



# Management of Segmental Bile Duct Injuries After Cholecystectomy: a Systematic Review

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## Abstract

**Background** Injuries to segmental or aberrant bile ducts are encountered less commonly than their major bile duct counterparts and present a unique diagnostic and therapeutic challenge, since the nature of this injury involves a transected bile duct that loses its communication with the main ductal system. In this systematic review, we aim to pool available data on this particular type of biliary injury in an effort to outline available diagnostic and therapeutic modalities and evaluate their efficacy.

**Materials and Methods** An extensive literature search was performed on MEDLINE, Scopus, and Web of Science to identify isolated segmental or aberrant bile duct injuries.

**Results** A total of 21 studies were included in this systematic report. Ten studies reported non-operative management of patients, while 12 reported operative management of included patients. Outcomes of interest were the choice of treatment interventions and their success. Overall, 23 patients were managed non-operatively with a 91% success rate and 30 patients were managed operatively with a 90% success rate.

**Conclusion** Non-operative management might be a viable alternative to surgery. Hepatobiliary surgeons should be encouraged to publish their results in treating these rare injuries to further elucidate the role and efficacy of such an approach.

**Keywords** Bile duct · Segmental · Isolated · Injury · Management · Non-operative

## Introduction

Bile duct injuries after laparoscopic or open cholecystectomies are a dreaded surgical complication with significant implications to both patient and surgeon. The incidence of bile duct injuries in various reports is historically estimated to be around 0.4 to 0.6%<sup>1–6</sup> and the risk factors that lead to such injuries are well documented and established.<sup>7</sup> A more recent longitudinal population study in Sweden by Törnqvist et al.<sup>8</sup> revealed an incidence rate of bile duct injury of 1.5%, indicating that the true incidence of bile duct injuries may be even higher when less severe lesions, such as those not requiring

intervention for their resolution, are taken into account. The resultant mortality from these injuries is estimated to be as high as 20%<sup>9</sup> with both early and long-term complications, which in cases are so severe that may even require liver transplantation.<sup>10</sup> Major bile duct injuries are usually injuries to the common bile duct or the hepatic ducts and are classified as type D or E injuries according to the Strasberg classification system,<sup>11</sup> while injuries to segmental bile ducts are classified either as type B or as type C injuries, taking into account the presence of a bile leak or not. These injuries are thought to be the result of aberrations in the normal biliary tree anatomy<sup>12,13</sup> leading to unexpected injuries in small caliber biliary radicles that fail to be recognized during the dissection of the gallbladder bed and the triangle of Calot.<sup>13</sup> In particular, segmental ducts might be injured during dissection, when they have a low-lying course, draining directly into the cystic or the common bile duct.<sup>14</sup> Injuries to these segmental ducts are encountered less commonly than their major bile duct counterparts<sup>13,15</sup> and present a unique diagnostic and therapeutic challenge, since the nature of this injury involves a transected bile duct that loses its communication with the main ductal system, thus rendering imaging modalities such

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as ERCP even less applicable for their diagnosis and affirming the important role of magnetic resonance studies such as the magnetic resonance cholangiopancreatography for the diagnosis and management of bile duct injuries.<sup>16,17</sup> Furthermore, in type C injuries, there is evidence in the literature that spontaneous cessation of the bile leak may occur, provided there is adequate drainage and sepsis control,<sup>18</sup> through a mechanism involving the formation of a biliary stricture that resolves the bile leak without the need for surgery. This implies a role for non-operative management of these specific injuries that is yet to be elucidated. Although management of type E injuries is straightforward with well-established algorithms,<sup>19–21</sup> injuries to segmental ducts that result in a type C injury are lacking well-defined diagnostic and treatment protocols.<sup>22</sup> In this systematic review of the literature, we aim to pool available data on segmental bile duct injuries to outline available diagnostic and therapeutic modalities and evaluate their efficacy.

## Materials and Methods

An extensive literature search was conducted on MEDLINE, Scopus, and Web of Science for published relevant articles. The following search terms were used in combination with the Boolean Operator AND or OR: “bile,” “hepatic,” “duct injury,” “right posterior,” “isolated,” “segmental,” “aberrant.” Reference lists in all extracted studies were manually searched for eligible citations. Only articles published in the English language were screened.

