Original Article

INCIDENCE OF INCISIONAL HERNIA AFTER LAPAROTOMY

INCIDÊNCIA DE HÉRNIA INCISIONAL APÓS LAPAROTOMIA

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ABSTRACT

Introduction: Incisional hernia is a common complication following laparotomy. We aim to estimate the incidence of incisional hernia during the 5 years post-laparotomy and, secondarily, to study the risk factors for its development. **Methods:** We performed a retrospective cohort study in patients (age>18 years old) who were submitted to a laparotomy for general surgery procedures, between June 2015 and May 2018, in São João Hospital and University Centre. Variables analyzed, through univariate and multivariate analysis, included patients' characteristics, surgical techniques employed and post-surgery complications. The statistical analysis was carried out with R studio and IBM SPSS version 29.0. **Results:** The cumulative incidence of incisional hernia was 22.7% at 5 years, among the 1134 participants analyzed. In the multivariate analysis, we found that higher body mass index (OR 1.056; p=0.007), superficial (OR 3.001; p=0.024) and organ-space (OR 2.686; p=0.004) surgical site infection and wound dehiscence (OR 4.787; p<0.001) were independently associated with incisional hernia development. In contrast, transverse incision (OR 0.189; p=0.007) and layered closure of the abdominal (OR 0.503; p<0.001) were associated with a lower risk for incisional hernia, compared with midline incision and mass closure, respectively. **Conclusion:** Elevated body mass index, surgical site infection and wound dehiscence seem to present as risk factors for incisional hernia, while the use of transverse incision and employing a layered closure of the abdominal wall are associated with a reduced incisional hernia occurrence. Efforts aimed at optimizing preoperative patients' characteristics, surgical technique and implementation of effective infection prevention measures can play a crucial role in mitigating the high incidence of this complication post-laparotomy.

Keywords: *incisional hernia; incidence; laparotomy; risk factors.*

RESUMO

Introdução: A hérnia incisional é uma complicação comum após laparotomia. O objetivo do estudo é estimar a incidência de hérnia incisional durante os 5 anos pós-laparotomia e, secundariamente, estudar os fatores de risco para o seu desenvolvimento. **Métodos:** Foi realizado um estudo de coorte retrospetivo em pacientes (idade>18 anos) submetidos a laparotomia para procedimentos de cirurgia geral, entre junho de 2015 e maio de 2018, no Centro

Hospitalar e Universitário do São João. As variáveis analisadas, por meio de análise univariada e multivariada, incluíram características dos pacientes, técnicas cirúrgicas utilizadas e complicações pós-cirúrgicas. A análise estatística foi realizada com R studio e IBM SPSS versão 29.0. **Resultados:** A incidência cumulativa de hérnia incisional foi de 22.7% aos 5 anos, entre os 1134 participantes analisados. Na análise multivariada, verificou-se que IMC elevado (OR 1.056; p=0.007), infeção do local cirúrgico superficial (OR 3.001; p=0.024) e espaço-órgão (OR 2.686; p=0.004) e deiscência da ferida (OR 4.787; p<0.001) estiveram independentemente associados ao desenvolvimento de hérnia incisional. Pelo contrário, a incisão transversa (OR 0.189; p=0.007) e o encerramento por planos da parede abdominal (OR 0.503; p<0.001) foram associados a um menor risco de hérnia incisional, em comparação com a incisão mediana e o encerramento em plano único, respetivamente. **Conclusão:** IMC elevado, infeção do local cirúrgico e deiscência da ferida parecem apresentar-se como fatores de risco para hérnia incisional, enquanto o uso da incisão transversa e o encerramento por camadas da parede abdominal estão associados a uma ocorrência reduzida de IH. Esforços destinados a otimizar as características dos pacientes na avaliação pré-operatória, a técnica cirúrgica utilizada e a implementação de medidas eficazes de prevenção de infeções podem desempenhar um papel crucial na mitigação da incidência desta complicação após laparotomia.

Palavras-chave: *hérnia incisional; incidência; laparotomia; fatores de risco.*

INTRODUCTION

Incisional hernia (IH) is a common complication following laparotomy[1]. Depending on the individual risk factors, type of procedure, follow-up period and diagnostic method, the incidence of IH varies between 12.8% (follow-up period of 23,7 months) and 27% (follow-up period of 72 months)[2-4]. Between 3.5% and 5.2% of individuals post-laparotomy are submitted to hernia repair, with the incidence rising to 17% among patients who undergo laparotomy of the digestive tract[1,3,5].

Risk factors for IH are multifactorial[1]. The patient-related factors include age, overweight or obesity – body mass index (BMI)≥25kg/m2 – having a direct proportionality with the increase of the BMI, diabetes, hypertension, chronic obstructive pulmonary disease (COPD), smoking, immunosuppression, increased thickness of preoperative subcutaneous adipose tissue and surgical site infection (SSI)[1,3-10]. Regarding the surgical techniques, the choice of which type of incision[8,11-13], type of closure of the abdominal wall[14-17] and suture material used[14,16,18,19], as well as the use of prophylactic measures in high-risk patients, such as mesh augmentation positioned onlay or retrorectus[20, 21], seems to influence the occurrence of incisional hernia. Additionally, the use of prophylactic negative pressure wound therapy on primary closed incisional wounds (iNPWT) has been associated with a decreased incidence of SSI[22-24] and a consensus article recommended the use of iNPWT in general surgery, under some clinical settings, to reduce the risk of surgical site occurrences[25].

