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## **PREVENTION OF INCISIONAL HERNIA AFTER OPEN HEPATO-PANCREATO-BILIARY SURGERY: A SYSTEMATIC REVIEW**

Memba R, Morató O, Estalella L, Pavel MC, Llàcer-Millán E, Achalandabaso M, Julià E, Padilla E, Olona C, O'Connor D, Jorba R

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## Prevention of incisional hernia after open hepato-pancreato-biliary surgery: a systematic review.

### Title:

PREVENTION OF INCISIONAL HERNIA AFTER OPEN HEPATO-PANCREATO-BILIARY SURGERY: A SYSTEMATIC REVIEW.

### Authors:

Robert Membai<sup>1,3</sup>, Olga Morató<sup>1</sup>, Laia Estalella<sup>1,3</sup>, Mihai C Pavel<sup>1,3</sup>, Erik Llàcer-Millán<sup>1,3</sup>, Mar Achalandabaso<sup>1,3</sup>, Elisabet Julià<sup>1</sup>, Erlinda Padilla<sup>2</sup>, Carles Olona<sup>2,3</sup>, Donal O'Connor<sup>4</sup>, Rosa Jorba<sup>1,3</sup>

### Affiliations:

<sup>1</sup>Hepato-Pancreato-Biliary Unit. General Surgery Department. University Hospital of Tarragona Joan XXIII. 4 Dr Mallafré Guasch. Tarragona. 43005. Spain.

<sup>2</sup>Abdominal Wall Surgery Unit. General Surgery Department. University Hospital of Tarragona Joan XXIII. 4 Dr Mallafré Guasch. Tarragona. 43005. Spain.

<sup>3</sup>School of Medicine. Rovira i Virgili University. 21 Sant Llorenç. Reus (Tarragona). 43201. Spain.

<sup>4</sup>Department of Surgery, School of Medicine. Trinity College Dublin. College Green. Dublin 2. Ireland.

### Short Title:

INCISIONAL HERNIA IN HEPATO-PANCREATO-BILIARY SURGERY.

**Corresponding author:** Robert Membai

Telephone number: +34646330433

E-mail address: [rmembai.hj23.ics@gencat.cat](mailto:rmembai.hj23.ics@gencat.cat)

Postal address: 4 Dr Mallafré Guasch.Tarragona. 43005. Spain

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## Abstract

### Introduction

Most hepato-pancreato-biliary (HPB) procedures are still performed through open approach. Incisional hernia (IH) is one of the most common complications after open surgery. To date, published data on IH after HPB surgery are scarce, therefore the aim of this study was to assess the current evidence regarding incidence, risk factors, and prevention.

### Methods

Medline/PubMed (1946-2020), EMBASE (1947-2020), and the Cochrane library (1995-2020)) were searched for studies on IH in open HPB surgery. Animal studies, editorials, letters, reviews, comments, short case series and liver transplant, laparoscopic or robotic procedures were excluded. The protocol was registered with PROSPERO (CRD42020163296).

### Results

A total of 5 079 articles were retrieved. 8 studies were finally included for the analysis. The incidence of IH after HPB surgery ranges from 7.7% to 38.8%. The identified risk factors were body mass index, surgical site infection, ascites, Mercedes or reversed T incisions and previous IH. Prophylactic mesh might be safe and effective.

### Conclusions

IH after open HPB surgery is still an important matter. Some of the risk factors are specific for the HPB operations and the incision type should be carefully considered. Randomised controlled trials are required to confirm the role of prophylactic mesh after HPB operations.

## **Introduction**

The use of minimally invasive surgery (MIS) for hepatobiliary and pancreatic operations is still not widely adopted. While laparoscopic cholecystectomy has been standard-of-care for nearly three decades, MIS has only become common for a minority of specific hepato-pancreato-biliary (HPB) procedures such as distal pancreatectomy or minor hepatectomies. Overall use of MIS approach for HPB surgery remains less than 10%[1, 2]. A major limitation for the expansion of MIS is the technically complex nature of liver and pancreas resections with steep learning curves even for the open approach. Robotic surgery has the potential to overcome some of these disadvantages but the specific devices needed to facilitate laparoscopic or robotic HPB procedures, for example, complex parenchymal liver resection are still evolving[1, 3]. Concerning pancreatic surgery, despite the favourable outcomes for MIS distal pancreatectomy[4, 5], laparoscopic or robotic pancreatoduodenectomies are performed in only a limited number of high-volume centres[6-8].

Abdominal wall complications are a clear disadvantage of open surgery compared to MIS and have particular impact in terms of quality of life, body image and healthcare utilization costs. Incisional hernia (IH), wound dehiscence, surgical site infection (SSI) are all more commonly associated to open HPB surgery[1, 2, 9]. IH is one of the most common complications after open surgery. The European Hernia Society (EHS)[10] published a consensus classification that has proven its use to compare different hernia studies and to analyse the differences according to the type of incision. IH after HPB procedures are commonly classified as lateral subcostal (L1). The incidence of IH in the lateral incisions commonly used for HPB surgery is lower than in midline laparotomies. However, surgical repair of lateral IH can be challenging due to the proximity of bone limits and intercostal nerves. In addition, lateral IH has high recurrence rates[11-13]. The true incidence of IH, while widely reported after liver transplantation (LT)[14-17], it is not been established for other HPB procedures[16, 18]. Overall risk factors such as wound infection and dehiscence, previous hernia repair, immunosuppression, type of incision and obesity are well described[19, 20, 16, 18, 21-23] although no consensus has been published regarding additional specific risk factors for IH development in HPB procedures other than LT[14, 15]. Conversely, some published reviews suggest a benefit of prophylactic mesh placement in terms of IH risk reduction for midline laparotomies in high-risk patients while only few reviews have assessed the evidence in other types of laparotomies[24-26].

