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Incidence of incisional hernia after closure of burst abdomen - a single-center, retrospective cohort study

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Introduction: Burst abdomen is a severe postoperative complication associated with high morbidity and a substantial risk of subsequent incisional hernia. Evidence regarding the optimal fascial closure technique following surgical repair remains limited.

Methods: This retrospective single-center cohort study included adult patients undergoing surgical repair of burst abdomen after midline laparotomy between 2017 and 2024. Patients with complete fascial closure and at least 30 days of follow-up were included. The primary objective was the development of incisional hernia within 6 years after the operation. Two closure strategies, interrupted polyglactin 910 and predominantly continuous polydioxanone, were compared in an exploratory analysis. Univariable and multivariable analyses were performed to identify independent risk factors. Death was treated as a competing event in a sensitivity analysis.

Results: A total of 104 patients were included. Median follow-up was 18.1 months. The cumulative incidence of incisional hernia was 26.3% at 12 months, 39.6% at 24 months and 45.1% at 36 months (24.0%, 34.7% and 38.9% when death was treated as a competing event). Hernia incidence did not differ significantly between interrupted polyglactin 910 closure (n = 85) and polydioxanone closure (n = 19, hazard ratio 1.21, 95% CI 0.49–2.97). Recurrent burst abdomen was more frequent after polydioxanone closure (26.3% versus 5.9%, p = 0.02). Increasing age was associated with incisional hernia formation (hazard ratio 1.05 per year, 95% CI 1.02–1.08, p = 0.003), consistently across alternative models. Its effect was not constant over time and was mainly apparent after the first year.

Discussion: Almost half of the patients developed an incisional hernia within 3 years of burst abdomen repair. The two closure strategies did not differ significantly in hernia incidence, but the small polydioxanone group and the confounding of suture material and technique preclude conclusions on the optimal closure. Increasing age was associated with abdominal wall failure. Prospective studies with a standardized and documented closure technique are needed to define optimal reconstructive strategies in this high-risk population.

KEYWORDS
abdominal wound dehiscence, burst abdomen, fascial closure, incisional hernia, polydioxanone, polyglactin

Introduction

Abdominal wound dehiscence, commonly referred to as burst abdomen, represents one of the most frequent complications following open abdominal surgery. It is characterized by partial or complete separation of the fascial layers after laparotomy and is associated with substantial postoperative morbidity, prolonged hospitalization, increased healthcare costs, and mortality rates reported between 10% and 45% [1, 2]. Despite advances in perioperative management and abdominal wall closure techniques, the incidence of burst abdomen remains between 0.4% and 3.5% following laparotomy [3]. Several patient- and procedure-related risk factors have been identified, including advanced age, malnutrition, obesity, smoking, diabetes mellitus, chronic pulmonary disease, wound infection, immunosuppression, emergency surgery, and intra-abdominal sepsis [2, 4]. Early studies demonstrated that wound dehiscence substantially increases the risk of later incisional hernia formation, with reported incidences considerably exceeding those observed after uncomplicated laparotomy closure [5, 6]. Incisional hernias are associated with impaired quality of life, chronic pain, reduced physical functioning, and frequently require additional surgical intervention [7].

Numerous studies have investigated optimal techniques for primary abdominal wall closure after elective and emergency laparotomy. Current guidelines recommend continuous fascial closure using slowly absorbable suture material with small tissue bites, referred to as the small-bites or small-stitch technique [8]. However, despite the use of standardized closure techniques, randomized controlled trials report incisional hernia rates after open abdominal surgery ranging from approximately 10%–30% [9–11]. The small-bites technique reduced the incidence of incisional hernia in the STITCH trial [12] and in the ESTOIH trial the short-stitch technique also reduced the rate of burst abdomen (1.40% versus 4.76%) [13]. A recent meta-analysis confirmed a lower rate of incisional hernia with small bites [14]. None of these trials, however, included patients undergoing repair of an established burst abdomen. Long-term follow-up studies have confirmed that patients suffering from abdominal wound dehiscence represent a particularly vulnerable population. Van Ramshorst et al. reported a high incidence of incisional hernia after abdominal wound dehiscence, accompanied by reduced body image and impaired quality of life during long-term follow-up [6]. Similarly, Jensen et al. demonstrated that even after implementation of a standardized mass-closure technique using slowly absorbable running sutures, approximately one-third of patients developed an incisional hernia during follow-up, emphasizing the persistent challenge of achieving durable abdominal wall reconstruction after burst abdomen [15]. Taken together, there is currently no consensus regarding the optimal surgical closure technique for postoperative fascial dehiscence. Furthermore, the incidence and risk factors of incisional hernia after surgical treatment of burst abdomen remain insufficiently investigated [6, 16]. In the Department of General, Visceral and Transplant Surgery of the University Hospital in Tübingen, Germany, patients with postoperative fascial dehiscence have been treated over the past 8 years using different closure strategies, including slowly absorbable and rapidly absorbable suture materials as well as continuous and interrupted fascial closure techniques. The present study therefore aims to evaluate the incidence of incisional hernia following surgical treatment of postoperative fascial dehiscence and to compare outcomes according to the closure strategy used.

Materials and methods

Study design and setting

This retrospective, single-center observational cohort study included all adult patients surgically treated for abdominal wound dehiscence, commonly referred to as burst abdomen, between January 1, 2017, and December 31, 2024, at the Department of General, Visceral and Transplant Surgery, University Hospital Tübingen, Germany. The University Hospital Tübingen is a tertiary referral center providing maximum-care surgical treatment. Patients were identified through the institutional electronic medical record system. Medical records, operative reports, discharge letters, outpatient follow-up documentation, and available radiological imaging were reviewed. The study was approved by the local ethics committee of the University Hospital Tübingen, Germany (approval number 101/2024BO2).

Definition of burst abdomen

Burst abdomen was defined as postoperative fascial dehiscence following laparotomy, characterized by partial or complete separation of the abdominal fascial layer requiring surgical treatment. The diagnosis was based on clinical findings, such as visible or palpable fascial separation or bowel in the wound, and/or intraoperative confirmation during revision surgery.

Inclusion and exclusion criteria

All patients aged 18 years or older who underwent surgical treatment for burst abdomen after midline laparotomy during the study period were assessed for eligibility. Patients were included if they fulfilled the following criteria: previous midline laparotomy, surgically treated postoperative burst abdomen, complete fascial closure during burst abdomen repair, and a minimum postoperative follow-up of 30 days. Patients were excluded if the primary incision was not a midline laparotomy, including L-shaped, flank, or Pfannenstiel incisions. Further exclusion criteria were follow-up shorter than 30 days, missing documentation regarding fascial closure, data from other departments, incomplete medical records, absence of fascial dehiscence, absence of complete fascial closure, and additional laparotomies or surgical revisions after the primary repair of burst abdomen and before follow-up assessment. Recurrent burst abdomen was explicitly exempt from this criterion.

Abdominal wall closure technique

During the study period, the fascial closure strategy for burst abdomen changed within the department. According to the

departmental standard, fascial closure was performed earlier in the study period with short-term absorbable braided suture material, namely polyglactin 910 USP size 1 (Vicryl, Ethicon, Somerville, NJ, USA), in an interrupted suture technique with medium bites (stitching only the fascia without the rectus muscle). Later, the departmental standard shifted toward long-term absorbable monofilament suture material, namely USP size 1 polydioxanone (PDS II, Ethicon Inc., Johnson & Johnson, Raritan, New Jersey, USA), applied as a continuous fascial closure with medium bites. Depending on the intraoperative situation and the surgeon's preference, the polydioxanone closure was reinforced in selected cases with additional interrupted polyglactin 910 sutures, some of them placed as figure-of-eight sutures. Through-and-through retention sutures were not used. Both closure strategies aimed to achieve complete fascial approximation. The exact suture material, suture caliber (USP size), suture technique, use of reinforcing sutures, and intraoperative findings were extracted from the operative reports. Bite size (distance from the wound edge), stitch interval and suture-to-wound-length ratio were not documented in any operative report and could not be reconstructed retrospectively. The use of medium bites is therefore an inference from the departmental standard and was not documented for individual patients. Because suture material and technique changed together, the two groups represent closure strategies rather than suture materials: Interrupted closure with polyglactin 910 (polyglactin group) and predominantly continuous closure with polydioxanone (polydioxanone group). Patients whose polydioxanone closure was reinforced with additional polyglactin 910 sutures were assigned to the polydioxanone group. The respective contributions of suture material and technique therefore cannot be separated, and all comparisons between the groups are exploratory.