It is important to acknowledge that an IH can impact the quality of life and the physical appearance of the individuals, as well as high direct and indirect costs to the patients and the health system[5,26,27]. Moreover, it can lead to serious consequences, being the most important incarceration and strangulation of the content of the hernia, which is usually an indication for an urgent surgery[28]. Hence, comprehending the epidemiology and identifying risk factors associated with the occurrence of IH is crucial for informed clinical decision-making, patient counselling, and the implementation of preventive measures.

From this observational study, we aim to retrospectively estimate the incidence rate of

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incisional hernia during the 5 years after laparotomy and, secondarily, to study the individual and surgical risk factors of the development of an IH, in a tertiary hospital.

METHODS

Data source and study population

The data in this study were retrospectively collected to a database from the electronic medical records of São João Hospital and University Centre, between September and December of 2023.

Patients (age>18) who had been submitted to a laparotomy for general surgery procedures, between June 1, 2015 and May 31, 2018, were included. Exclusion criteria included laparotomy for abdominal hernia repair. We aimed for a follow-up period of 5 years or until the development of IH. However, participants lost to follow-up by one of the following criteria: the timestamp of the last medical record and no possibility of contacting the patient, a renewed surgery with an overlapping incision or the death of the patient, were also considered to establish the incidence rate of IH after laparotomy. To mitigate the number of patients lost to follow-up, a thorough observation of the last abdominal computed tomography (CT) scans was conducted for individuals lacking medical records regarding the physical examination of the surgical site during the follow-up period. In instances where no abdominal CT scans were available, patients were contacted. Of the 315 patients subjected to contact, 16 self-reported the development of an incisional hernia after surgery, although no proof of that claim could be supported.

Data collection and definitions

The variables extracted from the electronic medical records were sex, age, BMI, comorbidities (diabetes, COPD and immunosuppression), previous abdominal surgeries, elective or urgent and oncologic or non-oncologic surgery, date of the laparotomy, type of surgery, degree of contamination of the surgical site, type of incision, type of closure of the abdominal wall, suture material, surgical site infection (superficial, deep and organ-space), occurrence of wound dehiscence with or without SSI, use of iNPWT and date of diagnosed of the IH.

Compound incisions (midline and transverse) were classified as midline incisions, for simplification purposes although this can introduce some degree of bias. Surgical site infection and dehiscence were considered when occurring within 30 days post-surgery. Wound dehiscence included occurrences with or without infection and dehiscence only the skin or dehiscence of the aponeurotic fascia. The degree of contamination was classified as clean, clean-contaminated, contaminated, and infected according to the Altemeier Classification [29]. Concerning the technique of closure of the abdominal, it was divided into mass closure (suture bite including all layers from the abdominal wall, except for the skin) versus layered closure (separated closure of the peritoneum and the aponeurotic fascia) and continuous versus interrupted suture. Until the end date of this study, the small-bites technique was not used in this tertiary hospital, so it was not considered.

Outcomes of interest

The primary outcome of this study was the estimated incidence of IH laparotomy for general surgery procedures. The secondary outcome was to identify the risk factors for IH development.

Statistical Analysis

The statistical analysis was carried out with R studio and IBM SPSS version 29.0. Categorical variables were compared through the chi-square test, or the Fisher test. A logistic regression was executed to compare continuous variables, defining the significance level with a p-value <0.05. The Kaplan-Meyer method was used to estimate the incidence of incisional hernia. A multivariate analysis was performed with all the variables that were considered statistically significant (p-value <0.05). Furthermore, a model with the variables that better predict the risk of IH was created by conducting an exhaustive search with Monte Carlo simulations, where two-thirds of the participants were used as a sample and one-third were used as a test. Participants with missing data were excluded from the univariate and multivariate analysis in the respective variable.

RESULTS

A total of 2147 patients were submitted to a laparotomy for general surgery procedures over 3 years. 1013 patients were excluded from the study for the following reasons: 182 died during hospitalization, 225 had no follow-up up and 606 were submitted to laparotomy for the repair of a ventral hernia (Fig. 1). Of these, 1134 patients were included and 809 had completed a follow-up period of 5 years or developed the primary outcome. Of these, 215 had developed incisional hernia. The median follow-up time of patients who developed the primary outcome was 0.961 years. Patients' demographics, comorbidities, intraoperative features, and postoperative complications are shown in Table 1.