To date, published data on IH after HPB surgery are scarce. Therefore, the aims of this review were to examine the true incidence and the risk factors for IH after open HPB surgery, the differences according to the type of incision and to evaluate the potential benefit and safety of prophylactic mesh in these patients.

## **Methods**

### Systematic literature search

A systematic electronic literature search was developed with a medical librarian to identify studies on IH in open HPB surgery using the following databases: Medline/PubMed (1946-2020), EMBASE (1947-2020), and the Cochrane library (Cochrane Database of Systematic Reviews (CDSR) (1995-2020), Cochrane Central Register of Controlled Trials (CENTRAL) (1996-2020), and Cochrane Clinical Answers (2012-2020)). Online lists of relevant conference proceedings were also searched. The search strategy was devised to identify articles relating to any

abdominal wall complication in non-midline incisions and in liver, pancreas or biliary procedures (see Supplementary Material 1 for complete search strategy including MeSH terms and the CoCoPop, PEO and PICOS models used to devise the literature search).

Two authors independently performed the search, title and abstract screening, (RM and OM) and any conflicts were resolved by an independent 3<sup>rd</sup> author (RS). Where a study was considered potentially relevant, a full copy of the publication was obtained for further review. The reference lists of the included studies were hand-searched for further relevant potential studies. The work has been reported in line with PRISMA[27] (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR[28] (Assessing the methodological quality of systematic reviews) Guidelines. PRISMA checklist is provided as Supplementary Material 2. This study was prospectively registered with the PROSPERO database (Registration number CRD42020163296). The search was last performed on 31<sup>st</sup> March 2020.

### Selection criteria

Randomised controlled trials (RCTs), including cluster RCTs, controlled (non-randomised) clinical trials (CCTs) or cluster trials, controlled before-after (CBA) studies, prospective and retrospective comparative cohort studies, and case-control or nested case-control studies were included if they reported on the incidence, risk factors or methods to prevent IH after open HPB surgery. No time or language restrictions were applied. Review articles, animal studies, editorials, letters, comments and case series with < five patients were excluded. Studies investigating IH in LT recipients, laparoscopic or robotic procedures were also excluded.

### Study outcome measures and quality assessment

The primary outcome measures sought were the true incidence, the risk factors and the potential benefit and safety of prophylactic mesh reinforcement to avoid IH after open HPB surgery. The secondary outcome measure was the difference according to the type of incision and closure method.

Methodological quality and standard of outcome reporting within included studies were assessed independently by two authors (RM and OM) using the Newcastle-Ottawa score (NOS) (score range 0-9 for non-randomised controlled studies[29]).

## **Results**

### Study selection

The search yielded 5 079 titles. After title and abstract screening, eight studies reporting outcomes in 3 717 patients were ultimately included in the systematic review qualitative analysis (see Figure 1 for PRISMA flow diagram). The characteristics of the included studies are summarised in Tables 1 and 2. The retrieved studies were not sufficiently comparable in terms of design and underlying clinical question so a quantitative meta-analysis was not feasible; therefore, a qualitative assessment and narrative synthesis was performed.

### Summary of studies included

Most of the selected studies were from European countries with two from Japan, and one from the United States. All the studies were published within the last 15 years and 6 out of 8 within the last 5 years. The median NOS score was 7 (range 6-9) indicating moderate to high quality. No randomised controlled trials have been published. Most studies were retrospective (6 out of 8), with only two based on a prospective cohort and also only two comparative studies[30, 31]. The average sample size was 465 patients (115-1426) and the study periods ranged from 1991 to 2017. Most studies shared as primary variable the incidence of IH and the assessment of the risk factors for IH development, while some others analysed the difference in the incidence according to the type of incision or to the use of prophylactic mesh (Table 1).

### Incidence of IH in HPB surgery

All the selected papers assessed the incidence of IH. First, D'Angelica[32], Togo[33], Kayashima[34], Arslan[35] and Nilsson[36] analysed liver resections. While D'Angelica[32], Togo[33] and Arslan[35] included all hepatectomies, Kayashima et al[34] focused on resections for hepatocellular carcinoma in cirrhotic patients and

Nilsson[36] included only colorectal metastases. Second, while Chen-Xu[18] evaluated all open HPB procedures, Blazquez[30] and Bravo[31] included subcostal laparotomies (the first one for elective and the second for emergency surgeries). Most elective subcostal laparotomies were performed for HPB procedures, 81% according to Blazquez[30] et al and 87% according to Bravo[31] et al. Notably, the exclusion criteria were heterogeneous among the selected studies. Moreover, the follow up was also significantly different, ranging from a minimum of 6 months up to 168 months. Therefore, as the populations are not readily comparable, an accurate global incidence is not presented from this review. The estimated incidence of IH after HPB surgery might range from 7.7% to 38.8% (Table 2).