Data extraction

Demographic, clinical, operative, microbiological, and follow-up data were extracted from the electronic medical records. Collected baseline variables included age, sex, body mass index, smoking status, alcohol consumption, American Society of Anesthesiologists physical status classification, and relevant comorbidities. Comorbidities included malignancy, diabetes mellitus, thyroid disease, neurological disease, arterial hypertension, atrial fibrillation, pulmonary disease, liver disease, renal disease and preoperative anemia. The preoperative hemoglobin concentration was also recorded. Procedure-related variables included previous laparotomies, type of index operation, elective versus emergency surgery, degree of contamination of the index operation, fascial closure technique, suture material and caliber at the index operation, intensive care unit stay, surgical site infection, intraoperative microbiological findings, presence of positive intraoperative cultures, and type of isolated microorganism. Variables related to burst abdomen repair included fascial closure technique, suture material and caliber, interrupted or continuous closure, use of reinforcing sutures, mesh reinforcement, negative-pressure wound therapy, the extent of the dehiscence (complete or partial), the condition of the skin (intact or open), contamination grade at burst abdomen repair, clinical infection at the time of repair, and the interval between the index operation and burst abdomen repair. The number of relaparotomies included the burst abdomen repair itself. The burst abdomen was classified as contaminated or dirty-infected if the report described an infected hematoma, pus or necrotic or devitalized tissue. Follow-up data included duration of follow-up, clinical diagnosis of incisional hernia, radiological diagnosis of incisional hernia, time to incisional hernia diagnosis, requirement for subsequent incisional hernia repair and vital status and date of death.

Outcome measures

The primary objective was the occurrence of incisional hernia following surgical repair of burst abdomen, assessed overall and according to the closure strategy used. Recurrent burst abdomen was recorded as a secondary outcome. Incisional hernia was defined as any abdominal wall hernia occurring in the previous midline laparotomy incision after burst abdomen repair. Diagnosis was based on clinical examination during inpatient or outpatient follow-up and/or radiological evidence on computed tomography, magnetic resonance imaging, or ultrasound. Intraoperative diagnosis during subsequent abdominal surgery was also considered evidence of incisional hernia. For the analysis of incisional hernia development, patients who died within the first 30 postoperative days after burst abdomen repair were excluded, as they were considered not to have sufficient follow-up time for reliable assessment of hernia formation. Surgical site infection at any time after the index operation was classified according to the CDC definitions as superficial, deep or organ/space infection [17]. Patients with infection at more than one tissue level were classified according to the deepest level involved, so that each patient was counted only once. Any surgical site infection was defined as the presence of at least one category.

Statistical analysis

Descriptive statistics and group comparisons were performed using IBM SPSS Statistics version 31.0. Time-to-event analyses, including Kaplan–Meier estimation, log-rank tests, Cox proportional hazards models and competing risk analyses, were performed in R version 4.6.0 (R Foundation for Statistical Computing, Vienna, Austria) using the packages survival and survminer. Figures were generated using survminer in R and matplotlib in Python 3.12. Categorical variables were compared using chi-square or Fisher's exact tests, and continuous variables using the Mann-Whitney U test. Time to incisional hernia was calculated from the date of burst abdomen repair to the date of hernia diagnosis, or, for patients without incisional hernia, to the date of the last examination at which an incisional hernia could have been detected, defined as the most recent abdominal imaging study (computed tomography, magnetic resonance imaging or ultrasound) or documented clinical examination of the abdominal wall. Routine clinical contacts without assessment of the abdominal wall were not counted as follow-up.

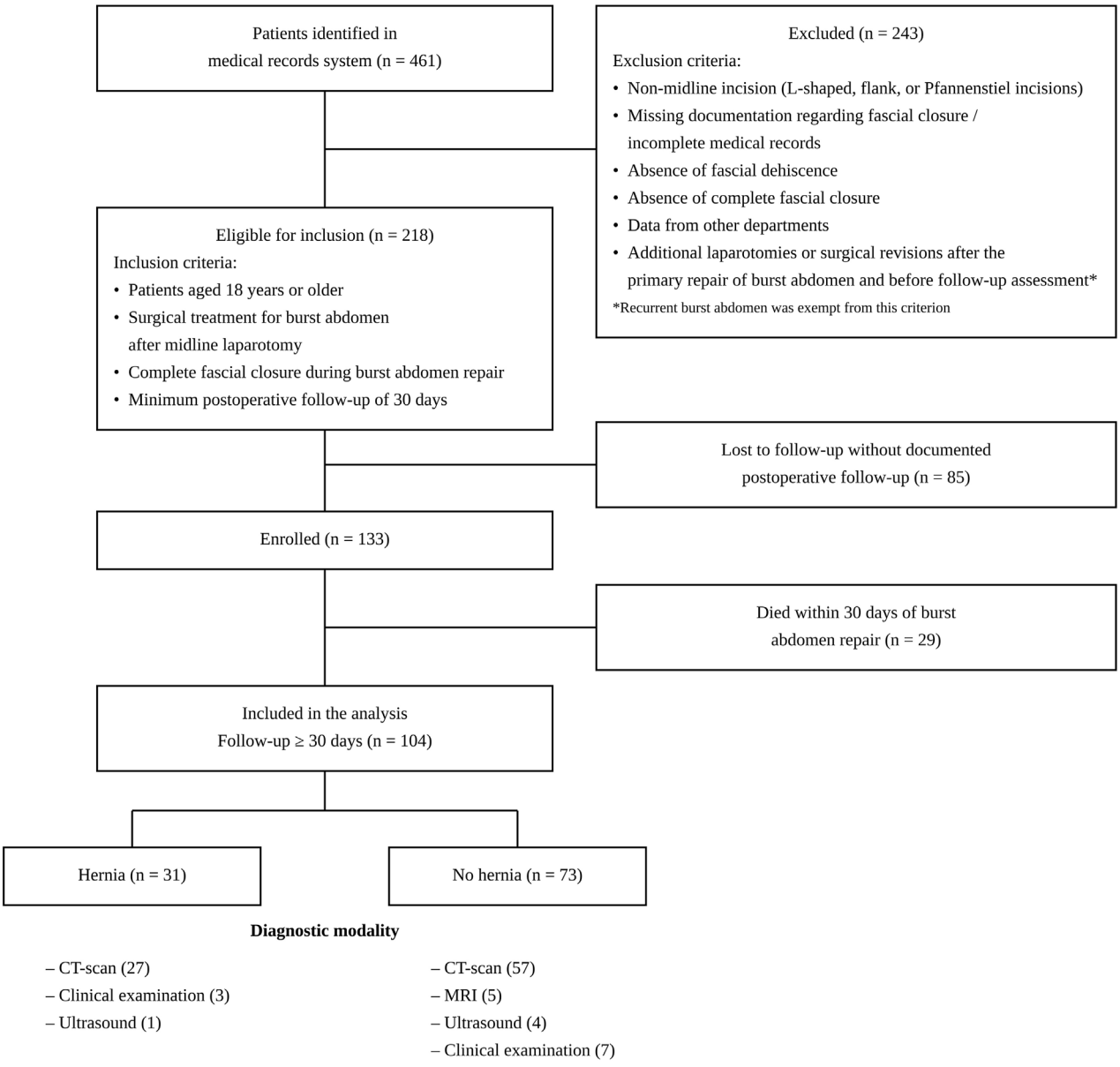


FIGURE 1
Flow chart of patient selection. Of 461 patients identified in the institutional electronic medical record system 243 were excluded because they did not meet the inclusion criteria. Because these patients were excluded in a single screening step of the medical records without recording the specific reason, the number of patients per exclusion criterion cannot be reported. Of the 218 eligible patients, 85 had no documented postoperative follow-up and 29 died within 30 days of burst abdomen repair, leaving 104 patients for the final analysis. Diagnostic modalities used to establish or exclude incisional hernia are shown separately for both groups.

Cumulative incidence was estimated using the Kaplan-Meier method and compared between closure groups using the log-rank test and Cox regression. Median follow-up was estimated using the reverse Kaplan-Meier method, in which the event indicator is reversed so that the distribution of censoring times is estimated. The covariates of the multivariable Cox proportional hazards model were selected on clinical grounds, independently of their association with incisional hernia in the present data: age and body mass index as established patient-related risk factors for incisional hernia, and the calendar period of repair (2017–2020 versus 2021–2024) to account for changes in perioperative management, surveillance intensity and imaging practice over time. In a sensitivity analysis, the variables associated with incisional hernia in univariable comparison (age, atrial fibrillation, neurological disease and contamination grade at repair) were entered instead. The proportional hazards assumption was assessed using scaled Schoenfeld residuals. Surgical site infection of organ/space could not be entered into this model because no patient who developed an incisional hernia had organ/space infection; the resulting complete separation prevents estimation of the coefficient, and organ/space infection is therefore reported descriptively only.

The risk-factor analysis and all comparisons between closure strategies were exploratory, and the comparison of

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TABLE 1 Baseline characteristics: polyglactin versus polydioxanone.