Abstracts of the citations that were identified by the database search were independently screened by two authors. All published clinical studies that included management of patients with segmental bile duct injuries after cholecystectomy were selected for further analysis. The exclusion criteria were as follows: (1) reviews and editorials; (2) studies not precisely describing the type of bile duct injury; (3) studies not describing the diagnostic or treatment modalities employed; (4) studies that did not include injuries to the right posterior, right anterior, aberrant, or segmental ducts; (5) bile duct injuries in trauma patients and patients undergoing liver transplantation or hepatectomy; (6) studies involving patients without bile leaks (i.e., segmental bile duct strictures or type B Strasberg injuries); (7) studies without explicit or incomplete information on injury type and management. Duplicate studies were also identified and excluded. Furthermore, patients with other concomitant injuries to the biliary tree and/or vascular injuries were excluded from the analysis.

Outcomes of interest were the choice of treatment interventions and their success. In addition, study population demographics as well as clinical parameters, such as the interval from symptom presentation to diagnosis, the diagnostic modality employed, and daily biliary drainage (before intervention), were also extracted.

The available published studies concerning isolated right posterior bile duct injuries consist of case reports or single-center case series or retrospective reviews. The choice of management of these injuries, whether surgical or conservative, was based on local expert opinion.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was used to perform this systematic review.<sup>23</sup>

## Statistical Analysis

Pooled data extracted from eligible studies were entered in an Excel spreadsheet (Microsoft, Redmond, WA, USA) and descriptive statistics were analyzed by two authors.

## Results

Database search yielded 691 results. After screening, 21 studies<sup>13–15,18,22,24–39</sup> were deemed eligible for inclusion in the final analysis. The PRISMA diagram is demonstrated in Fig. 1. Pooled data analysis included 59 patients with segmental bile duct injuries, identified in the literature as right anterior bile duct injuries, right posterior bile duct injuries, segmental bile duct injuries, and aberrant bile duct injuries (not otherwise anatomically specified), after cholecystectomy. Study characteristics and patient demographics are shown in Table 1. The studies were published between the years 1983 and 2016. The mean age of patients included was 52 years and 70% were female. Four of the included studies did not state demographic information. In the entire study population, 59% of patients had right posterior bile duct injuries, 4% had right anterior bile duct injuries, 27% had segmental bile duct injuries, and 10% had aberrant right hepatic bile duct injuries. The included studies and patient populations were divided into a non-operative management group and an operative management group, based on the treatment intervention described.