### Risk factors for IH development in HPB surgery

Both univariate and multivariate analysis were carried out in most of the studies to analyse potential risk factors. The risk for each potential factor was expressed as odds ratio (OR), hazard ratio (HR) or adjusted relative risk (ARR). Significance level  $p < 0.05$  was considered statistically relevant, corresponding to a confidence interval (CI) of 95%. Table 2 summarises only the risk factors identified in the multivariate analysis. Worth noting that Blazquez et al[30] were the only researchers who did not analyse the risk factors. In contrast, Bravo et al[31] identified SSI (4.905 HR, CI 2.116-11.37,  $p < 0.001$ ), previous hernia repair (2.86 HR, CI 1.24-6.61,  $p = 0.014$ ) and perioperative or postoperative shock (2.64 HR, CI 1.01-6.93,  $p = 0.048$ ) as significant risk factors in the multivariate analysis. Presenting the three risk factors meant a 99.5% (95.0-99.9) probability of developing an IH, while having none reduced the probability to 13% (7.76-18.7). Chen-Xu et al[18] published the sole study also performing a multivariate model regression to assess IH risk factors after pancreatic surgery. SSI (6.698 HR, CI 2.116-21.199,  $p = 0.001$ ), superficial wound dehiscence (26.402 HR, CI 4.114-160.43,  $p = 0.001$ ), height  $> 167.5$  cm (4.835 HR, CI 1.181-19.798,  $p = 0.028$ ) and subcutaneous fat thickness  $> 23.3$  mm (3.692 HR, CI 1.080-12.621,  $p = 0.037$ ) were determined as risk factors of IH after pancreatic surgery. Perirenal fat thickness  $> 14.7$  mm (2.251 HR, CI 1.028-4.931,  $p = 0.043$ ) and body mass index (BMI)  $> 26$  kg/m<sup>2</sup> (2.694 HR, CI 1.063-6.824,  $p = 0.037$ ) were the risk factors identified after hepatobiliary procedures. The four risk factors identified in the multivariate regression model by d'Angelica et al[32] were incision type (Mercedes type)(2.1 OR, CI 1.3-3.4,  $p = 0.003$ ), male sex (1.6 OR, CI 1.0-2.6,  $p = 0.04$ ), BMI (1.07 OR, CI 1.03-1.11,  $p < 0.001$ ) and SSI (2.3 OR, CI 1.2-4.2,  $p = 0.01$ ). Cirrhosis was also identified in this multivariate analysis (81% vs 19%,  $p = 0.01$ ). The multivariate analysis by Kayashima et al[34] for hepatectomies in cirrhotic patients identified intractable ascites (24.83 OR, CI 3.78-500.93,  $p = 0.0003$ ), abdominal wall closure by a single-layer mass closure with a continuous running suture (4.59 OR, CI 1.33-20.77,  $p = 0.0143$ ), preoperative BMI  $> 25$  kg/m<sup>2</sup> (3.36 OR, CI 1.53-7.59,  $p = 0.0025$ ), and preoperative serum N-terminal pro-peptide of type IV collagen 7S domain (P4NP 7S) levels  $> 5$  ng/mL (3.13 OR, CI 1.16-9.12,  $p = 0.0234$ ). The multivariate analysis by Nilsson et al[36] in hepatectomies for colorectal metastases were preoperative chemotherapy  $> 6$  cycles (2.12 HR, CI 1.14-3.94,  $p = 0.017$ ), preoperative bevacizumab (3.63 HR, CI 1.86-7.08,  $p < 0.0001$ ) and previous IH (3.50 HR, 1.98-6.18,  $p < 0.0001$ ). Arslan et al[35] identified malignancy as the only risk factor in the multivariate analysis (2.12 HR, CI 1.07-4.18,  $p = 0.03$ ). Finally, according to Togo et al[33], the multivariate regression model showed the following risk factors: reversed T incision (4.775 ARR, CI 2.313-9.857,  $p < 0.0001$ ), ascites (4.373 ARR, CI 1.590-12.029,  $p = 0.0043$ ), BMI  $> 25$  kg/m<sup>2</sup> (4.573 ARR, CI 2.279-9.173,  $p < 0.0001$ ), repeat hepatectomy (4.081 ARR, CI 1.774-9.388,  $p = 0.0009$ ) and steroids use (48.845 ARR, CI 5.413-440-797,  $p = 0.0005$ ). Table 3 shows the common risk factors identified exclusively in the multivariate analysis of the selected studies. Even though the different studies analysed different risk factors and most did not coincide, the risk factors identified in more than one publication were BMI, SSI, ascites, incision type and previous IH.