Within the participants cohort, 623 (54.9%) were male. The median age of the patients included in the study was 63 years, with a corresponding median BMI of 25.03 kg/m^2. Diabetes mellitus was reported in 186 (18.7%), COPD in 43 (3.8%), and immunosuppression in 146 (12.9%). Additionally, a history of one previous abdominal surgery with coincident site incision was identified in 165 cases (14.7%), two in 50 (4.5%), three in 20 (1.8%), four in 6 (0.5%) and five in 4 (0.3%). Data concerning the BMI and history of previous abdominal surgery with coincident site incision were missing in 188 and 12 subjects, respectively.

Oncologic surgery was performed in 589 (51.9%) participants. In relation to the timing of the laparotomy, 780 (68.8%) were elective and 354 (31.2%) were urgent. According to the Altemeier classification, 129 (11.4%) patients were submitted to a laparotomy considered clean, 639 (56.3%) clean-contaminated, 221 (19.5%) contaminated and 145 (12.8%) infected. The type of surgery was

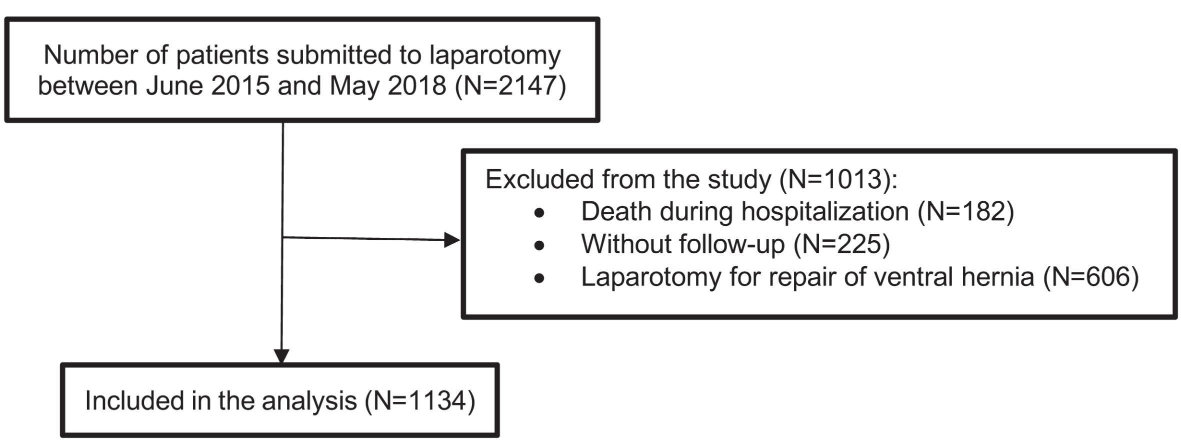

Figure 1 – **Study flowchart of the participants.**

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Table 1 – **Information about the population of the study: demographics, clinical details, and outcome**