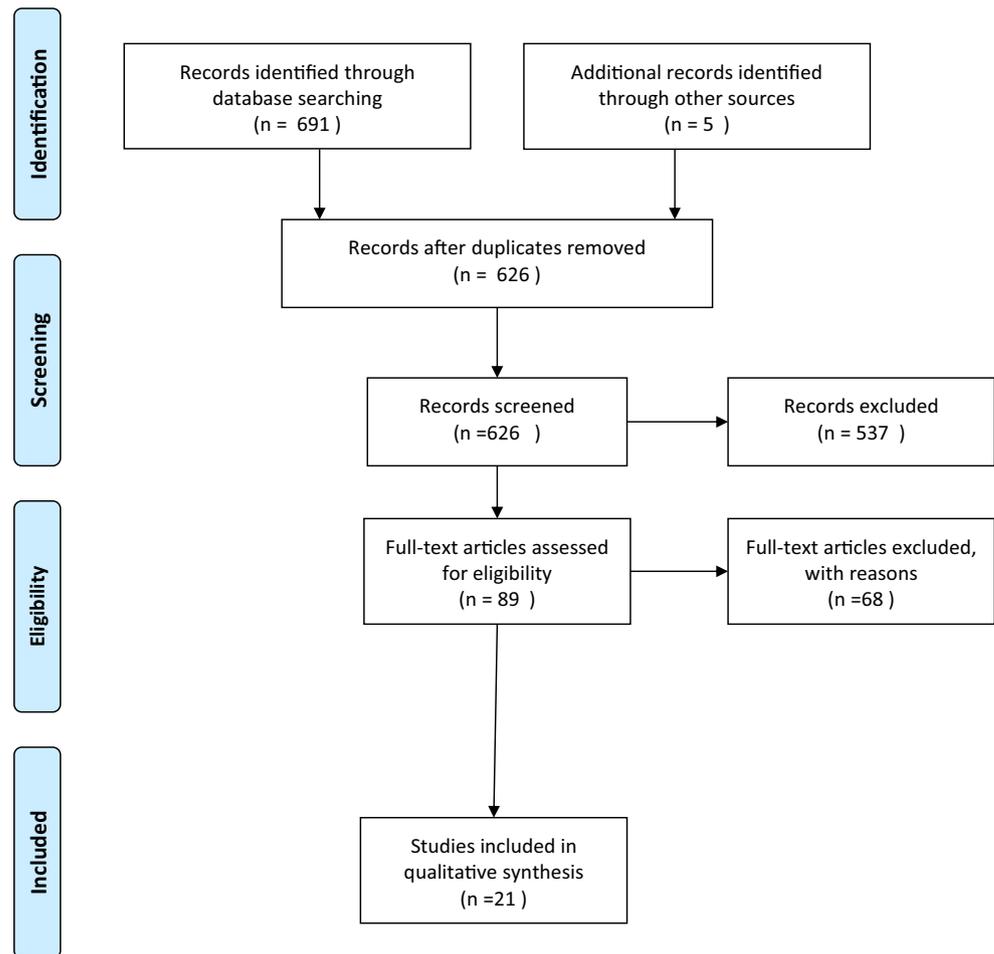
### Interval to Diagnosis

The time elapsed from cholecystectomy to the diagnosis of the bile leak is reported in 14 studies<sup>13,18,26–33,35–37,39</sup> for a total of 26 patients. The diagnosis was made at the time of the initial cholecystectomy in 10 patients (38%). For the remaining 16 patients, whose diagnosis was made in the postoperative period, the mean interval to diagnosis was 29.5 days.

### Daily Bile Leak

The daily bile leak produced by abdominal drains was reported in 10 studies<sup>14,25–27,30,33,35–37,39</sup> for a total of 21 patients. The mean daily bile leak reported was 364 mL/day.

**Fig. 1** PRISMA 2009 flow diagram (from Moher et al.<sup>40</sup>)



### Modality Used for Diagnosis

Nineteen studies<sup>13–15,18,24–28,30–39</sup> report on the modality employed for the diagnosis and categorization of the bile leak that occurred, for a total of 52 patients. The diagnosis was made using intraoperative cholangiography for 10 (19%) patients and direct visualization of the transected duct upon laparotomy was diagnostic for 1 (2%) patient.<sup>28</sup> The imaging modalities used for the diagnosis were as follows: percutaneous transhepatic cholangiography (PTC) for 16 (31%) patients, fistulography for 14 (27%) patients, magnetic resonance cholangiopancreatography (MRCP) for 8 (15%) patients, endoscopic retrograde cholangiopancreatography (ERCP) for 3 (6%) patients.

All the above results are summarized in Table 1.

### Non-operative Management

We identified 10 studies<sup>18,24–27,32,34–37</sup> and a total of 23 patients that underwent non-operative management of their bile duct injuries. Resolution of the bile leak and patient symptoms without the need for further intervention was considered as a

success of treatment; however, liver function test derangements and/or segmental liver atrophies did exist in some of these patients and are reported on Table 2. Thirteen patients were managed by percutaneous drainage (PCD) and expectant management with a success rate of 84% and two reported failures that eventually required surgery. Two patients underwent management with percutaneous transhepatic cholangiography and biliary drainage (PTCD) and sclerotherapy<sup>32,37</sup> with 100% success rate. One patient underwent PTCD and selective portal vein embolization for segmental liver atrophy induction<sup>34</sup> which resulted in success as well. Overall, the success rate of non-operative management was 91% for the included patients. Nine studies<sup>18,25–27,32,34–37</sup> report on the length of follow-up which can be reviewed on Table 2.