### Prevention of IH in HPB surgery

Bravo[31] and Blazquez[30] published the only two comparative studies assessing the prevention of IH. Blazquez et al[30] compared prospectively two groups of elective patients undergoing bilateral subcostal laparotomies (mesh group and control). There was a significant difference between the two groups regarding the IH incidence (17.54% vs 1.72%,  $p = 0.0006$ ), with no differences in terms of complications. Similarly, Bravo et al[31] conducted a retrospective comparison between two groups of emergency unilateral subcostal laparotomies (mesh group and control). No long-term complications such as mesh removal, chronic infection, or chronic pain occurred in mesh group and the incidence of IH was lower (19.1% vs 3.8%,  $p = 0.008$ ). Preoperative variables were significantly worse in mesh group: Preoperative shock (26.5% vs 40.0%,  $p = 0.039$ ), vasoactive drugs treatment (25.1% vs 40.0%,

p=0.020) and rate of intensive care unit admission (42.5% vs 31.4%, p = 0.018). By contrast, the degree of contamination was lower in the mesh group (51.7% vs 70%, p=0.008). However, this fact did not have an impact on SSI or skin dehiscence, as differences were not detected among groups. Therefore, according to both studies, mesh reinforcement appears to be effective and safe to prevent IH in elective and emergency subcostal laparotomies.

#### Differences according to type of incision and closure method

The secondary outcome of our review was to identify the best incision type and closure method. On the one hand, both d'Angelica[32] and Togo[33] considered the differences in the incidence of IH according to the type of incision as part of their main outcome. On the other hand, Kayashima[34], Nilsson[36] and Chen-Xu[18], also registered the incision type, however just as another variable. D'Angelica et al[32] found a twofold higher rate of IH in Mercedes incision when compared to right subcostal incision with vertical midline extension (ERSC) after liver resections (9.8% vs 4.8%, p=0.001). Togo et al[33] compared RTVE (right transverse incision with vertical extension at the midline from subumbilical region to the xiphoid process), J-shaped incision (right transverse incision with a vertical extension at the midline to the xiphoid process) and reversed T incision (bilateral transverse incision with a vertical extension to the xiphoid process) in hepatectomies. According to logistic analysis of this study, when the reversed T incision was performed, the risk of IH increased by 4.775 times (midline 6.3% vs J-shaped 4.7% vs RTVE 5.4% vs reversed T 21.7%, p<0.01). On the contrary, Kayashima et al[34] did not find significant differences when comparing J-shaped to midline, right subcostal or Mercedes type incisions (33.6% vs 15.8% vs 15.8% vs 15.8%, p=0.2776). No association between Mercedes and ERSC and IH incidence was found by Nilsson et al[36] either (30.3% vs 30.7%, p=0.948). Finally, the study published by Chen-Xu et al[18] did not show either significant differences when comparing J-incision, L-incision, midline, subcostal or transverse incisions (12.6% vs 17.6% vs 16.5% vs 6.8% vs 14.2%, p=0.296). To summarise, according to the studies that included the type of incision as primary outcome, Mercedes and reversed T incision might be associated with a higher incidence of IH, while J-shaped and ERSC incisions could involve a lower risk. With regard to closure methods, as shown in Table 2, there was also a considerable heterogeneity among the selected studies. Moreover, no comparisons between different closure methods were performed, except of in the publication by Kayashima[34] et al. This study found a higher risk of IH in the event of using a running suture in comparison with an interrupted suture. Nevertheless, the fact that this study was only focused in cirrhotic patients, should also be beard in mind. Therefore, providing any insight regarding the ideal closure method in open HPB surgery is not viable as there is not enough evidence in the literature to give a solid recommendation.

#### **Discussion**

Although IH are not usually life-threatening complications outside of the setting of intestinal obstruction, they are a major source of morbidity and can significantly impair quality of life. This is all the more pertinent as survival has improved for many HPB cancers bringing a focus toward increasing patient's satisfaction. Therefore, more studies should center the attention on value-based care, patient-centered and longer-term outcomes. The increase in the rate of admissions and reoperations secondary to IH has also a significant economic impact and consequently a substantial cost burden for society[37, 38, 20, 39]. As stated before, most HPB operations are performed through lateral incisions. Unfortunately, high evidence-based data are lacking and there are no consensus guidelines focused in the management of abdominal wall complications after non midline laparotomies[11]. Furthermore, current evidence on LT recipients cannot be extrapolated either to all other HPB operations, due to confounding roles of immunosuppression or end-stage liver cirrhosis. Likewise, many HPB procedures are due to malignant disorders, and cancer itself as well as chemotherapy regimens have an impact on cicatrization too[16, 40].