Characteristic	All, n = 104	Polyglactin, n = 85	Polydioxanone, n = 19	p-value
Age, years, mean (SD)	67.4 (13.5)	67.3 (14.2)	67.7 (10.1)	0.48m
Sex, n (%)				0.07f
Male	82 (78.8)	64 (75.3)	18 (94.7)	
Female	22 (21.2)	21 (24.7)	1 (5.3)	
BMI, kg/m2, mean (SD)	25.6 (4.6)	25.9 (5.0)	24.6 (2.3)	0.22m
Preoperative hemoglobin, g/dL, mean (SD)	12.1 (2.1)	12.2 (2.1)	11.5 (2.1)	0.24m
Smoking, n (%)	27/103 (26.2)	20 (23.5)	7/18 (38.9)	0.24f
Alcohol, n (%)	29/103 (28.2)	21 (24.7)	8/18 (44.4)	0.15f
Malignancy, n (%)	58 (55.8)	46 (54.1)	12 (63.2)	0.61f
Diabetes mellitus, n (%)	19 (18.3)	17 (20.0)	2 (10.5)	0.51f
Thyroid disease, n (%)	25 (24.0)	23 (27.1)	2 (10.5)	0.15f
Neurological disease, n (%)	20 (19.2)	16 (18.8)	4 (21.1)	0.76f
Arterial hypertension, n (%)	66/103 (64.1)	55/84 (65.5)	11 (57.9)	0.60f
Atrial fibrillation, n (%)	16 (15.4)	13 (15.3)	3 (15.8)	1.00f
Pulmonary disease, n (%)	26 (25.0)	20 (23.5)	6 (31.6)	0.56f
Liver disease, n (%)	27 (26.0)	17 (20.0)	10 (52.6)	**0.007f**
Renal disease, n (%)	21 (20.2)	18 (21.2)	3 (15.8)	0.76f
Previous abdominal surgery, n (%)	62 (59.6)	52 (61.2)	10 (52.6)	0.61f
Preoperative anemia, n (%)	80 (76.9)	64 (75.3)	16 (84.2)	0.55f
ASA score, n (%)				0.18x
1	2 (1.9)	2 (2.4)	0 (0.0)	
2	24 (23.1)	22 (25.9)	2 (10.5)	
3	74 (71.2)	59 (69.4)	15 (78.9)	
4	4 (3.8)	2 (2.4)	2 (10.5)	

BMI, body mass index; ASA, American Society of Anesthesiologists; Percentages are calculated from patients with available data. Where data were missing, the denominator is shown explicitly as n/N for categorical variables and as [n =] for continuous variables. Missing values: smoking n = 1, alcohol n = 1, arterial hypertension n = 1, f = Fisher's exact test; x = Pearson chi-square test; m = Mann-Whitney U test. Bold values indicate statistical significance ($p < 0.05$).

patients with and without reinforcing sutures within the polydioxanone group was not planned (*post hoc*). In a sensitivity analysis, death without a preceding incisional hernia was treated as a competing event: the cumulative incidence of incisional hernia was estimated with the Aalen–Johansen estimator, and the multivariable model was refitted as a Fine–Gray subdistribution hazards model with the same covariates, both using the survival package. In this analysis, follow-up of patients who died without incisional hernia ended at death. The same approach was used to examine whether competing mortality explained the associations of surgical site infection and contamination at repair with incisional hernia. Microbiological comparisons were exploratory and were not adjusted for multiple testing. Statistical significance was defined as a two-sided p-value of less than 0.05. Hazard ratios are reported with 95% confidence intervals.

Results

Patient selection and characteristics

Between January 2017 and December 2024, 461 patients were identified through the institutional electronic medical record system and assessed for eligibility. After primary screening, 243 patients were excluded because they did not fulfill the inclusion criteria, leaving 218 patients for further evaluation. Among these, 85 patients had no documented follow-up in the institutional electronic medical records. Twenty-nine patients died within the first 30 postoperative days after burst abdomen repair and were therefore excluded from the analysis of incisional hernia development. Accordingly, 104 patients were available for the final analysis. The patient selection process, loss to follow-up, and the final study cohort are summarized in Figure 1. The mean age

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TABLE 2 Characteristics of the index operation: polyglactin versus polydioxanone.

Characteristic	All, n = 104	Polyglactin, n = 85	Polydioxanone, n = 19	p-value
Surgical setting, n (%)				0.80x
Elective	63 (60.6)	51 (60.0)	12 (63.2)	
Emergency	41 (39.4)	34 (40.0)	7 (36.8)	
Surgical field, n (%)				0.07x
HPB	29 (27.9)	21 (24.7)	8 (42.1)	
Upper GI	8 (7.7)	5 (5.9)	3 (15.8)	
GI	55 (52.9)	48 (56.5)	7 (36.8)	
Sarcoma	1 (1.0)	0 (0.0)	1 (5.3)	
Transplantation	3 (2.9)	3 (3.5)	0 (0.0)	
Peritoneal carcinomatosis	6 (5.8)	6 (7.1)	0 (0.0)	
Other	2 (1.9)	2 (2.4)	0 (0.0)	
Degree of contamination, n (%)				0.58x
Aseptic	29 (27.9)	22 (25.9)	7 (36.8)	
Clean-contaminated	59 (56.7)	49 (57.6)	10 (52.6)	
Contaminated	16 (15.4)	14 (16.5)	2 (10.5)	
Fascial closure at index operation, n (%)				0.50x
Continuous polydioxanone	96 (92.3)	79 (92.9)	17 (89.5)	
Interrupted polyglactin 910	6 (5.8)	5 (5.9)	1 (5.3)	
Continuous polydioxanone + interrupted polyglactin 910	2 (1.9)	1 (1.2)	1 (5.3)	
Suture caliber at index operation (USP), n (%)				0.73x
2-0	8 (7.7)	6 (7.1)	2 (10.5)	
0	2 (1.9)	2 (2.4)	0 (0.0)	
1	80 (76.9)	68 (80.0)	12 (63.2)	
2	2 (1.9)	2 (2.4)	0 (0.0)	
Not documented	12 (11.5)	7 (8.2)	5 (26.3)	
VAC therapy after index surgery, n (%)	12 (11.5)	12 (14.1)	0 (0.0)	0.12f

HPB, hepato-biliary-pancreatic; GI, gastrointestinal; VAC, vacuum-assisted closure; USP, United States Pharmacopeia; f, Fisher's exact test; x, Pearson chi-square test; m, Mann-Whitney U test.

of the final cohort was 67.4 years (SD 13.5), and the mean body mass index was 25.6 kg/m^2 (SD 4.6). The majority of patients were male (82/104, 78.8%). Most patients had substantial comorbidity, including malignancy in 58 patients (55.8%), arterial hypertension in 66 out of 103 patients (64.1%), pulmonary disease in 26 patients (25.0%), liver disease in 27 patients (26.0%), renal disease in 21 patients (20.2%), diabetes mellitus in 19 patients (18.3%), atrial fibrillation in 16 patients (15.4%), and neurological disease in 20 patients (19.2%). Previous abdominal surgery had been performed in 62 patients (59.6%). Table 1 summarizes patient characteristics.

Primary operation

The indications for the index operation were heterogeneous and reflected the broad spectrum of a tertiary referral center. Gastrointestinal procedures formed the largest group, comprising colorectal, appendiceal and small bowel surgery for malignancy, inflammatory bowel disease, volvulus, ischemia, perforation, obstruction, adhesions and incarcerated hernia, and accounted for 55 of 104 cases (52.9%). Hepatobiliary and pancreatic procedures represented the second largest group, including liver resections, pancreatic resections, biliary surgery, and cholecystectomy, with 29 cases (27.9%). Upper gastrointestinal procedures, including gastric, duodenal, and PEG-related operations, were performed in 8 patients (7.7%). Peritoneal surface malignancies treated with cytoreductive surgery with or without HIPEC accounted for 6 cases (5.8%), transplantation for 3 cases (2.9%) and retroperitoneal sarcoma for 1 case (1.0%). The remaining 2 patients (1.9%) underwent other procedures. Regarding the setting of the index operation, 63 of 104 patients underwent elective surgery, whereas

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TABLE 3 Characteristics of burst abdomen repair according to closure strategy.