### Operative Management

Twelve studies<sup>13,15,18,22,27–31,33,38,39</sup> report on 30 total patients treated surgically for their bile duct injuries. Twenty-one patients (70%) underwent Roux-en-Y hepaticojejunostomies, 4 (14%) underwent end to end anastomosis of the injured ducts,

**Table 1** Details of patient population in published studies of segmental/sectoral bile duct injuries after laparoscopic cholecystectomy

Author	Type of study	Year	Patients	Sex (female)	Age (mean)	Type of injury	Interval to diagnosis (days)	Bile leak (mean, mL/day)	Diagnostic modality
Rappoport	Case report	1983	2	2	52	aRHD	13	500	IOC ( <i>n</i> = 1) PTC ( <i>n</i> = 1)
Meyers	Retrospective	1996	5	N/A	N/A	SD*	N/A	600	PTC
Schipper	Case series	1996	1	1	75	aRHD	7	–	Laparotomy
Ohtsuka	Case report	1999	1	1	47	RPSD	125	150	Fistulography
Lillemoe	Retrospective	2000	9	8	50	SD*	N/A	N/A	PTC
Mutignani	Case report	2002	2	2	38	RPSD, RASD	N/A	350	Fistulography ( <i>n</i> = 1), MRCP ( <i>n</i> = 1)
Soderlund	Retrospective	2005	1	N/A	N/A	RPSD	Intraop. ( <i>n</i> = 1)	–	N/A
Williams	Case report	2006	1	1	42	RPSD	15	200	IOC
Christoforidis	Retrospective	2007	1	1	N/A	aRHD	N/A	N/A	ERCP
Hwang	Case report	2007	1	1	60	RPSD	N/A	N/A	MRCP
Subrt	Case report	2009	1	1	74	RPSD	N/A	N/A	Fistulography
Portilla	Case report	2008	1	0	79	SD	45	400	IOC
Babel	Case series	2009	3	N/A	N/A	RPSD ( <i>n</i> = 2), SD ( <i>n</i> = 1)	Intraop. ( <i>n</i> = 3)	–	IOC
Li	Retrospective	2010	1	N/A	N/A	SD	N/A	N/A	N/A
Mazer	Case series	2011	6	5	42	RPSD	31	182	MRCP ( <i>n</i> = 3), ERCP ( <i>n</i> = 1), IOC ( <i>n</i> = 1), fistulography ( <i>n</i> = 1)
Choi	Case report	2011	1	1	34	RPSD	7	N/A	MRCP
Perera	Retrospective	2011	15	11	51	RPSD	Intraop. ( <i>n</i> = 3)	–	IOC ( <i>n</i> = 3), fistulography ( <i>n</i> = 10)
Chung	Retrospective	2012	3	3	50	aRHD ( <i>n</i> = 2), RPSD ( <i>n</i> = 1)	Intraop. ( <i>n</i> = 3)	–	N/A
Wojcicki	Case series	2013	2	2	18	RPSD	26	250	MRCP ( <i>n</i> = 1), ERCP ( <i>n</i> = 1)
Pandya	Case report	2016	1	1	54	RPSD	6	200	MRCP
Park	Case report	2016	1	0	67	RPSD	4	400	PTC

SD, segmental duct; aRHD, aberrant right hepatic duct (not otherwise specified); RPSD, right posterior segmental duct; RASD, right anterior segmental duct; CBDI, common bile duct; MRCP, magnetic resonance cholangiopancreatography; ERCP, endoscopic retrograde cholangiopancreatography; IOC, intraoperative cholangiography; PTC, percutaneous transhepatic cholangiography; Intraop., intraoperative; N/A, non-available

\*Segmental duct VII–VIII

3 (10%) underwent ligation of the injured bile duct, and 2 (6%) underwent hepatectomies. Eight out of the 12 studies<sup>13,15,18,22,29,33,38,39</sup> report the length of follow-up (Table 2). Four studies<sup>27,28,30,31</sup> report no follow-up after discharge of the patient. The success rate in this group of patients, according to the criteria mentioned in the non-operative management section as success of treatment, is 90%, with three cases (10%) of postoperative anastomotic strictures after previous hepaticojejunostomy being reported.