The EHS guidelines recommend using imaging for the follow-up of IH prospective studies in order to increase the detection rate[10]. Computed tomography (CT) scan provides a more accurate diagnosis than ultrasound (US) [41] although at least 2-years of follow up is required [42]. In our review, most of the studies analysed, except of the published by d'Angelica et al[32] and by Arslan et al[35], used CT scan or US. Median or mean follow-up was of at least 2 years. Therefore, data regarding the real incidence in the majority of the individual studies could be considered reliable. Even though the studies pooled an heterogenous population, we can presume that the

incidence is considerable, as some studies report IH in up to one third of their patients. Nonetheless, a higher number of comparable studies are needed in order to definitively establish this incidence rate. Risk factors for IH development are divided into patient and surgical technique-related factors. Surgical technique factors include incision type, suturing material choice, wound tension, type of closure (running vs interrupted), use of mesh or surgeon's skills. Unlike patient risk factors, surgical technique factors depend entirely on the surgeon and can be optimized [34, 9, 21]. HPB procedures are frequently complex from the technical point of view, and accordingly are conducted by senior surgeons, or senior trainees under supervision. However, abdominal wall closure is regularly performed by junior trainees, and often without adequate supervision. Obviously, an adequate technique is required in all cases, although identifying evidence-based risk factors might help to pay especial attention to those patient subsets. The benefit-risk ratio of measures such as mesh prophylaxis would also be higher in this group of high-risk patients. The fact that the different studies did not investigate the same risk factors was an issue. Furthermore, some studies established as exclusion criteria some of the risk factors demonstrated in the other studies, such as hemodynamic instability[30], re-laparotomy[34] or prior subcostal or supraumbilical laparotomy[30, 31]. Therefore, in order to analyse all the risk factors identified in the different articles, more studies with broader inclusion criteria are needed. BMI was the most commonly identified risk factors [32-34, 18], a finding not unexpected considering other gastrointestinal operations as well as LT[19, 21, 22]. It is worth highlighting that another commonly identified risk factor was SSI. While it was significant in the multivariate analysis of the studies published by Chen-Xu[18], Bravo[31] and d'Angelica[32]; Togo et al[33] only identified wound infection as risk factor in the univariate analysis. This data regarding SSI is also reported in other publications[19]. Likewise, cirrhosis and ascites decompensation were also in the list of the most common risk factors[32-34]. It must be kept in mind that the heterogeneity among population of the studies also makes it difficult to draw conclusions in this specific matter. In fact, in studies including only cirrhotic patients[34], the probability of having ascites is much higher than in those where cirrhosis is uncommon such as in hepatectomies for colorectal metastases, in pancreatectomies or in other biliary procedures[36, 18]. End stage liver cirrhosis and ascites have also been associated to IH development in LT recipients[43]. Also, as expected, presenting a previously repaired IH was reported as a risk factor for developing a new IH, although only by Nilsson[36] and Bravo[31]. Although a higher incidence of incisional hernia could be expected in patients with type B or C pancreatic fistula after pancreatic surgery, this association was not found in the multivariate analysis of any of the studies. Finally, while chemotherapy, which is common in HPB procedures such as hepatectomies for metastases and pancreatectomies for pancreatic cancer, was only identified as a significant risk factor by Nilsson et al[36], Arslan et al[35] also observed a non-significant trend between IH and postoperative chemotherapy. Wound healing impairment secondary to systemic or intraperitoneal chemotherapy have been reported as a risk factor for IH formation[44] however, there was not a clear association seen in our review. More studies exclusively analysing the incidence of IH after liver resections for colorectal metastases should be designed to confirm the association of chemotherapy found by Nilsson et al[36].

Collecting the current evidence regarding the prevention of IH after open HPB procedures was one of our main objectives. Unfortunately, to date there are no published randomised studies. As discussed earlier, mesh prophylaxis appears to be safe despite the high level of contamination commonly found in emergency surgery. Furthermore, mesh reinforcement also seemed to reduce the incidence of IH even when mesh group had more risk factors such as perioperative shock, reoperation and surgical field contamination[31]. Similarly, in other types of laparotomies, there is increasing evidence that synthetic meshes are safe in contaminated wounds[45, 9, 46]. However, there is not enough evidence to determine yet the optimal type of mesh or its placement (onlay, sublay/retrorectus or underlay/preperitoneal) or if mesh should be used in all patients or only in high-risk subsets[42]. There are further two ongoing studies whose results may also contribute to current knowledge on the topic. The first study is the PRINC trial, based in LT recipients. The hypothesis of this RCT is that prevention with a fully absorbable mesh will reduce the incidence of IH after LT with minimal risks for complications[47]. With regards to non-LT patients, another ongoing Polish trial aims to evaluate risk factors for development of IH in transverse epigastric incisions in patients after oncologic surgery.

Regarding the closure method, a Cochrane review published in 2017[25] did not find high quality evidence to determine the best type of suture material or technique. Only monofilament were shown to reduce the risk of IH when compared to polyfilament sutures. In our review, Kayashima et al[34] did show a possible association

between closure method and risk of IH formation. Several studies have demonstrated a benefit using a small bites technique for fascial closure in reducing IH in midline laparotomies. Theoretically, this may apply subcostal incisions but this has not been demonstrated [48, 20, 30, 49]. Finally, with regard to incision type, a multitude of incisions have been described. According to our review [32, 33], Mercedes and reversed T incisions should be avoided and J-shaped or ERSC should be the preferred. Ischemia in the trifurcation point from the midline fascia probably plays a role in both Mercedes and reversed T incisions. While it might be argued that Kayashima [34] and Nilsson [36] did not find differences according to the type of incision, this variable was not part of their primary outcome and the number of J-shape or ERSC in both studies was significantly higher. We believe this might have had an influence in their results. In fact, other authors also reported similar recommendations in terms of incision type for both LT and liver resections [50, 35, 21].