Characteristic	Polyglactin 910 n = 85	Poly-dioxanone n = 19	p-value	Poly-dioxanone without reinforcing sutures n = 11	Poly-dioxanone with reinforcing sutures n = 8	p-value
Characteristics of the dehiscence						
Days from index operation to repair, median (IQR)	9 (7–14) [n = 84]	8 (5–11)	0.11m	8 (6–11)	8 (4–14)	0.93m
Complete dehiscence, n (%)	21/80 (26.3)	3 (15.8)	0.55f	1 (9.1)	2 (25.0)	0.55f
Skin intact (covered dehiscence), n (%)	48/81 (59.3)	15 (78.9)	0.12f	9 (81.8)	6 (75.0)	1.00f
(Dirty) contamination at repair, n (%)	21/81 (25.9)	5 (26.3)	1.00f	4 (36.4)	1 (12.5)	0.34f
Clinical infection at repair, n (%)	13/80 (16.3)	5 (26.3)	0.33f	4 (36.4)	1 (12.5)	0.34f
Positive intraoperative culture, n/N (%)	69/82 (84.1)	15/18 (83.3)	1.00f	10/11 (90.9)	5/7 (71.4)	0.53f
Repair technique						
Fascial closure technique, n (%)			–			–
Interrupted	84 (98.8)	2 (10.5)		1 (9.1)	1 (12.5)	
Continuous	0 (0.0)	17 (89.5)		10 (90.9)	7 (87.5)	
Not documented	1 (1.2)	0 (0.0)		0 (0.0)	0 (0.0)	
Reinforcing interrupted polyglactin 910 sutures, n (%)	0 (0.0)	8 (42.1)	–	0 (0.0)	8 (100)	–
Caliber of the fascial suture (USP), n (%)			–			–
0	3 (3.5)	0 (0.0)		0 (0.0)	0 (0.0)	
1	71 (83.5)	17 (89.5)		10 (90.9)	7 (87.5)	
2	0 (0.0)	2 (10.5)		1 (9.1)	1 (12.5)	
Not documented	11 (12.9)	0 (0.0)		0 (0.0)	0 (0.0)	
Mesh reinforcement, n (%)	0 (0.0)	0 (0.0)	–	0 (0.0)	0 (0.0)	–
Negative-pressure wound therapy after repair, n (%)	13 (15.3)	0 (0.0)	0.12f	0 (0.0)	0 (0.0)	–
Recurrent burst abdomen, n (%)	5 (5.9)	5 (26.3)	**0.02f**	5 (45.5)	0 (0.0)	**0.045f**

CDC, Centers for Disease Control and Prevention; IQR, interquartile range; USP, United States Pharmacopeia; f, Fisher's exact test; m = Mann–Whitney U test. Bold values indicate statistical significance ($p < 0.05$).

41 patients underwent emergency surgery, corresponding to 60.6% and 39.4% of the cohort, respectively.

At the index operation, the fascia was closed with a continuous polydioxanone suture in 96 of 104 patients (92.3%), with interrupted polyglactin 910 sutures in 6 (5.8%), and with a continuous polydioxanone suture combined with interrupted polyglactin 910 sutures in 2 (1.9%). The suture caliber was USP 1 in 80 patients, USP 2-0 in 8, USP 0 in 2 and USP 2 in 2, and was not documented in 12. Bite size and suture-to-wound-length ratio were not documented. The closure technique of the index operation did not differ between the two repair groups (continuous polydioxanone closure in 79 of 85 versus 17 of 19 patients, $p = 0.50$) and was not associated with subsequent incisional hernia ($p = 0.69$). A summary can be found in Table 2.

Repair of burst abdomen

The burst abdomen was repaired a median of 9 days (IQR 6–13) after the index operation. The dehiscence was complete in 24 of

99 patients (24.2%), the skin was intact in 63 of 100 (63.0%), the wound was contaminated or dirty-infected in 26 of 100 (26.0%), and a clinical infection was present at repair in 18 of 99 (18.2%). None of these characteristics, nor the interval to repair, differed significantly between the closure strategies ($p \geq 0.11$; Table 3). Intraoperative cultures obtained at repair were positive in 69 of 82 patients (84.1%) of the polyglactin group and in 15 of 18 (83.3%) of the polydioxanone group ($p = 1.00$). At repair, the fascia was closed with interrupted polyglactin 910 sutures in 84 of 85 patients of the polyglactin group; in one patient the technique was not documented. In the polydioxanone group, 10 of 19 patients received a continuous polydioxanone suture alone and 7 a continuous polydioxanone suture reinforced with additional interrupted polyglactin 910 sutures, placed as figure-of-eight sutures in 2 of them; 2 patients received an interrupted polydioxanone closure, one of them with additional polyglactin 910 sutures. Reinforcing sutures were thus used in 8 of 19 patients of the polydioxanone group and in none of the polyglactin group. The fascial suture was USP 1 in most patients (71 of 85 in the polyglactin and 17 of 19 in the polydioxanone group); USP 0 was used in 3 patients of the polyglactin group and USP 2 in 2 patients of the polydioxanone group, and the caliber was not documented in 11 patients of the polyglactin group. Stitch interval, distance from the wound edge and suture-to-wound-length ratio were not documented in any operative report and can only be inferred from the departmental standard. No mesh was used. Negative-pressure wound therapy was applied after repair in 13 of 85 patients (15.3%) of the polyglactin group and in none of the polydioxanone group ($p = 0.12$). The characteristics of the repair are summarized in Table 3.

Incidence of incisional hernia after burst abdomen

During the study period, different fascial closure strategies were used for surgical treatment of burst abdomen. Of the 104 patients included in the final analysis, 85 patients underwent closure with polyglactin 910, interrupted in all patients with documented technique, whereas 19 patients were treated with polydioxanone predominantly as a continuous suture (8 of them with additional interrupted polyglactin 910 sutures). Because suture material and technique changed together, the following comparison reflects two closure strategies rather than two suture materials and is exploratory. Baseline characteristics were largely comparable between the two groups, with the exception of liver disease, which was significantly more frequent in the polydioxanone group (52.6% versus 20.0%, $p = 0.007$). This imbalance parallels the higher proportion of hepatobiliary and pancreatic index procedures in the polydioxanone group (42.1% versus 24.7%). Although polydioxanone was used more often in the second half of the study period (13 of 44 repairs in 2021–2024 versus 6 of 60 in 2017–2020), the case mix did not change over time (liver disease 25.0% versus 26.7%; hepatobiliary and pancreatic index procedures 27.3% versus 28.3%). Within 2021–2024, however, liver disease remained more frequent after polydioxanone closure (7 of 13 versus 4 of 31 patients, $p = 0.008$), indicating that the imbalance reflects the selection of the closure strategy rather than a change in the patient population over time. Confounding by indication therefore cannot be excluded. Mean age was similar in the polyglactin and polydioxanone groups, with 67.3 and 67.7 years, respectively. No other statistically significant differences were observed between the two closure groups regarding major baseline variables. Median follow-up was 18.1 months. In the final cohort, 31 of 104 patients developed an incisional hernia, whereas 73 patients had no evidence of incisional hernia during follow-up. Because follow-up differed substantially between patients, the crude proportion underestimates the true event rate: the cumulative incidence of incisional hernia was 26.3% at 12 months, 39.6% at 24 months and 45.1% at 36 months (Figure 2A). During follow-up, 15 of the 73 patients without incisional hernia died; when death was treated as a competing event, the cumulative incidence of incisional hernia was 24.0%, 34.7% and 38.9% at 12, 24 and 36 months (Figure 3). Beyond 36 months only 15 patients remained at risk, and estimates thereafter should be regarded as exploratory. As shown in Figure 1, diagnosis of incisional hernia was established predominantly by CT scan (27/31), followed by clinical examination (3/31) and ultrasound (1/31). Among patients without incisional hernia, hernia exclusion during follow-up was based on CT scan in 57 patients, MRI in 5 patients, ultrasound in 4 patients, and clinical examination in 7 patients (Figure 1). Incisional hernia occurred in 25 of 85 patients in the polyglactin group and in 6 of 19 patients in the polydioxanone group. Median follow-up was shorter in the polydioxanone group than in the polyglactin group (13.1 versus 19.0 months). In time-to-event analysis, the cumulative incidence at 12 months was 25.4% (95% CI 16.3%–38.3%) and at 24 months 37.5% (95% CI 25.7%–52.4%) after polyglactin and 30.9% (95% CI 12.5%–64.1%) and 50.6% (95% CI 26.0%–80.9%) after polydioxanone closure, without a statistically significant difference between groups (hazard ratio 1.21, 95% CI 0.49–2.97, $p = 0.68$; Figure 2B). At 12 months, 16 incisional hernias had been diagnosed in the polyglactin group, with 40 patients still at risk, and 4 in the polydioxanone group, with 7 at risk; at 24 months, the corresponding numbers were 21 (22 at risk) and 6 (4 at risk). No hernia occurred in the polydioxanone group after month 15, when only four patients remained at risk, so that the course of this curve beyond 15 months should not be interpreted. Hernia incidence did not differ between repairs performed in 2017–2020 and in 2021–2024 (hazard ratio 1.37, 95% CI 0.63–2.98), but median follow-up was considerably shorter in the later period (9.6 versus 26.7 months). Within 2021–2024, median follow-up was similar after polyglactin and polydioxanone closure (8.9 versus 9.8 months), and the imaging modality used to diagnose or exclude incisional hernia was similar in both periods (computed tomography in 50 of 60 versus 34 of 44 patients, $p = 0.46$). Recurrent burst abdomen occurred in 10 of 104 patients. Recurrent burst abdomen was observed more frequently after polydioxanone than after polyglactin 910 closure (5 of 19, 26.3%, versus 5 of 85, 5.9%; $p = 0.02$), although the absolute number of events was low. In a *post hoc* subgroup analysis, all five recurrences in the polydioxanone group occurred after a continuous polydioxanone suture without reinforcing sutures (5 of