Variable	Total (N=1134)	IH (N=215)	No IH – 5 years follow-up (N=594)
Sex:			
• Male	623 (54.9%)	126 (58.6%)	305 (51,3%)
• Female	511 (45.1%)	89 (41.4%)	289 (48,7%)
Age, median, year (IQR)	63 (51 – 72)	64 (55 – 73.50)	59,5 (46-69)
BMI, median, kg/m^2 (IQR) (N=946)	25.03 (22.4 – 28.01)	26.23 (23.30 – 29)	25.41 (22.43 – 28)
Diabetes	186 (18.7%)	49 (22.8%)	95 (16%)
COPD	43 (3.8%)	15 (7%)	14 (2.4%)
Immunosuppression	146 (12.9%)	22 (10.2%)	63 (10.6%)
Previous abdominal surgery with coincident site incision (N=1122):			
• 0	877 (78.2%)	156 (72.6%)	482 (81.7%)
• 1	165 (14.7%)	38 (17.7%)	76 (12.9%)
• 2	50 (4.5%)	14 (6.5%)	21 (3.6%)
• 3	20 (1.8%)	4 (1.9%)	7 (1.2%)
• 4	6 (0.5%)	3 (1.4%)	1 (0.2%)
• 5	4 (0.3%)	0 (0%)	3 (0.5%)
Oncologic surgery	589 (51.9%)	93 (43.1%)	267 (44.9%)
Timing:			
• Urgent	354 (31.2%)	70 (32.6%)	203 (34.9%)
• Elective	780 (68.8%)	145 (67.4%)	391 (65.8%)
Contamination:			
• Clean	129 (11.4%)	21 (9.8%)	69 (11.6%)
• Clean-contaminated	639 (56.3%)	117 (54.4%)	331 (55.7%)
• Contaminated	221 (19.5%)	37 (17.2%)	121 (20.4%)
• Infected	145 (12.8%)	40 (18.6%)	73 (12.3%)
Type of surgery:			
• Ileocecal appendix	120 (10.6%)	7 (3.3%)	97 (16.3%)
• Spleen	33 (2.9%)	0 (0%)	27 (4.6%)
• Colorectal	386 (34%)	79 (36.7%)	177 (29.8%)
• CRS-HIPEC with hollow viscus resection	18 (1.6%)	4 (1.9%)	6 (1%)
• CRS-HIPEC without hollow viscus resection	2 (0.2%)	0 (0%)	2 (0.3%)
• Exploratory surgery and peritoneum	100 (8.8%)	27 (12.6%)	43 (7.2%)
• Esophagus, stomach, and duodenum	142 (12.5%)	18 (8.4%)	85 (14.3%)
• Liver	111 (9.8%)	22 (10.2%)	53 (8.9%)
• Jejunum and ileum	61 (5.4%)	22 (10.2%)	29 (4.9%)
• Pancreas	79 (7%)	22 (10.2%)	36 (6.1%)
• Laparostomy Status	7 (0.6%)	5 (2.3%)	2 (0.3%)
• Adrenal	4 (0.3%)	1 (0.5%)	2 (0.3%)
• Gallbladder and bile ducts	71 (6.3%)	8 (3.7%)	35 (5.9%)
Type of incision (N=1128):			
• Midline	1003 (88.9%)	211 (98.1%)	488 (82.6%)
• Transverse	125 (11.1%)	4 (1.9%)	103 (17.4%)
Type of closure of the abdominal wall (N=1125):			
• Mass closure	387 (34.4%)	100 (46.7%)	168 (28.5%)
• Layered closure	738 (65.1%)	114 (53.3%)	421 (71.5%)
Type of suture:			
• Continuous	1123 (99%)	209 (97.2%)	591 (99.5%)
• Interrupted	99 (1%)	6 (2.8%)	3 (0.5%)
Suture Material (N=1004):			
• Monofilament/Slowly absorbable	781 (77.8%)	169 (89.9%)	369 (70.3%)
• Monofilament/ Nonabsorbable	106 (10.6%)	12 (6.4%)	64 (12.2%)
• Multifilament/Absorbable	115 (11.4%)	7 (3.7%)	90 (17.1%)
• Multifilament/Nonabsorbable	2 (0.2%)	0 (0%)	2 (0.4%)
iNPWT	40 (3.5%)	14 (6.5%)	17 (2.9%)
Re-laparotomies			
• 0	1057 (93.2%)	183 (85.1%)	569 (95.8%)
• 1	64 (5.6%)	27 (12.6%)	19 (3.2%)
• 2	10 (0.9%)	4 (1.9%)	5 (0.8%)
• 3	3 (0.3%)	1 (0.5%)	1 (0.2%)
SSI:			
• Superficial	53 (4.7%)	22 (10.2%)	12 (2%)
• Deep	13 (1.1%)	8 (3.7%)	1 (0.2%)
• Organ-space	82 (7.3%)	29 (13.4%)	30 (5.1%)
• Organ-space/Superficial	3 (0.3%)	2 (0.9%)	1 (0.2%)
• Organ-space/Deep	2 (0.2%)	1 (0.5%)	1 (0.2%)
Wound dehiscence	72 (6.3%)	30 (14%)	20 (3.9%)

Legend: IH: Incisional Hernia; IQR: Interquartile Range; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; CRS-HIPEC: Cytoreductive Surgery and Hyperthermic Intraperitoneal Chemotherapy; iNPWT: Incisional Negative Pressure Wound Therapy; SSI: Surgical Site Infection.

divided into the following 13 categories: ileocecal appendix (n=120; 10.6%), spleen (n=33; 2.9%), colorectal (n=386; 34%), CRS-HIPEC with hollow viscus resection (n=18; 1.6%), CRS-HIPEC without hollow viscus resection (n=2; 0.2%), exploratory surgery and peritoneum (n=100; 8.8%), esophagus, stomach, and duodenum (n=142; 12.5%), liver (n=111; 9.8%), jejunum and ileum (n=61; 5.4%), pancreas (n=79; 7%), laparostomy status (n=7; 0.7%), adrenal (n=3; 0.3%) and gallbladder and bile ducts (n=58; 5.8%). Two incision types and two types of closure of the abdominal wall were employed during surgeries, including midline incision in 1003 (88.9%), transverse incision in 125 (11.1%), mass closure in 387 (34.4%), and layered closure in 651 (65.6%). Continuous suture technique was predominantly used in 1123 (99%) cases, while interrupted suture was chosen in 99 (1%) cases. The type of incision and type of closure of the abdominal wall data were not documented in 6 and 9 patients' records, respectively. Regarding the suture material, four main types were identified: monofilament and slowly absorbable was used in 781 (77.8%) cases, monofilament and nonabsorbable was used in 106 (10.6%) cases, multifilament and absorbable was used in 115 (11.4%) cases and multifilament and nonabsorbable was used in 2 (0.2%) cases. The suture material utilized was lacking in 130 patients' reports. Only in 40 (3.5%) participants, the iNPWT was applied.

Considering the post-surgery complications, 64 (5.6%) patients had one re-laparotomy, 10 (0.9%) patients had two re-laparotomies, and 3 (0.3%) patients had three re-laparotomies. Furthermore, the surgeries executed were accounted for superficial SSI (n=53; 4.7%), deep SSI (n=13; 1.1%), organ-space SSI (n=82; 7.3%), both superficial and organ-space SSI (n=3; 0.3%), deep and organ-space SSI (n=2; 0.2%) and wound dehiscence (n=72; 6.3%).