The main limitation of our review was the lack of comparative studies. Our assessment is also limited by the heterogeneity of the available studies, including differences in patients' types, procedures, follow-up, closure methods and exclusion criteria. However, this review covers this important topic exclusively for open HPB procedures.

### **Conclusion**

In conclusion, this review demonstrates that IH after open HPB surgery is a prevalent issue. While many important risk factors are patient-related, surgical factors such as incision type are also significant and the authors suggest that alternatives to Mercedes and reversed T incisions should be considered where possible. Randomised controlled trials or at least observational comparative studies with broader inclusion criteria, homogeneous group of patients/surgical procedures and consistent outcome measures to analyse the potential benefit and safety of prophylactic meshes are needed.

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### **Statement of ethics**

This study complies with the guidelines for human studies. The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. As a systematic review of the literature, the paper is exempt from Ethical Committee approval.

### **Conflict of Interest Statement**

All named authors hereby declare that they have no conflict of interest to disclose.

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### **Author Contributions**

Conception and study design: Memba R, Jorba R, Morató O, Olona C, O'Connor DB, Pavel MC. Screening and selection of papers: Memba R, Morató O, Jorba R, Padilla E. Interpretation of data: Memba R, Morató O, Jorba R, Estalella E, Llàcer-Millán E, Achalandabaso M, Julià E. Writing original draft: Memba R. Critical review of the manuscript: Morató O, Estalella E, Pavel MC, Llàcer-Millán E, Achalandabaso M, Julià E, Padilla E, Olona C, O'Connor DB, Jorba R. Final approval: Memba R, Jorba R, O'Connor DB, Morató O, Olona C, Estalella E, Pavel MC, Llàcer-Millán E, Achalandabaso M, Julià E, Padilla E.

### **Data availability statement**

All data generated or analysed during this study are included in this article [and/or] its supplementary material files. Further enquiries can be directed to the corresponding author.

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#### Figure Legend

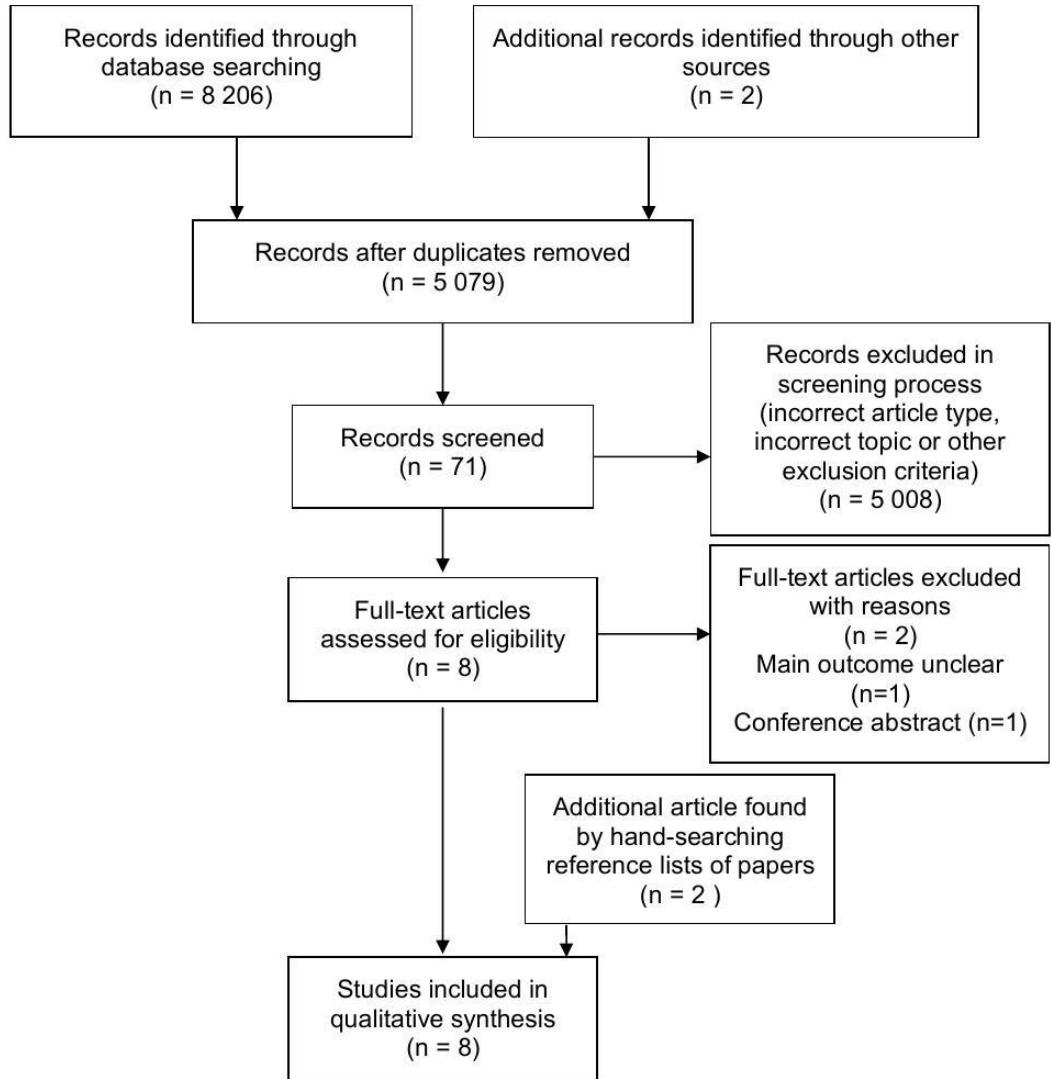
Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram for study selection