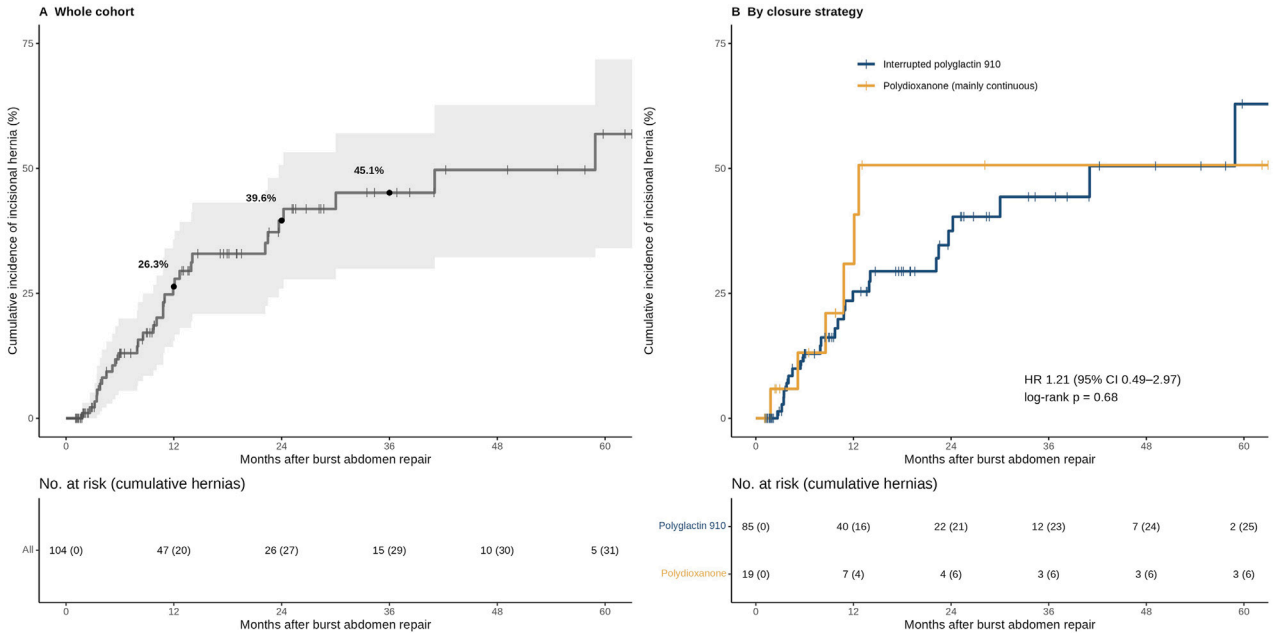


FIGURE 2
Cumulative incidence of incisional hernia after surgical repair of burst abdomen, estimated using the Kaplan-Meier method. **(A)** Whole cohort; the shaded area indicates the 95% confidence interval, vertical marks indicate censored observations, and percentages indicate the cumulative incidence at 12, 24 and 36 months. **(B)** Stratified by closure strategy (interrupted polyglactin 910 versus predominantly continuous polydioxanone), compared using the log-rank test. The hazard ratio for polydioxanone versus polyglactin 910 closure is given with its 95% confidence interval. Numbers at risk, with the cumulative number of incisional hernias in parentheses, are given below each panel. Beyond 36 months fewer than 16 patients remained at risk, and estimates thereafter should be interpreted as exploratory; in the polydioxanone group, only four patients remained at risk after month 15.

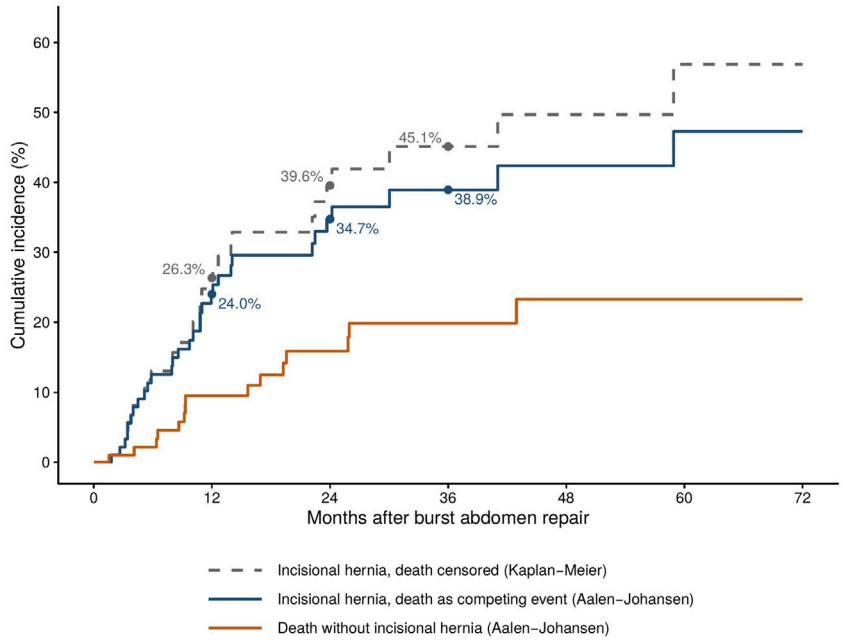


FIGURE 3
Cumulative incidence of incisional hernia after surgical repair of burst abdomen with and without death as a competing event. The dashed gray line shows the Kaplan–Meier estimate, in which patients who died were censored at their last examination (primary analysis). The solid blue line shows the Aalen–Johansen estimate, in which death without a preceding incisional hernia was treated as a competing event, and the orange line shows the cumulative incidence of death without incisional hernia. Values indicate the cumulative incidence of incisional hernia at 12, 24 and 36 months (Kaplan–Meier 26.3%, 39.6% and 45.1%; Aalen–Johansen 24.0%, 34.7% and 38.9%). Fewer than 16 patients remained at risk beyond 36 months.

11 patients without versus 0 of 8 with reinforcing sutures, p = 0.045, Table 3). Because reinforcing sutures were placed at the surgeon's discretion, this comparison is hypothesis-generating only.

Surgical site infection

Overall, any surgical site infection was documented in 39 of 104 patients (37.5%). Classified according to the deepest tissue level involved, it was superficial incisional in 3, deep incisional in 24 and organ/space in 12 patients. Superficial and deep incisional infections were distributed similarly between patients with and without subsequent incisional hernia (0% versus 4.1%, p = 0.55, and 19.4% versus 24.7%, p = 0.62, respectively). Organ/space infection, in contrast, was documented in 12 of 73 patients without incisional hernia (16.4%) and in none of the 31 patients who developed an incisional hernia (p = 0.02). Consequently, any surgical site infection was less frequent among patients with incisional hernia than among those without (6 of 31, 19.4%, versus 33 of 73, 45.2%; p = 0.02), a difference driven largely by the absence of organ/space infections in the hernia group. Because organ/space infection did not occur in any patient with an incisional hernia, the resulting complete separation precluded its inclusion in the multivariable model. Similarly, (dirty) contamination at repair was less frequent in patients who developed an incisional hernia (10.0% versus 32.9%, p = 0.02). To account for differences in follow-up time and for death as a competing event, the associations were further examined with Cox regression and Fine–Gray models. In the Cox model, surgical site infection remained associated with a lower risk of incisional hernia (hazard ratio 0.38, 95% CI 0.16–0.93), whereas (dirty) contamination at repair was not significantly associated with incisional hernia (hazard ratio 0.39, 95% CI 0.12–1.28). Death without incisional hernia was not more frequent after surgical site infection (5 of 39 versus 10 of 65 patients), and the Fine–Gray estimates were almost identical to the Cox estimates (surgical site infection: subdistribution hazard ratio 0.38, 95% CI 0.16–0.92; (dirty) contamination: subdistribution hazard ratio 0.35, 95% CI 0.11–1.17). Patients with surgical site infection were, however, younger than those without (mean 62.8 versus 70.2 years, p = 0.01), and after adjustment for age the association was attenuated and no longer significant (hazard ratio 0.53, 95% CI 0.21–1.36; subdistribution hazard ratio 0.52, 95% CI 0.19–1.47). Median follow-up was shorter for patients after surgical site infection (17.2 versus 22.6 months) and, more markedly, with (dirty) contamination at repair (10.9 versus 23.6 months), whereas the imaging modality used to diagnose or exclude incisional hernia did not differ (computed tomography in 31 of 39 versus 53 of 65 patients with and without surgical site infection). Intraoperative cultures obtained at repair yielded growth in 84 of 100 patients (84.0%) with a predominantly enteric spectrum; no pathogen or pathogen group was associated with subsequent incisional hernia formation (Supplementary Figure S1).