The estimated incidence of incisional hernia at 1 year was 10.8% (CI95% 0.088 – 0.128), at 2 years was 15.7% (CI95% 0.133 – 0.181), at 3 years was 18.7% (CI95% 0.162 – 0.212), at 4 years was 21.2% (CI95% 0.187 – 0.237) and at 5 years was 22.7% (CI95% 0.200 – 0.254) (Fig. 2).

In the univariate analysis of individual and technical surgical factors (Table 2), some variables emerged as significantly associated with the

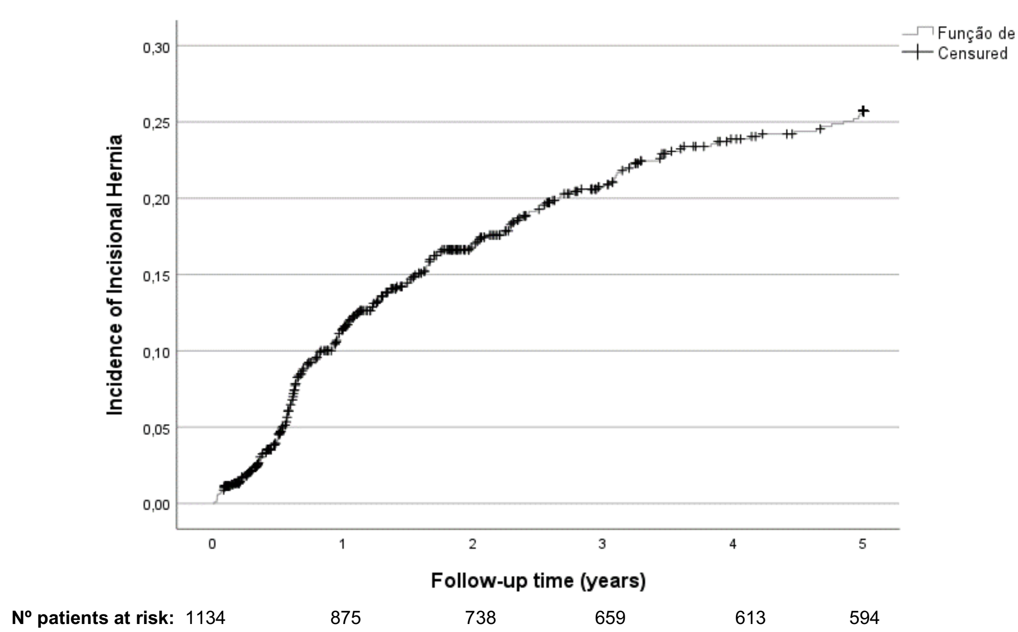

Figure 2 – **Kaplan Meier Curve to estimate the incidence of IH.**

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Table 2 – **Univariate and multivariate analysis of risk factors for IH development at 5 years follow-up**