No patient deaths were recorded in any of the included patients managed by either approach.

## Discussion

As stated previously, the aim of this systematic review is to identify existing literature concerning segmental or aberrant

bile duct injuries that are complicated with a bile leak. The rarity of these complications, however, results in only a handful of publications, with considerable heterogeneity among them concerning the reported type of injury, the presence of a bile leak or not, the presence of concurrent injury to the main duct (i.e., the common bile duct, the common hepatic duct, the right or the left hepatic ducts) or arterial/portal system, and whether the patients they include were treated operatively or not and what is the outcome in each case. To account for this, we applied strict inclusion criteria, as stated in the “Materials and Methods” section, resulting in the inclusion of 59 patients dispersed in 21 studies. The majority (64%) of injuries reported were defined as right posterior/anterior segmental duct injuries; the remaining 36% were termed as segmental or aberrant duct injuries and therefore were not anatomically specified. Furthermore, two studies<sup>14,15</sup> report on injured ducts originating from liver segments VII–VIII which we classified

**Table 2** Subsets of patients managed either by a non-operative or operative approach and reported intervention outcomes

Author	Patients	Initial treatment	Follow-up	Outcome
<b>Non-operative management</b>				
Rappoport	1	PCD	30	Success
Ohtsuka	1	PCD	120	Failure (eventually required surgery)
Mutignani	2	PCD/ERCP	795	Success (asymptomatic, but with atrophied segment)
Christoforidis	1	PCD/ERCP	N/A	Success
Hwang	1	PVE/PTC (atrophy induction)	900	Success (asymptomatic but with atrophied segment)
Mazer	6	PCD	219	Success (asymptomatic but with atrophied segment, or LFT elevations)
Choi	1	PTC sclerotherapy	180	Success (asymptomatic but with atrophied segment)
Perera	8	PCD	1740 (median)	Success ( $n = 7$ ), success (asymptomatic but with LFT elevation and mild biliary dilation)
Pandya	1	PCD	42	Failure (eventually required surgery)
Park	1	PTC sclerotherapy	120	Success
Total	23			
<b>Operative management</b>				
Rappoport	1	Duct ligation	N/A	Success
Schipper	1	HepJ	N/A	Success
Lillemo	9	HepJ	2100 (mean)	Success ( $n = 6$ ), failure ( $n = 3$ ) (required dilations for anastomotic stricture)
Soderlund	1	Duct ligation	450	Success
Williams	1	HepJ	N/A	Success
Subrt	1	Hepatectomy	360	Success
Portilla	1	HepJ	360	Success
Babel	2	Duct-to-duct anastomosis	N/A	Success
Li	1	HepJ	1290	Success
Perera	7	HepJ ( $n = 6$ ), duct ligation ( $n = 1$ )	1740 (median)	Success ( $n = 6$ ), success ( $n = 1$ ) (asymptomatic but with LFT elevation and mild biliary dilation)
Chung	3	HepJ ( $n = 1$ ), duct-to-duct anastomosis ( $n = 2$ )	420	Success
Wojcicki	2	HepJ ( $n = 1$ ), hepatectomy ( $n = 1$ )	465	Success
Total	30			

PCD, percutaneous drainage; ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous transhepatic cholangiography; PVE, portal vein embolization; LFT, liver function tests; HepJ, hepaticojejunostomy; N/A, non-available

as segmental ducts (Table 1). The terms segmental, aberrant, and isolated duct were considered interchangeable by the authors and in each case described small caliber extrahepatic biliary ducts.