Risk factors for incisional hernia

Patients who developed an incisional hernia were older than patients without hernia (72.6 ± 11.9 versus 65.2 ± 13.6 years, p = 0.01). Among baseline comorbidities, neurological disease was more common in patients who developed a hernia (32.3% versus 13.7%, p = 0.05). Atrial fibrillation was significantly associated with subsequent hernia formation (29.0% versus 9.6%, p = 0.02). Complete dehiscence was more frequent (37.9% versus 18.6%, p = 0.07) and intact skin less frequent (50.0% versus 68.6%, p = 0.11) without reaching statistical significance. No other baseline, treatment or dehiscence-related variable was associated with incisional hernia development (Table 4). Body mass index, smoking status, alcohol consumption, malignancy, diabetes mellitus, hypertension, pulmonary disease, liver disease, renal disease, previous abdominal surgery, preoperative anemia, intensive care unit stay, and number of relaparotomies were not significantly associated with incisional hernia development. Age and body mass index have been described as important risk factors for incisional hernia [18–20] and were therefore included in the multivariable model. To account for changes in perioperative management, surveillance intensity and imaging practice over time, we also added the calendar period of repair (2017–2020 versus 2021–2024). This is particularly relevant for the comparison of closure strategies, because polydioxanone was used mainly in 2021–2024. In the multivariable Cox model including age, body mass index and calendar period of repair (104 patients, 31 incisional hernias), increasing age was associated with incisional hernia (hazard ratio 1.05 per year, 95% CI 1.02–1.08, p = 0.003), corresponding to an approximately 1.6-fold increase in hazard per decade of age. Body mass index (hazard ratio 1.07 per kg/m^2, 95% CI 0.98–1.17, p = 0.11) and repair in 2021–2024 compared with 2017–2020 (hazard ratio 1.66, 95% CI 0.74–3.75, p = 0.22) were not significantly associated with incisional hernia. The effect of age was not constant over time (scaled Schoenfeld residuals, p = 0.026). When estimated separately, the hazard ratio for age was 1.04 per year (95% CI 1.00–1.07, p = 0.06) during the first 12 months after repair and 1.09 (95% CI 1.02–1.18, p = 0.014) thereafter. With death treated as a competing event, the subdistribution hazard ratio for age was 1.05 (95% CI 1.01–1.08, p = 0.004). In the sensitivity analysis with the variables associated with incisional hernia in univariable comparison (age, atrial fibrillation, neurological disease and (dirty) contamination at repair; 100 patients), the hazard ratio for age was 1.04 (95% CI 1.01–1.08, p = 0.025), whereas none of the other variables was significantly associated. Surgical site infection of organ/space was not included in the model because no patient with an incisional hernia had an organ/space infection, which precludes estimation of the corresponding coefficient. Patient and treatment characteristics can be found in Table 4.

Discussion

The present study evaluated the incidence of incisional hernia following surgical repair of burst abdomen and explored different fascial closure strategies in a contemporary cohort. The main findings were that the cumulative incidence of incisional hernia reached 39.6% at two years and 45.1% at three years (34.7% and 38.9% when death was treated as a competing event), that hernia incidence did not differ significantly between interrupted

TABLE 4 Patient and treatment characteristics according to incisional hernia formation.

Characteristic	All, n = 104	No hernia, n = 73	Hernia, n = 31	p-value
Baseline characteristics				
Age, years, mean (SD)	67.4 (13.5)	65.2 (13.6)	72.6 (11.9)	0.01m
Sex, n (%)				0.77x
Male	82 (78.8)	57 (78.1)	25 (80.6)	
Female	22 (21.2)	16 (21.9)	6 (19.4)	
BMI, kg/m2, mean (SD)	25.6 (4.6)	25.3 (5.0)	26.4 (3.5)	0.12m
Preoperative hemoglobin, g/dL, mean (SD)	12.1 (2.1)	12.1 (2.1)	12.0 (2.1)	0.75m
Smoking, n (%)	27/103 (26.2)	20 (27.4)	7/30 (23.3)	0.81f
Alcohol, n (%)	29/103 (28.2)	20 (27.4)	9/30 (30.0)	0.81f
Malignancy, n (%)	58 (55.8)	43 (58.9)	15 (48.4)	0.39f
Diabetes mellitus, n (%)	19 (18.3)	13 (17.8)	6 (19.4)	1.00f
Thyroid disease, n (%)	25 (24.0)	18 (24.7)	7 (22.6)	1.00f
Neurological disease, n (%)	20 (19.2)	10 (13.7)	10 (32.3)	0.05f
Arterial hypertension, n (%)	66/103 (64.1)	43/72 (59.7)	23 (74.2)	0.19f
Atrial fibrillation, n (%)	16 (15.4)	7 (9.6)	9 (29.0)	0.02f
Pulmonary disease, n (%)	26 (25.0)	16 (21.9)	10 (32.3)	0.32f
Liver disease, n (%)	27 (26.0)	19 (26.0)	8 (25.8)	1.00f
Renal disease, n (%)	21 (20.2)	15 (20.5)	6 (19.4)	1.00f
Previous abdominal surgery, n (%)	62 (59.6)	44 (60.3)	18 (58.1)	0.83f
Preoperative anemia, n (%)	80 (76.9)	57 (78.1)	23 (74.2)	0.80f
ASA score, n (%)				0.70x
1	2 (1.9)	2 (2.7)	0 (0.0)	
2	24 (23.1)	18 (24.7)	6 (19.4)	
3	74 (71.2)	50 (68.5)	24 (77.4)	
4	4 (3.8)	3 (4.1)	1 (3.2)	
Characteristics of the index operation				
Surgical setting, n (%)				0.92x
Elective	63 (60.6)	44 (60.3)	19 (61.3)	
Emergency	41 (39.4)	29 (39.7)	12 (38.7)	
Surgical field, n (%)				0.50x
HPB	29 (27.9)	20 (27.4)	9 (29.0)	
Upper GI	8 (7.7)	8 (11.0)	0 (0.0)	
GI	55 (52.9)	36 (49.3)	19 (61.3)	
Sarcoma	1 (1.0)	1 (1.4)	0 (0.0)	
Transplantation	3 (2.9)	2 (2.7)	1 (3.2)	
Peritoneal carcinomatosis	6 (5.8)	5 (6.8)	1 (3.2)	
Other	2 (1.9)	1 (1.4)	1 (3.2)	
Degree of contamination, n (%)				0.31x

(*Continued*)

TABLE 4 Continued

Characteristic	All, n = 104	No hernia, n = 73	Hernia, n = 31	p-value
Aseptic	29 (27.9)	22 (30.1)	7 (22.6)	
Clean-contaminated	59 (56.7)	38 (52.1)	21 (67.7)	
Contaminated	16 (15.4)	13 (17.8)	3 (9.7)	
VAC therapy after index surgery, n (%)	12 (11.5)	7 (9.6)	5 (16.1)	0.34f
Continuous polydioxanone fascial closure at index operation, n (%)	96 (92.3)	68 (93.2)	28 (90.3)	0.69f
Characteristics of the burst abdomen				
Days from index operation to repair, median (IQR)	9 (6–13) [n = 103]	9 (7–13)	9 (6–15) [n = 30]	0.79m
Complete dehiscence, n (%)	24/99 (24.2)	13/70 (18.6)	11/29 (37.9)	0.07f
Skin intact (covered dehiscence), n (%)	63/100 (63.0)	48/70 (68.6)	15/30 (50.0)	0.11f
(Dirty) contamination at repair, n (%)	26/100 (26.0)	23/70 (32.9)	3/30 (10.0)	**0.02f**
Clinical infection at repair, n (%)	18/99 (18.2)	15/70 (21.4)	3/29 (10.3)	0.26f
Outcomes				
ICU stay, days, median (IQR)	1 (0–3)	1 (0–3)	1 (0–3)	0.48m
SSI superficial, n (%)	3 (2.9)	3 (4.1)	0 (0)	0.55f
SSI deep, n (%)	24 (23.1)	18 (24.7)	6 (19.4)	0.62f
SSI organ/space, n (%)	12 (11.5)	12 (16.4)	0 (0)	**0.02f**
SSI, any, n (%)	39 (37.5)	33 (45.2)	6 (19.4)	**0.02f**
Recurrent burst abdomen, n (%)	10 (9.6)	5 (6.8)	5 (16.1)	0.16f
Relaparotomies, median (IQR), including burst abdomen repair	1 (1–2)	1 (1–2)	1 (1–2)	0.78m