Variable	Univariate analysis Odds Ratio (CI 95%)	P value	Multivariate analysis Odds Ratio (CI 95%)	P value
Sex				
• Female	Reference		-	-
• Male	1.340 (0.979 – 1.842)	0.068	-	-
Age (for 1 unit increased)	1.026 (1.016 – 1.038)	**<0.001**	1.013 (0.997 – 1.030)	0.118
BMI (for 1 unit increased)	1.060 (1.024 – 1.098)	**0.001**	1.050 (1.007 – 1.094)	**0.025**
Diabetes	1.551 (1.047 – 2.277)	**0.026**	1.100 (0.581 – 1.618)	0.719
COPD	3.100 (1.454 – 6.649)	**0.002**	2.108 (1.148 – 3.069)	0.128
Immunosuppression	0.965 (0.566 – 1.590)	0.878	-	-
Previous abdominal surgery with coincident site incision (for 1 unit increased)	1.303 (1.063 – 1.593)	**0.010**	0.977 (0.664 – 1.290)	0.884
Oncologic surgery	0.934 (0.681 – 1.279)	0.668	-	-
Timing:				
• Elective	Reference		-	-
• Urgent	0.931 (0.665 – 1.294)	0.667	-	-
Contamination:		**0,119**		
• Clean	Reference		-	-
• Clean-contaminated	1.136 (0.676 – 1.979)	0.626	-	-
• Contaminated	1.029 (0.562 – 1.922)	0.919	-	-
• Infected	1.835 (0.992 – 3.468)	0.051	-	-
Type of surgery: * **		**<0,001**		
• Colorectal ****	Reference		Reference	
• Ileocecal appendix	0.162 (0.074 – 0.367)	**<0.001**	1.511(N/A – 3.220)	0.636
• Spleen	Undefined**	**<0.001**	4.881 E-8 (N/A -1566.610)	0.983
• CRS-HIPEC with hollow viscus resection	1.494 (0.502 – 15.456)	0.508*	1.057 (0.948 -1.166)	0.953
• CRS-HIPEC without hollow viscus resection	Undefined**	0.346*	2.506 E-8 (N/A – 4989.769)	0.994
• Exploratory surgery and peritoneum	1.407 (0.839 – 2.697)	0.222	1.543 (0.829 – 2.257)	0.234
• Esophagus, stomach, and duodenum	0.474 (0.278 – 0.855)	**<0.001**	0.733 (0.029 – 1.437)	0.387
• Liver	0.930 (0.551 – 1.732)	0.801	1.316 (0.589 – 2.043)	0.459
• Jejunum and ileum	1.700 (0.958 – 3.673)	0.088	1.388 (0.487 – 2.288)	0.475
• Pancreas	1.369 (0.788 – 2.771)	0.298	1.175 (0.287 – 2.064)	0.722
• Laparostomy Status	5.601 (1.703 – N/A)	**0.036***	3.825 (1.708 – 5.943)	0.214
• Adrenal	1.120 (0.160 – N/A)	1.000*	1.449 E-7 (N/A – 2.118)	0.997
• Gallbladder and bile ducts	0.512 (0.241 – 1.243)	0.102	0.697 (N/A – 1.793)	0.519
Type of incision:				
• Midline	Reference		Reference	
• Transverse	0.093 (0.028 – 0.226)	**<0,001**	0.159 (N/A – 2.203)	0.078
Type of closure of the abdominal wall				
• Mass closure	Reference		Reference	
• Layered closure	0.455 (0.329 – 0.629)	**<0,001**	0,634 (0.138 – 1.129)	0.071
Type of suture used on the closure of the abdominal wall:				
• Continuous	Reference		Reference	
• Interrupted	5.503 (1.392 – 27.825)	**0.013***	1.054 (N/A – 2.977)	0.957
Suture Material:		**<0,001**		
• Monofilament/Slowly absorbable ****	Reference		Reference	
• Monofilament/ Nonabsorbable	0.409 (0.223 – 0.805)	**0,005**	0.402 (N/A – 1.197)	**0.025**
• Multifilament/Absorbable	Undefined**	1.000	0.753 (N/A – 2.028)	0.663
• Multifilament/Nonabsorbable	0.170 (0.079 – 0.382)	**<0.001***	9.804 E-8 (N/A – 5451.780)	0.995
iNPWT	2.188 (1.018 – 4.594)	**0.034**	1.335 (0.211 – 2.459)	0.614
Re-laparotomies (for 1 unit increased)	2.509 (1.636 – 3.948)	**<0.001**	1.342 (0.728 – 1.957)	0.348
SSI		**<0.001***		
• Superficial	6.518 (3.191 – 13.973)	**<0.001**	3.197 (2.105 – 4.289)	**0.037**
• Deep	25.428 (4.518 – 642.727)	**<0.001***	1.120 E8 (1.120 E8 – 1.121 E8)	0.990
• Organ-space	3.462 (2.005 – 5.972)	**<0.001**	1.834 (0.977 – 2.691)	0.165
• Organ-space/Superficial	6.722 (0.541 – 211.837)	0.123*	5.057 (2.571 – 7.543)	0.201
• Organ-space/Deep	3.580 (0.091 – 139.972)	0.390*	5.988 E-8 (N/A – 7754.113)	0.997
Wound dehiscence	4.631 (2.578 – 8.491)	**<0.001**	5.282 (4.448 – 6.115)	**<0.001**

Legend: CI: Confidence Interval; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; CRS-HIPEC: Cytoreductive Surgery and Hyperthermic Intraperitoneal Chemotherapy; iNPWT: Incisional Negative Pressure Wound Therapy; SSI: Surgical Site Infection.
*Fisher test used instead of chi-shared; ** The odds ratio cannot be calculated due to the presence of zero cells in the contingency tables; *** Generalized Variance Inflation Factor (GVIF)>5 in the multivariate analysis; **** Category with more participants used as reference

development of IH. This included age (OR 1.026; p<0.001), BMI (OR 1.060; p=0.001), diabetes (OR 1.551; p=0.026), COPD (OR 3.100; p=0.002), history of previous abdominal surgeries with a coincident site incision (OR 1.303; p=0.010), laparostomy status (OR 5.601; p=0.036), interrupted suture technique (OR 5.503; p=0.013), iNPWT (OR 2.188; p=0.034), re-laparotomies (OR 2.509; p<0.001), superficial SSI (OR 6.518; p<0.001), deep SSI (OR 25.439; p<0.001) and organ-space SSI (OR 3.462; p<0.001). Conversely, surgeries involving the ileocecal appendix (OR 0.162; p<0.001), spleen and the esophagus, stomach and duodenum (OR 0.474; p<0.001), as well as the transverse incision (OR 0.093; p<0.001), layered closure (OR 0.455; p<0.001) and the use of monofilament nonabsorbable (OR 0.409; p=0.005) and multifilament nonabsorbable sutures (OR 0.170; p<0.001), were significantly associated with a decreased odds of development of an IH.