Identification

Screening

Eligibility

Included





Author, year	Country	Study design	n	Study interval	Main outcome	NOS
D'Angelica, 2006[32]	USA	Retrospective comparative (prospective maintained database)	1426	1991-2001	Analyse difference regarding early and late IH <sup>1</sup> complications between Mercedes incision and ERSC <sup>2</sup> after liver resections	6 (moderate)
Togo, 2007[33]	Japan	Retrospective comparative	626	1991-2006	Analyse risk factors of IH and the difference between type of incisions after partial hepatectomy	7 (high)
Kayashima, 2015[34]	Japan	Retrospective observational	192	2009-2013	Incidence and risk factors of IH <sup>1</sup> after hepatectomy for HCCA <sup>3</sup> in cirrhotic patients	9 (high)
Nilsson, 2016[36]	Sweden	Retrospective observational	256	2010-2013	Incidence, location and risk factors of IH <sup>1</sup> after open hepatectomy for colorectal metastases	8 (high)
Blazquez, 2016[30]	Spain	Prospective comparative cohort	115 Controls (57) Mesh (58)	2009-2013	Development of IH <sup>1</sup> (efficacy) and safety (SSI <sup>4</sup> , seroma, mesh rejection, other complications) of prophylactic mesh) in elective subcostal incisions	8 (high)
Arslan, 2017[35]	Turkey	Prospective observational	165	2007-2014	Determine short and long-term wound-related complications, incidence of IH <sup>1</sup> and risk factors for IH <sup>1</sup> after hepatectomies	7 (high)
Chen-Xu, 2018[18]	Portugal	Observational retrospective	654	2010-2016	Evaluation of incidence and risk factors of IH <sup>1</sup> in HPB <sup>5</sup> surgery	7 (high)
Bravo, 2019[31]	Spain	Retrospective comparative	283 Suture (203) Mesh (80)	2011-2017	Incidence of IH <sup>1</sup> and efficacy of prevention with prophylactic mesh in emergency subcostal incisions and risk factors of IH <sup>1</sup>	7 (high)

**Table 1. Summary of included studies.** <sup>1</sup>IH: Incisional Hernia. <sup>2</sup>ERSC: Right subcostal incision with vertical midline extension. <sup>3</sup>HCCA: Hepatocellular carcinoma. <sup>4</sup>SSI: Surgical Site Infection. <sup>5</sup>HPB: Hepato-Pancreato-Biliary.

Author, year	Patient population	Follow-up	Exclusion criteria	Incision type and closure method	Incisional hernias n (%)	Risk factors	Prevention of IH assessed
D'Angelica, 2006[32]	Elective liver resections	Minimum 12 months Max or median not defined	Combination of other major gastrointestinal procedures, perioperative death and lost to follow-up only included in early complications analysis, not for late complications	Mercedes (60%) ERSC <sup>1</sup> (40%) Single-layer mass closure running slowly absorbable. 2-layer in cirrhotic patients.	99 (7.8%) Mercedes 9.8% ERSC <sup>1</sup> 4.8% p=0.001 Based on medical records (no CT <sup>2</sup> confirmation)	Incision type (Mercedes), male sex, BMI <sup>3</sup> , SSI <sup>4</sup> . Cirrhosis (lack of complete data in 15%)	No
Togo, 2007[33]	Elective liver resections	Mean 52.8 months (12-168)	Concomitant resection of other organs, bilioenteric anastomosis, perioperative death or death due to recurrence within 1 year.	J-shaped <sup>6</sup> (37.2%) RTVE <sup>5</sup> (32.9%) Midline (15.2%) Reversed T <sup>7</sup> incision (14.7%) 2-layer interrupted non absorbable or absorbable sutures	48 (7.7%) Midline (6.3%) J-shaped <sup>6</sup> (4.7%) RTVE <sup>5</sup> (5.4%) Reversed T <sup>7</sup> (21.7%) p<0.01 CT <sup>2</sup> confirmation	BMI <sup>3</sup> , steroids use, type of incision (reversed T <sup>7</sup> ), repeat hepatectomy and ascites	No
Kayashima, 2015[34]	Elective liver resection for hepatocellular carcinoma I cirrhotic patients	Median 27 months (1-64)	Death, re-laparotomy and lost to follow-up within 12 months after surgery	J-shaped <sup>6</sup> (79.2%) Mercedes (3.6%) Midline (9.9%) Right subcostal (7.3%) Single-layer mass closure running slowly absorbable or interrupted absorbable	60 (31.3%) Cumulative incidence 12 months 19.8% 24 months 28.7% 36 months 32.5% 48 months 34% 60 months 38.8% CT <sup>2</sup> confirmed	Postoperative intractable ascites, running closure, preoperative BMI <sup>3</sup> , serum P4NP 7S <sup>8</sup> >5 ng/mL	No
Nilsson, 2016[36]	Elective liver resection for colorectal metastases	Median 13 months (2-59)	Death, no available CT <sup>2</sup> images	ERSC <sup>1</sup> (77.3%) Mercedes (20.3%) Midline (1.2%) 2-layer running slowly absorbable	78 (30.5%) 60 months 34.9% CT <sup>2</sup> confirmed	Preoperative chemotherapy, preoperative bevacizumab, IH <sup>1</sup> from previous colorectal surgery	No
Blazquez, 2016[30]	Elective bilateral subcostal laparotomies	Minimum 24 months (not completed in 15.22% mesh group and 18% control group)	<18 years old, rejection to participate, prior subcostal or supraumbilical laparotomy, life expectancy < 1 year, emergency operations, hemodynamic instability	Subcostal bilateral incision. 2-layer running slowly absorbable +/- self-fixating poly-propylene and polyglycolic acid mesh	11 (9.5%) Group C 10 (17.54%) Group M 1 (1.72%) p=0.0006 CT <sup>2</sup> confirmed	Not assessed	Yes More efficacy in mesh group and no significant difference in complication rate