BMI, body mass index; ASA, American Society of Anesthesiologists; HPB, hepato-biliary-pancreatic; GI, gastrointestinal; VAC, vacuum-assisted closure; SSI, surgical site infection; ICU, intensive care unit; IQR, interquartile range; Percentages are calculated from patients with available data. Where data were missing, the denominator is shown explicitly as n/N for categorical variables and as [n =] for continuous variables. Missing values: smoking n = 1, alcohol n = 1, arterial hypertension n = 1, interval from index operation to repair n = 1, extent of dehiscence n = 5, condition of the skin n = 4, (dirty) contamination at repair n = 4, clinical infection at repair n = 5; f = Fisher's exact test; x = Pearson chi-square test; m = Mann-Whitney U test. Bold values indicate statistical significance ($p < 0.05$).

polyglactin 910 and predominantly continuous polydioxanone closure, and that increasing age was associated with incisional hernia formation.

The cumulative incidence of incisional hernia observed in the present study exceeds most previous reports once the variable duration of follow-up is accounted for. The crude proportion of 29.8% is comparable with published figures, but it reflects a median follow-up of only 18.1 months and therefore substantially underestimates long-term risk. Fink et al. demonstrated in pooled data from two prospective trials that the incisional hernia rate after midline laparotomy rose from 12.6% at 1 year to 22.4% at 3 years, a relative increase of more than 60%, and concluded that a minimum of 3 years of follow-up is mandatory in any study reporting incisional hernia. The time-to-event approach used here is therefore preferable to the crude proportions reported in much of the burst abdomen literature [21]. Gislason et al. reported high rates of incisional hernia following burst abdomen irrespective of the closure technique used, while Jensen et al. demonstrated that approximately one-third of patients developed an incisional hernia despite a standardized mass-closure technique using slowly absorbable running sutures [5, 15]. Likewise, van Ramshorst et al. confirmed that abdominal wound dehiscence remains one of the strongest risk factors for subsequent incisional hernia during long-term follow-up. These findings suggest that the burst abdomen itself is a major determinant of long-term abdominal wall integrity [6].

One of the objectives of the present study was to compare the two closure strategies used in our department, interrupted closure with rapidly absorbable polyglactin 910 and predominantly continuous closure with slowly absorbable polydioxanone. Because suture material and technique changed together, any difference, or its absence, cannot be attributed to the suture material alone. No significant difference in incisional hernia formation was observed between both groups, either in crude proportions or in time-to-event analysis. Given the small number of patients treated with polydioxanone, the available data nevertheless cannot exclude a clinically relevant difference in either direction. At first sight, this finding contrasts with studies investigating primary laparotomy closure, in which slowly absorbable monofilament sutures and standardized continuous closure techniques have been associated with lower incisional hernia rates and are therefore recommended by the current European and American Hernia Society guidelines [1, 7–11, 13].

The contemporary evidence on abdominal wall closure identifies the suture technique, with small tissue bites and a suture-to-wound-length ratio of at least 4:1, rather than the suture material alone, as the main modifiable determinant of fascial healing [8]. In the STITCH trial, small bites reduced incisional hernia at 1 year from 21% to 13% (p = 0.0220, covariate adjusted odds ratio 0.52, 95% CI 0.31–0.87; p = 0.0131) [12]. In the ESTOIH trial, the short-stitch technique reduced burst abdomen from 4.76% to 1.40%; the unadjusted comparison was borderline (odds ratio 0.2830, p = 0.0513), but the prespecified Cox model showed a significant reduction (hazard ratio 0.1783, 95% CI 0.0427–0.7435, p = 0.0179) [13]. After 1 year, the combined endpoint of burst abdomen or incisional hernia was reached by 4.8% versus 11.3% of patients (p = 0.018), whereas incisional hernia alone did not differ significantly after one (3.3% versus 6.4%, odds ratio 1.97, 95% CI 0.77–5.05; p = 0.173) or 5 years (9.1% versus 13.9%, odds ratio 1.60, 95% CI 0.82-3.10; p = 0.155) [22, 23]. The recent SUBITE meta-analysis confirms fewer incisional hernias with small bites (odds ratio 0.47, 95% CI 0.38–0.58; p < 0.00001; I^2 = 11%). Linea alba dehiscence was less frequent after small bites (49 versus 127 events in nine studies; odds ratio 0.58, 95% CI 0.42–0.82, p = 0.002), although the difference was not significant when the five randomized trials were analyzed alone (p = 0.25) [14].

An earlier meta-analysis showed a significant reduction of incisional hernia for retention sutures and small bites (pooled ORs 0.28 95% CI 0.13–0.62 and 0.44 95% CI 0.31–0.62) [24].

This trend was also shown by another meta-analysis. Small bites showed significantly lower rates of incisional ventral hernia in subgroup analysis on elective procedures (odds ratio 0.58, 95% CI 0.37–0.92, p = 0.02). However, there was no significant reduction in burst abdomen (odds ratio 0.71, 95% CI 0.10–4.95, p = 0.73) [20].

Whether these findings extend to emergency surgery is less certain. The 2023 WSES guideline on the closure of emergency laparotomy suggests continuous small-bites closure with slowly absorbable sutures and recommends monofilament material and a suture-to-wound-length ratio of at least 4:1, but acknowledges that the evidence for small bites derives mainly from elective surgery [25]. After implementation of a standardized continuous mass closure with small steps in emergency laparotomy, dehiscence decreased from 6.6% to 3.8% (p = 0.03) and incisional hernia from 27.0% to 15.0% (p = 0.02) compared with historical controls [26, 27]. Randomized trials comparing interrupted with continuous closure after emergency laparotomy favor interrupted sutures for early fascial failure: In a meta-analysis of 25 trials with 3,548 patients, interrupted closure roughly halved wound dehiscence (risk ratio 0.47, 95% CI 0.38-0.57, p < 0.001) without affecting incisional hernia (risk ratio 0.83, 95% CI 0.57–1.22, p = 0.34), although many included trials had moderate to high risk of bias and were heterogeneous regarding suture material [28]. The German CONTINT trial, which compared the two strategies used in the present cohort (interrupted rapidly absorbable versus continuous slowly absorbable sutures) after emergency laparotomy for a septic focus, found no difference in burst abdomen or incisional hernia and was stopped for futility [29]. Mehdorn et al. reported in a single-center cohort of 111 patients with burst abdomen that interrupted fascial sutures, combined with intraperitoneal mesh augmentation, reduced burst abdomen recurrence and the need for further revision surgery (odds ratio 0.14, 95% CI 0.03–0.78) [30], while Jensen et al. found that a standardized primary repair protocol reduced the rate of fascial redehiscence [15].

None of these trials included patients undergoing repair of an established burst abdomen, in whom edema, contamination and loss of fascial substance may limit the applicability of small bites [3, 6, 16]. For this setting, the EHS guideline identified only four observational studies. In a pooled analysis incisional hernia occurred in 33.6% of patients after both continuous (95% CI 19.3%–49.7%) and interrupted closure (95% CI 25.1%–42.6%). The EHS guideline states: “as a clinical expertise guidance continuous monofilament sutures following a SL:WL [suture length to wound length] ratio of at least 4:1 should be used to close a BA [burst abdomen]” [31]. According to the guideline, clinical expertise guidance is distinct from recommendations graded with the GRADE methodology and is given where published evidence is absent or insufficient to justify a formal recommendation. The quality of the underlying evidence was rated as very low [31, 32]. In a recent prospective series, continuous mass closure used 2–3 cm bites with a median suture-to-wound-length ratio of 15:1 [33] and a similar closure was followed by incisional hernia in 33% of patients after a median of 17 months [15]. This crude proportion corresponds to the pooled estimate of the guideline (33.6%), whereas the cumulative incidence of 45.1% at 3 years in the present cohort, irrespective of the closure strategy, lies within the higher range of 40%–60% that the guideline cites from earlier series [31, 34, 35]. Recent case-series data indicate that mesh reinforcement at the time of burst abdomen repair is feasible and safe in selected patients, although long-term hernia-prevention data in this specific setting are still lacking [36]. Because bite size and suture-to-wound-length ratio were not documented in our operative reports and can only be inferred from internal standards at that time, our data cannot test the guideline statements, and none of the available trials answers how a burst abdomen should be closed.