In the multivariate analysis (Table 2), including all previously significant variables, BMI (OR 1.051; p=0.025), superficial SSI (OR 3.197; p=0.037) and wound dehiscence (OR 5.282: p<0.001) were identified as independent factors significantly associated with IH occurrence. The application of monofilament and nonabsorbable suture (OR 0.402; p=0.025) was independently linked with a reduced odd for IH development.

A second multivariate analysis (Table 3) showed that BMI (OR 1.056; p=0.007), transverse incision (OR 0.189; p=0.007), layered closure (OR 0.503; p<0.001), superficial SSI (OR 3.001; p=0.024), organ space SSI (OR 2.686; p=0.004) and wound dehiscence (OR 4.787; p<0.001) were significantly associated with IH occurrence. Through Monte Carlos Simulations, a predictive model of IH development was constructed, with a sensitivity of 47.9%, a specificity of 93.2%, a misclassification of 18.8%, and an area under the receiver operating characteristic curve (AUROC) of 0.7608 (Fig. 3). The predictive variables comprehended in this model were SSI, wound dehiscence, BMI, type of closure of the abdominal wall, and type of incision.

Table 3 – **Multivariate analysis, through Monte Carlo Simulations, of risk factors for IH development at 5 years follow-up**

Variable	Odds Ratio (CI 95%)	P value
BMI (for 1 unit increased)	1.056 (1.017 – 1.096)	**0.007**
Type of incision:		
• Midline	Reference	
• Transverse	0.189 (N/A – 1.405)	**0.007**
Type of closure of the abdominal wall:		
• Mass closure	Reference	
• Layered closure	0.503 (0.098 – 0.909)	**←0.001**
SSI		
• Superficial	3.001 (2.046 – 3.956)	**0.024**
• Deep	1.6483 E7 (1.6481 E7 – 1.6484 E7)	0.976
• Organ-space	2.686 (2.010 – 3.362)	**0.004**
• Organ-space/Superficial	7.237 (4.817 – 9.657)	0.109
• Organ-space/Deep	4.440 E-7 (N/A – 2852.579)	0.992
Wound dehiscence	4.787 (4.029 – 5.544)	<**0.001**

Legend: CI: Confidence Interval; BMI: Body Mass Index; SSI: Surgical Site Infection.

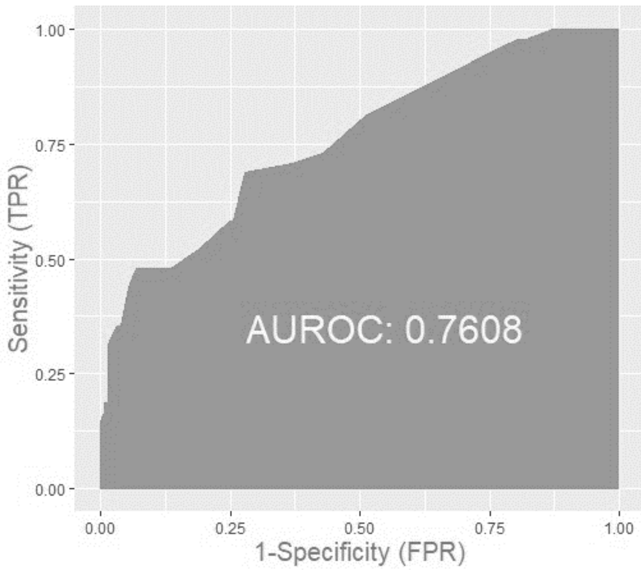

Figure 2 – **KROC Curve of the predictive model for IH development.**

AUROC: Area Under the Receiver Operating Characteristic Curve

DISCUSSION

In our study population, the cumulative incidence was 22.7% at the end of the 5 years of follow-up, which is within the range of the previously reported incidence[2, 4]. The incidence of IH increased by 45.4% in the 2nd year, 19.1% in the 3rd year, 13.4% in the 4th year, and 7.1% in the 5th year. Although the increase in the incidence of incisional hernia is more prominent in the first 2 years, the occurrence of IH is still reported in the last year of follow-up of this study, which underscores the importance of a large follow-up time. Most of the prior studies had reported a shorter follow-up period, potentially leading to an underestimated incidence.

Consistent with prior research[3-5,10,14], our analysis found that a higher BMI was a significant independent predictor, with each unit increase linked with a 5% increased odds of IH development. This finding could be explained by increased intrabdominal pressure in these patients[30], as well as an increased risk of SSI[31].

Regarding the intraoperative factors significantly influencing IH occurrence, the use of monofilament and nonabsorbable sutures had shown decreased odds of the development of the primary outcome. Previous literature found no significant differences between slowly absorbable sutures and nonabsorbable sutures when using an equal suture technique[14]. It's important to consider the collinearity of the type of surgeries performed (GVIF>5), as this variable could have influenced the association of monofilament and nonabsorbable suture with a lower risk of IH development when compared with a monofilament slowly absorbable suture. We used the chi-squared test to verify this association, and the material used in each type of surgery was significantly different (p<0,001).