Our results demonstrate that segmental bile duct injuries follow a more indolent course<sup>41</sup> compared to their main bile duct injury counterparts.<sup>42</sup> We calculated a mean interval to diagnosis of 29.5 days, which is longer when compared to the interval of 11 days to diagnosis reported by Hart et al. for major bile duct injuries.<sup>43</sup> This result is because segmental ducts are of smaller caliber, and thus smaller bile leak rates are to be expected. Therefore, bilomas accumulate more slowly and symptoms take more time to develop. It should be noted that the injury was recognized during the cholecystectomy in 10 patients, hence comprising 38% of our patient pool, compared to 14–46% reported in big patient series concerning mainly major bile duct injuries.<sup>44–48</sup> The mean

daily bile output from these injuries was calculated to be around 364 mL/day. No data, to this date, exist on whether there is a cutoff value above which the possibility of damage to the main biliary duct structures should be contemplated. Nevertheless, any case of documented bile leak, regardless of magnitude, warrants further biliary imaging.

Although the main modalities used in the diagnosis of these injuries are like those employed for the diagnosis of main bile duct injuries, their usefulness is more limited. The most common diagnostic modality in our patient population was percutaneous transhepatic cholangiography (PTC) followed by tract fistulography. These types of imaging studies allow the delineation of damaged biliary radicles that exist in isolation from the rest of the biliary tree, and therefore, their superiority in diagnosing these unique types of injuries is reasonable and should be considered as the imaging studies of choice. Moreover, PTC enables the placement of percutaneous biliary

drains for bile leakage control, with a risk for major procedural complications cited to be around 2%.<sup>49</sup> Intraoperative cholangiography, where applicable, was also useful, achieving diagnosis in 19% of patients (Table 1). ERCP was diagnostic for only 6% of the included patients. Its diagnostic capabilities were limited to the imaging of the normal biliary tree that retained its continuity with the main ductal system, while the injured ductal system was commonly overlooked.<sup>39,50</sup> Adequate characterization of the anatomic intricacies that underlie the injured biliary segment is paramount for the effective application of any treatment strategy.<sup>19</sup> Since the introduction of MRCP in our diagnostic arsenal in 1991, it has quickly risen in popularity and is now firmly established as a valuable adjunct in the diagnosis and management of bile duct injuries, regardless of extent or severity, and should always be employed in such cases.<sup>17,51</sup> Patients with segmental bile duct injuries may present with signs and symptoms of sepsis due to protracted bile leakage. We therefore recommend initiating evaluation of these patients with a conventional CT scan to ensure adequate bile drainage and then proceeding with an MRI/MRCP scan to identify the damaged biliary radicle and its relation to the normal biliary tree. The diagnostic accuracy in identifying the precise location of the bile leak site can be further enhanced by the use of intravenous contrast media.<sup>52,53</sup> Further evaluation with PTC is warranted in cases where the MRI/MRCP results are equivocal or in cases where PTC is deemed appropriate for establishing biliary drainage. Despite the fact that in the included studies all PTC attempts were successful, the technical difficulty of cannulating non-dilated bile ducts, as is the case in patients with ongoing bile leaks, should not be underemphasized.<sup>54,55</sup>

Surgery is the cornerstone of the management of biliary injuries. Roux-en-Y biliary anastomosis was the most commonly employed (70% of operatively managed cases) surgical technique for restoration of biliary continuity.<sup>56</sup> Their reported outcomes appear to be on par with the results reported for reconstructions following main bile duct injuries from centers of excellence.<sup>42,57,58</sup> Other surgical interventions documented were duct ligation and end to end anastomoses; however, they were applicable only in select isolated cases.<sup>13,18,27,29,31</sup> Hepatectomy of liver segments drained by the injured duct is a viable alternative in the case of a surgically fit patient, which avoids the cumbersome dissection in an inflamed field as is the case in a Roux reconstruction.<sup>59–61</sup>