Arslan, 2017[35]	Elective liver resections	Median 25.4 months (6-96)	Combination of other major gastrointestinal procedures, perioperative death, lost to follow-up and unresectable cases	J-shaped <sup>6</sup> incision. 2-layer mass closure running slowly absorbable. Corner point U stich polypropylene	38 (23%) CT <sup>2</sup> or physical examination	Malignancy	No
Chen-Xu, 2018[18]	Elective hepatobiliary and pancreatic laparotomies. 210 pancreatic surgery 444 hepatobiliary surgery	Median 28 months (up to 94 months)	< 18 years old, no follow up	J-shaped <sup>6</sup> (64%) L-shaped (3%) Midline (16%) Subcostal (16%) Transverse (1%) No reference to incision (0.9%) Small bites 6:1 Single layer in midline and layered closure in transversal portion Absorbable 7.7%, non absorbable 51.4%, slowly absorbable 40.1% Prophylactic mesh 0.3%	83 (12.7%) Cumulative incidence 12 months 7.6% 24 months 12.2% 36 months 14.6 % 72 months 21.6%  Pancreas surgery 21 (10%) Hepatobiliary surgery 62 (14%) CT <sup>2</sup> or physical examination	Pancreatic surgery: SSI <sup>4</sup> , superficial wound dehiscence, height and subcutaneous fat thickness  Hepatobiliary surgery: Perirenal fat thickness and BMI <sup>5</sup>	No Prophylactic mesh only used in 2 patients
Bravo, 2019[31]	Emergency subcostal unilateral laparotomy	Mean 39.3 months (6-60)	Concomitant abdominal wall hernia, previous subcostal incision, association of midline laparotomy, delayed abdominal closure, postoperative death	Subcostal unilateral incision. 2-layers polydioxane large bite running suture +/- PVDF <sup>9</sup> mesh sutured with polypropylene	Group S 29 (19,1%) Group M 2 (3,8%) p=0.008 CT <sup>2</sup> or US confirmed	SSI <sup>4</sup> , previous hernia surgery, perioperative and postoperative shock	Yes More efficacy in mesh group. More complications, operative time and hospital stay in mesh group.

**Table 2. Study descriptives and results.** <sup>1</sup>ERSC: Right subcostal incision with vertical midline extension. <sup>2</sup>CT: Computed Tomography. <sup>3</sup>BMI: Body mass index. <sup>4</sup>SSI: Superficial site infection. <sup>5</sup>RTVE: Right transverse incision with vertical extension at the midline from subumbilical region to the xiphoid process. <sup>6</sup>J-shaped incision: Right transverse incision with a vertical extension at the midline to the xiphoid process. <sup>7</sup>Reversed T incision: Bilateral transverse incision with a vertical extension to the xiphoid process. <sup>8</sup>P4NP: N-terminal pro-peptide of type IV collagen 7S domain. <sup>9</sup>PVDF: polyvinylidene difluoride

Risk factors	Number of studies
BMI <sup>1</sup>	****
SSI <sup>2</sup>	***
Ascites/cirrhosis	***
Incision type (Mercedes or reversed T)	**
Previous hernia surgery or IH from colorectal surgery	**
Gender (male)	*
Steroids use	*
Repeat hepatectomy	*
Running closure	*
P4NP <sup>3</sup>	*
Chemotherapy	*
Bevacizumab	*
Superficial wound dehiscence	*
Height	*
Subcutaneous fat thickness	*
Perirenal fat thickness	*
Perioperative or postoperative shock	*
Malignancy	*

**Table 3. Risk factors of incisional hernia in hepatobiliary and pancreatic surgery.** <sup>1</sup>BMI: Body mass index. <sup>2</sup>SSI: Surgical site infection. <sup>3</sup>P4NP: N-terminal pro-peptide of type IV collagen 7S domain