

The protocol for this multicenter research project was approved by a suitably constituted Ethics Committee of each institution, and it conforms to the provisions of the Declaration of Helsinki. Committee of principal institution Approval No. R2018-006. Informed consent was obtained from the patients and/or guardians.

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REFERENCES

1. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. Lancet. 2003;362:1561–71.
2. Breuing K, Butler CE, Ferzoco S, Franz M, Hultman CS, Kilbridge JF, et al. Incisional ventral hernias: review of the literature and recommendations regarding the grading and technique of repair. Surgery. 2010;148:544–58.
3. Takesue Y. Standardization of abdominal wound closure and use of intra-abdominal drain in gastroenterological surgery in Japan. J Jpn Soc Surg Infect. 2014;11:93–101.
4. Diener MK, Voss S, Jensen K, Buchler MW, Seiler CM. Elective midline laparotomy closure: the INLINE systematic review and meta-analysis. Ann Surg. 2010;251:843–56.
5. van 't Riet M, Steyerberg EW, Nellensteyn J, Bonjer HJ, Jeekel J. Meta-analysis of techniques for closure of midline abdominal incisions. Br J Surg. 2002;89:1350–6.
6. Bickenbach KA, Karanicolas PJ, Ammori JB, Jayaraman S, Winter JM, Fields RC, et al. Up and down or side to side? A systematic review and meta-analysis examining the impact of incision on outcomes after abdominal surgery. Am J Surg. 2013;206:400–9.
7. Togo S, Nagano Y, Masumoto C, Takakura H, Matsuo K, Takeda K, et al. Outcome of and risk factors for incisional hernia after partial hepatectomy. J Gastrointest Surg. 2008;12:1115–20.
8. Kayashima H, Maeda T, Harada N, Masuda T, Guntani A, Ito S, et al. Risk factors for incisional hernia after hepatic resection for hepatocellular carcinoma in patients with liver cirrhosis. Surgery. 2015;158:1669–75.
9. Nilsson JH, Strandberg Holka P, Sturesson C. Incisional hernia after open resections for colorectal liver metastases - incidence and risk factors. HPB (Oxford). 2016;18:436–41.
10. Owens WD, Felts JA, Spitznagel EL Jr. ASA physical status classifications: a study of consistency of ratings. Anesthesiology. 1978;49:239–43.
11. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Infect Control Hosp Epidemiol. 1999;20(4):250–78; quiz 79-80.
12. Berrios-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for disease control and prevention guideline for the prevention of surgical site infection, 2017. JAMA Surg. 2017;152:784–91.
13. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240:205–13.
14. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg. 2009;250:187–96.
15. Kossler-Ebs JB, Grummich K, Jensen K, et al. Incisional hernia rates after laparoscopic or open abdominal surgery-a systematic review and meta-analysis. World J Surg. 2016;40:2319–30.
16. Ihedioha U, Mackay G, Leung E, Molloy RG, O'Dwyer PJ. Laparoscopic colorectal resection does not reduce incisional hernia rates when compared with open colorectal resection. Surg Endosc Other Intervent Tech. 2008;22:689–92.
17. Singh R, Omiccioli A, Hegge S, McKinley C. Does the extraction-site location in laparoscopic colorectal surgery have an impact on incisional hernia rates? Surg Endosc Other Intervent Tech. 2008;22:2596–600.
18. Taylor GW, Jayne DG, Brown SR, Thorpe H, Brown JM, Dewberry SC, et al. Adhesions and incisional hernias following laparoscopic versus open surgery for colorectal cancer in the CLASICC trial. Br J Surg. 2010;97:70–8.
19. Reoch J, Mottillo S, Shimony A, Filion KB, Christou NV, Joseph L, et al. Safety of laparoscopic vs open bariatric surgery: a systematic review and meta-analysis. Arch Surg. 2011;146:1314–22.
20. Ghobrial RM, Freise CE, Trotter JF, Tong L, Ojo AO, Fair JH, et al. Donor morbidity after living donation for liver transplantation. Gastroenterology. 2008;135:468–76.
21. Butler JR, O'Brien DC, Kays JK, Kubal CA, Ekser B, Fridell JA, et al. Incisional hernia after orthotopic liver transplantation: a systematic review and meta-analysis. Transplant Proc. 2021;53:255–9.
22. Mudge M, Harding KG, Hughes LE. Incisional hernia. Br J Surg. 1986;73:82.
23. Makela JT, Kiviniemi H, Juvonen T, Laitinen S. Factors influencing wound dehiscence after midline laparotomy. Am J Surg. 1995;170:387–90.
24. Franchi M, Ghezzi F, Buttarelli M, Tateo S, Balestreri D, Bolis P. Incisional hernia in gynecologic oncology patients: a 10-year study. Obstet Gynecol. 2001;97:696–700.
25. Hoer J, Lawong G, Klinge U, Schumpelick V. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg. 2002;73:474–80.

26. Junge K, Klinge U, Klosterhalfen B, Rosch R, Stumpf M, Schumpelick V. Review of wound healing with reference to an unrepairable abdominal hernia. Eur J Surg. 2002;168:67–73.

27. Sorensen LT, Hemmingsen UB, Kirkeby LT, Kallehave F, Jorgensen LN. Smoking is a risk factor for incisional hernia. Arch Surg. 2005;140:119–23.

28. O'Dwyer PJ, Courtney CA. Factors involved in abdominal wall closure and subsequent incisional hernia. Surgeon. 2003;1:17–22.

29. Bosanquet DC, Ansell J, Abdelrahman T, et al. Systematic review and meta-regression of factors affecting midline incisional hernia rates: analysis of 14,618 patients. PLoS One. 2015;10:e0138745.

30. Millbourn D, Cengiz Y, Israelsson LA. Effect of stitch length on wound complications after closure of midline incisions: a randomized controlled trial. Arch Surg. 2009;144:1056–9.

31. Patel SV, Paskar DD, Nelson RL, Vedula SS, Steele SR. Closure methods for laparotomy incisions for preventing incisional hernias and other wound complications. Cochrane Database Syst Rev. 2017;11:CD005661.

32. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg. 2000;231:436–42.

33. Gupta H, Srivastava A, Menon GR, Agrawal CS, Chumber S, Kumar S. Comparison of interrupted versus continuous closure in abdominal wound repair: a meta-analysis of 23 trials. Asian J Surg. 2008;31:104–14.

34. Seiler CM, Bruckner T, Diener MK, Papyan A, Golcher H, Seidlmayer C, et al. Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: a multicenter randomized trial (INSECT: ISRCTN24023541). Ann Surg. 2009;249:576–82.

35. Heger P, Pianka F, Diener MK, Mihaljevic AL. [Current standards of abdominal wall closure techniques: conventional suture techniques]. Chirurg. 2016;87:737–43.

36. Henriksen NA, Deerenberg EB, Venclauskas L, Fortelny RH, Miserez M, Muysoms FE. Meta-analysis on materials and techniques for laparotomy closure: the MATCH review. World J Surg. 2018;42:1666–78.

37. Trimbos JB, Smit IB, Holm JP, Hermans J. A randomized clinical trial comparing two methods of fascia closure following midline laparotomy. Arch Surg. 1992;127:1232–4.

38. Brolin RE. Prospective, randomized evaluation of midline fascial closure in gastric bariatric operations. Am J Surg. 1996;172:328–31.

39. Rahbari NN, Knebel P, Kieser M, et al. Design and current status of CONTINT: continuous versus interrupted abdominal wall closure after emergency midline laparotomy - a randomized controlled multicenter trial [NCT00544583]. Trials. 2012;13:72.