Furthermore, findings resulting from the Monte Carlos Simulations indicate a significant association between the choice of incision and closure of the abdominal wall technique with the development of IH. Transverse incisions were linked to a lower likelihood of IH compared with midline incisions, strengthening the previous analysis[11-13]. However, this type of incision must not section a large amount of muscle or damage the vascular nerve bundles. Halm et al.[11], in a randomized controlled trial, also indicated that transverse incisions were associated with fewer patients reporting pain in the first days after surgery, as well as higher satisfaction with the aesthetic appearance. Concerning the closure of the abdominal wall technique, our retrospective analysis indicates that layered closure exhibited a reduced odds of IH occurrence compared with mass closure, contrary to preceding studies. A meta-analysis published in 2017[18], including five RCTs didn't find a significant difference between these two techniques, however, the quality evidence of some of these trials was considered very low. In contrast, the initial results from a randomized clinical trial that compares mass closure with layered closure in upper abdominal transverse incisions, published in 2021, suggest that the layered closure

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should be preferred over the previous one in upper abdominal transverse incisions, due to lower risk of SSIs and a higher suture-to-wound length ratio (SWLR)[32].

Regarding the postoperative complications, consistent with prior research[33-35], SSI emerged as a risk predictor of IH, with both superficial and organ-space SSIs independently increasing the likelihood of IH development. These findings underline the importance of effective infection prevention strategies, including skin antisepsis, suitable antimicrobial prophylaxis and possibly the use of antibiotic-coated suture material [36]. Additionally, dehiscence of the surgical wound was identified as an independent risk factor for IH occurrence after laparotomy, which aligns with the evidence reported from existing studies[37,38].

Respecting the application of iNPWT, the significantly increased risk of incisional hernia occurrence, in the univariate analysis, was not expected, however, it's important to consider that it was used in a very small number of patients that presented a higher proportion, when compared with the overall population of the study, of significant contamination or status of laparostomy before surgery, as well as a higher median BMI. Despite the lack of evidence of iNPWT as a protective factor of IH development, it has been associated with a significantly decreased incidence of superficial, and deep SSIs when compared with conventional dressings[39].

Resulting from an exhaustive search through Monte Carlos Simulations, the following variables – BMI, type of incision, type of closure and wound dehiscence, and SSI – were considered as the better predictors for the development of incisional hernia, which permitted the development of a predictive model with a high specificity and an AUROC of 0.7608, however with a low sensitivity. As this model includes post-operative complications, it doesn't allow for prediction of the risk of each patient before the surgery, however, it could be useful for the risk stratification of patients after surgery.

While this study has the benefit of a large cohort and follow-up time, it's also subject to several limitations and biases that must be acknowledged. Firstly, it's retrospective, non-randomized, and conducted in a single tertiary hospital study, which precludes that the generalization of our results to other patients' populations could be limited. Missing data concerning the information on participants' comorbidities, surgical techniques and materials used, and post-surgery complications might have influenced our results in the identified risk factors of IH development. Additionally, taking into consideration that the data were collected retrospectively, it is possible that some data could have been misclassified, as in some cases, where it was not possible to confirm if the wound infections classified as superficial could be deep SSIs. Moreover, the lost participants to follow up, which was not possible to avoid through the steps described in the methods section, may have introduced some selection bias. It's also important to mention that, despite our efforts, some potential confounders were not included in this analysis, for example, it was not possible to evaluate the SWLT and the needle size, considering that this information was not available. On the other hand, the predictive model also has some limitations, regarding that it's influenced by the study population, and its generalization and utility in clinical practice are dependent on external validation in future studies with different cohorts.

Future research efforts should focus on prospective studies with multicentre cohorts and RCTs to corroborate our findings. Furthermore, as suggested by the European Guidelines[19], more appropriate definitions of the technique used in the closure of the abdominal wall must be utilized, dividing into mass closure, layered closure, and single-layer aponeurotic closure, as well as evaluating the use of the small-bites technique, to validate the importance of this surgical procedure in the development of incisional hernia. Additionally, future studies endeavors should be employed in

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RCTs to evaluate the use of iNPWT in the closed wounds of general surgery procedures and the use of prophylactic mesh augmentation.

CONCLUSION

In conclusion, higher BMI, superficial and organ space SSIs and wound dehiscence seem to increase the risk of IH development. On the other hand, the use of a transverse incision and a layered closure of the abdominal wall seem to reduce the likelihood of this post-surgery complication.

Given the findings of this study, it seems crucial to undergo a pre-operative optimization of the individual characteristics of patients submitted to general surgeries, whenever possible, a careful choice of the technique used in the abdominal wall closure procedure and an effective implementation of preventive infection measures.

Author Contributions

Study design, data collection and analysis, writing and critical review of the manuscript – Beatriz Sá and Eva Barbosa MD

Data analysis – João P Morais

Critical review of the manuscript – Telma Fonseca MD, António M Gouveia MD PhD and Silvestre Carneiro MD PhD

Conflict of interests

The authors declare there is no conflict of interest regarding the material discussed in the manuscript.

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