Recurrent burst abdomen occurred significantly more often in the polydioxanone group. In a post-hoc subgroup analysis, all five recurrences in this group occurred after a continuous polydioxanone suture without reinforcing sutures, whereas none occurred among the eight patients whose closure was reinforced with additional interrupted sutures. Our findings still should be interpreted cautiously and only hypothesis-generating because only ten recurrent dehiscence events occurred in the entire cohort and only nineteen patients underwent a polydioxanone closure. Moreover, the departmental closure strategy changed during the study period, and polydioxanone was increasingly adopted in later years. Therefore, selection bias and confounding by indication cannot be excluded, and the observed difference should not be interpreted as evidence that polydioxanone increases the risk of recurrent fascial dehiscence.

A further consideration is that all repairs in this cohort were performed with sutures alone. For mesh reinforcement during burst abdomen repair, the EHS guideline pooled four observational studies, in which the proportion of incisional hernia was 32.9% (95% CI 24%–42.4%, I^2 = 44.9%) after suture closure alone and 12.5% (95% CI 4.9%–23.1%, I^2 = 61.8%) after additional mesh reinforcement, whereas surgical site occurrences, reported in two

of these studies, were more frequent with mesh (48.8%, 95% CI 12.05%–86.4%, I^2 = 91.0%) than without (23.5%, 95% CI 13.3%–35.5%, I^2 = 0%). The EHS guideline states: "as a good practice statement mesh reinforcement should be used whenever fascial closure is possible. Mesh is related to an increased incidence of SSO [surgical site occurrence]. The decision to use a mesh, the type of mesh used and the location of the mesh should be considered by the surgeon" [31]. Like the statement on suture closure, this good practice statement is not a recommendation graded with GRADE, and the quality of the underlying evidence was rated as very low [31, 32]. For prophylactic mesh after emergency laparotomy, the evidence is conflicting. In one randomized trial, onlay mesh reduced fascial dehiscence after emergency laparotomy [37], and a meta-analysis of randomized trials reported fewer incisional hernias with prophylactic mesh also in its small emergency subgroup, but no reduction of wound dehiscence across all settings [38]. Another meta-analysis restricted to emergency laparotomy likewise favored mesh, but it was based on two non-randomized studies that its authors considered biased by confounding [39]. In contrast, a recent randomized trial found no reduction of incisional hernia with retrorectus mesh compared with small-stitch closure 2 years after emergency midline laparotomy, and mesh-related complications occurred in 9% of patients in the mesh group. However, the trial was terminated early because of slow recruitment, and its authors state that definitive conclusions cannot be drawn [40]. Given the cumulative incidence of 45.1% at 3 years observed here, a suture-only strategy may be insufficient in this population. The multicenter randomized HULC trial is running to answer this question for elective midline laparotomy in the era of small stitch abdominal wall closure [41].

Age was associated with incisional hernia in the multivariable analysis, and its hazard ratio was similar in all model specifications. Its effect was, however, not constant over time and was mainly apparent after the first year. Although atrial fibrillation and neurological disease were associated with hernia formation in the univariable analysis, these associations disappeared after multivariable adjustment, suggesting that they mainly reflect the higher burden of comorbidity in elderly patients. Previous studies have consistently identified advanced age as an important risk factor for impaired wound healing and incisional hernia formation because of reduced collagen synthesis, impaired tissue regeneration and diminished abdominal wall strength. Our findings are therefore in accordance with the existing literature [42–45].

An unexpected finding was the inverse association between overall surgical site infection and subsequent incisional hernia. Patients without incisional hernia had a higher documented rate of surgical site infection than those who later developed a hernia. This finding contrasts with the existing literature, in which surgical site infection has consistently been identified as one of the strongest risk factors for fascial dehiscence and subsequent incisional hernia formation [17, 46, 47]. The same pattern was seen for a contaminated or dirty-infected wound at the time of repair. Competing mortality does not explain these associations in our data: patients with surgical site infection did not die more often without a hernia, and the Fine–Gray estimates were almost identical to those of the Cox model. Patients with surgical site infection were, however, considerably younger, and the association was attenuated and no longer significant after adjustment for age. In addition, follow-up was shorter after surgical site infection and, more markedly, after a contaminated or dirty-infected wound at repair, which reduces the opportunity to detect a hernia. Confounding by age, differences in surveillance and chance are therefore the most plausible explanations, and this finding should not be considered evidence of a protective effect of surgical site infection. No specific microorganism was associated with subsequent incisional hernia formation in the present study. This extends earlier work that examined whether abdominal fascial dehiscence is associated with a distinct microbial spectrum, and suggests that the overall inflammatory response and impairment of fascial healing may be more important determinants of long-term abdominal wall integrity than the presence of a particular pathogen [3, 6, 7].

The present study has several limitations. It is limited by its retrospective design, the relatively small sample size and the unequal distribution between treatment groups, including a significantly higher prevalence of liver disease and of hepatobiliary and pancreatic index procedures in the polydioxanone group, which indicates selection of patients for this closure strategy. Confounding by indication therefore cannot be excluded. Because polydioxanone was used mainly in 2021–2024, the comparison may also be confounded by changes in perioperative management, surveillance and imaging over time, which adjustment for calendar period cannot fully remove, particularly as follow-up was considerably shorter in the later period. Importantly, suture material and suture technique were not varied independently: Polyglactin was predominantly used in an interrupted and polydioxanone in a continuous fashion, so that the respective contributions of material and technique to the observed outcomes cannot be separated in this cohort. Bite size, stitch interval and suture-to-wound-length ratio were not documented in the operative reports and could not be reconstructed, although they are considered the main modifiable determinants of fascial healing. Furthermore, a considerable number of patients was lost to long-term follow-up, introducing the possibility of selection bias. The limited number of incisional hernia events reduced the statistical power of the multivariable analysis and the effect of age was not constant over time (scaled Schoenfeld residuals, p = 0.026): it was weak during the first year and more pronounced thereafter, so the hazard ratio for age represents an average over the follow-up period. Follow-up was heterogeneous and predominantly based on imaging performed for other clinical indications, so that hernia detection was effectively interval-censored and dependent on surveillance intensity. Finally, in a cohort with this burden of comorbidity, death precludes rather than delays hernia formation. With death treated as a competing event, the cumulative incidence at 36 months was 38.9% instead of 45.1%, so the Kaplan–Meier estimate should be regarded as an upper estimate of the true risk.

Conclusion

Patients undergoing surgical repair of burst abdomen remain at high risk of incisional hernia, with a cumulative incidence of 45.1% at 3 years (38.9% when death was treated as a competing event). No difference in hernia incidence was observed between the two closure

strategies, but the small polydioxanone group and the confounding of suture material and technique preclude conclusions on the optimal closure. Increasing age was associated with incisional hernia. Prospective multicenter studies with a standardized and documented closure technique, including the evaluation of mesh reinforcement, are needed to define the optimal closure strategy in this high-risk population.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The datasets are not publicly available due to restrictions related to patient privacy and the terms of the ethics approval. Anonymised data are available from the corresponding author on reasonable request. Requests to access these datasets should be directed to MI, mohammed.ibrahim@med.uni-tuebingen.de.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the Medical Faculty of the Eberhard Karls University and at the University Hospital Tübingen. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because the analysis was performed exclusively on existing medical data in a retrospective manner.

Author contributions

All authors contributed to the study conception and design. Data collection was performed by MI, GZ, PR, and JN. Radiological assessment of imaging studies was performed by JB. Statistical analysis was performed by MI and SS. The first draft of the manuscript was written by MI and JN, and CY and AM critically revised the manuscript for important intellectual content. The study was supervised by JN, AM, and CY. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. During the preparation of this work, the authors used Claude (Anthropic) to improve the language and readability of the manuscript and to assist with statistical programming in R and Python. The authors reviewed and verified all output, independently checked all statistical results, and take full responsibility for the content of the publication.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/jaws.2026.17799/full#supplementary-material

SUPPLEMENTARY FIGURE S1
Microbiological spectrum of intraoperative cultures obtained during burst abdomen repair, stratified by subsequent incisional hernia formation. **(A)** Pathogen groups; patients with more than one isolate belonging to the same group are counted once. **(B)** Individual species detected in at least three patients. Bars show the proportion of patients with a positive intraoperative culture, with absolute numbers in parentheses. Denominators are patients with a positive culture who did not (n = 61) and did (n = 23) develop an incisional hernia; intraoperative cultures were obtained in 100 of 104 patients and yielded growth in 84 (84.0%). Vancomycin-resistant *Enterococcus faecium* isolates (n = 2) are reported together with *Enterococcus faecium*. p values are two-sided Fisher's exact tests, presented without adjustment for multiple comparisons; all microbiological comparisons are exploratory.

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