Conservative management of 23 patients yielded equally successful results to their surgical counterparts in our review. Percutaneous drainage (PCD) of the bile leak leads to the spontaneous closure of the biliary fistula in 90% of cases while portal vein embolization (PVE) for segmental liver atrophy induction<sup>34</sup> was also successful in resolving the bile leak in one case. This approach presents an acceptable solution for avoiding a technically demanding surgery, especially in a critically ill or septic patient. Similarly, Choi et al.<sup>32</sup> and

subsequently Park et al.<sup>37</sup> reported successful attempts at treating a total of two patients by injecting acetic acid into the leaking bile duct, thus sealing the leak and inducing fibrosis of the affected segment of the biliary tree (a procedure termed PTC sclerotherapy) followed by atrophy of the corresponding liver segments. In both cases, PTC sclerotherapy was used as an alternative to surgery with reported indications being patient refusal of surgery<sup>37</sup> or the surgeon's preference to avoid a demanding biliary reconstruction in the acute setting.<sup>32</sup> Further experience with this promising procedure is required in order to evaluate its effectiveness and safety. Despite their success, one should bear in mind the fact that all the above approaches may lead to liver function test derangements and segmental atrophy in a considerable number of patients (Table 2) with unknown potential long-term consequences. Concerning the studies that included non-operatively managed patients, it is important to state that no specific criteria were reported for electing a non-operative approach. Exclusion of concurrent major bile duct injury or arterial injuries, resolution of patient symptoms during the initial planning stage for surgery,<sup>35</sup> and patient refusal of surgery<sup>34</sup> were some of the criteria cited; however, most studies did not state the surgeons' reasoning for choosing a non-operative approach. When there is a case of injury to the common bile duct, the common hepatic duct, or the right hepatic duct, with or without concurrent vascular injuries, surgical reconstruction is the only reasonable treatment option<sup>62</sup> available.

In a recently published article by Cho et al.,<sup>63</sup> the concept of primary and secondary patency is introduced, in an effort to avoid confusion regarding the success of treatment interventions used in managing patients with bile duct injuries. According to these definitions, primary patency was achieved for 18 patients (78%) in the non-operative group versus 27 patients (90%) in the operative group. Secondary patency was achieved for the remaining patients by means of surgical intervention or PTC and anastomotic dilation (5 patients in the non-operative group versus 3 patients in the operative group). This result suggests that surgery might be the single most effective treatment intervention in resolving these injuries.

The maximum amount of time a surgeon can wait until deciding that the non-operative approach has failed is unclear. In two cases of non-operative management failure,<sup>26,36</sup> the duration of the watchful waiting period was 6 weeks and 16 weeks. In the studies in which the non-operative management was successful,<sup>18,25,27,32,34,35,37</sup> a mean interval of 8 weeks elapsed before resolution of the bile leak. The length of this time interval coincides with the one stated for "late" bile duct repairs after major bile duct injuries.<sup>5,8,46,61</sup>

Based on the above, we may derive that non-operative management is initially feasible if the surgeon can achieve sufficient drainage and sepsis control and provided that major bile duct injury is excluded. While employing a watchful

waiting approach such as this, the surgeon must always be alert to patient status deterioration and be ready to operate when the bile leak or patient symptoms fail to resolve. Consequently, such patients should preferably be managed in high-volume tertiary hepatobiliary centers.<sup>8,64</sup> We thus propose the following stepwise management algorithm which follows four steps:

- (A) Identification of the bile leak.
- (B) Ensuring adequate drainage with placement of percutaneous abdominal drains.
- (C) Diagnostic evaluation of the biliary tree and classification of the injury (ideally utilizing at least two imaging modalities to rule out concomitant vascular injuries).
- (D) Expectant management for a period of at least 12 weeks.
- (E) If the bile leak and patient symptoms fail to resolve, surgery.

In conclusion, aberrant or segmental bile duct injuries present a unique management challenge both for their diagnosis and for their treatment. Non-operative management might be a viable alternative to surgery in critical or comorbid patients, but treatment should be tailored to each individually, considering potential long-term consequences. Hepatobiliary surgeons should be encouraged to publish their results in treating these rare injuries, using current nomenclature, to accrue larger patient series that will elucidate the role of non-operative management.

**Authors' Contributions** Study conception and design: D.S., D.P.

Writing the manuscript: D.S., D.P., D.M.

Acquisition of data: D.P., A.B., E.S., N.K.

Analysis and interpretation of data: D.S., D.M., D.T.

Drafting of manuscript: D.M., G.K.

Critical revision: E.F., D.D.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflicts of interest.

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