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ORIGINAL ARTICLE

A retrospective analysis of bile duct injuries treated in a tertiary center: the utility of a universal classification—the ATOM classification

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Abstract

Background Bile duct injuries (BDI) are the most feared complications that can occur after laparoscopic cholecystectomy (LC). BDI have a high variability and complexity, several classifications being developed along the years in order to correctly assess and divide BDI. The EAES ATOM classification encompasses all the important details of a BDI: A (for anatomy), To (for time of), and M (for mechanism) but have not gained universal acceptance yet. Our study intents to analyze the cases of BDI treated in our institution with a focus on the clinical utility of the ATOM classification.

Methods We conducted a retrospective study, on a 10-year period (2011–2020), including patients diagnosed with BDI after LC, with their definitive treatment performed in our tertiary center. All injuries were retrospectively classified using the Strasberg, Hannover, and ATOM classifications.

Results We included in our study 100 patients; 15% of the BDI occurred in our center. No classification system was used in 73% of patients; 23% of the BDI were classified by the Strasberg system, 3% were classified by the Bismuth classification, 1% being classified by the ATOM classification. After retrospectively assessing all BDI, we observed that especially the Strasberg classification, as well as Hannover, over-simplifies the characteristics of the injury, many types of BDI according to ATOM being included in the same Strasberg or Hannover category. Most main bile duct injuries underwent a bilio-digestive anastomosis (60%), as a definitive treatment. An important percentage of cases (31%) underwent a primary treatment in the hospital of origin, reintervention with definitive treatment being done in our department.

Conclusion The ATOM classification is the best suited for accurately describing the complexity of a BDI, serving as a template for discussing the correct management for each lesion. Efforts should be made toward increasing the use of this classification in day-to-day clinical practice.

Keywords Bile duct injury · ATOM classification · Laparoscopic cholecystectomy

Laparoscopic cholecystectomy (LC) is one of the most common performed surgical procedures in the world, being used in elective settings for the treatment of symptomatic gallstones and in emergency setting as well, for the treatment of acute cholecystitis [1]. Often dimmed a simple and low-risk procedure, serious complications can occur after this surgical intervention. Bile duct injury (BDI) is the most feared complication that can occur after LC, increasing the early postoperative mortality and morbidity, but also the long-term quality of life in the affected patients [2–7]. The

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incidence of BDI registers a low percentage (0–3%) [8–10], but given the large number of LC performed worldwide, these cases constitute a substantial problem in terms of prevention, early diagnosis, and management. Bile duct injuries have a broad spectrum of diversity, regarding their severity, the localization, the type of injury, the time of detection, associated injuries, and so on, making the discussion regarding a proper management that more difficult. To solve this problem, several classifications have been developed throughout the years, but unfortunately with no universally accepted system, given each of their limitations. [6, 11, 12] The European Association of Endoscopic Surgery proposed in 2013 a new classification that confines all the complex aspects of BDI: A (for anatomy), To (for time of), and M (for mechanism) [13].

The aim of our study was to create a comprehensive overview of the BDI treated in our department in the last 10 years and apply the ATOM classification for each patient, while analyzing its potential utility in clinical practice.

Materials and methods

We conducted a retrospective analytical cohort study on patients diagnosed with bile duct injuries, treated in the Surgical Department of the Regional Institute of Gastroenterology and Hepatology Prof. Dr. Octavian Fodor Cluj-Napoca, on a 10-year period, admitted from January 2011 to December 2020. The study was approved by our Institutional Review Board.

We included patients with bile duct injuries that underwent laparoscopic cholecystectomies, including the ones that needed conversion to open cholecystectomy. We excluded bile duct injuries resulted from other surgical interventions and patients with insufficient data. Data were extracted from the institution's electronic database, as well as from the patient sheets.

We collected the following data for our analysis:

- Demographic patient data (sex, age)
- Indication for cholecystectomy (elective or emergency surgery)
- Symptoms and signs after the BDI occurred
- Time from injury to diagnosis
- Imagistic studies performed (ultrasound, CT scan, magnetic resonance cholangiopancreatography MRCP, endoscopic retrograde cholangiopancreatography ERCP)
- Characteristics of the BDI: severity, level of injury, type of injury, mechanism of injury, vascular injuries
- Previous surgical interventions performed in other hospitals
- Definitive treatment
- Postoperative complications and reinterventions
- Duration of in-hospital stay
- Used classifications of BDI

  All injuries were reclassified retrospectively using the ATOM, Strasberg, and Hannover classification systems. The ATOM classification [13] includes the following factors:
- Anatomical characteristics

  Anatomic level

  - MBD—main bile duct

    - level 1—more than 2 cm from lower border of superior biliary confluent
    - level 2—less than 2 cm from lower border of superior biliary confluent
    - level 3—injury involves the superior biliary confluent, but communication right left is preserved
    - level 4 – the injury involves superior biliary confluent, but communication right left is interrupted
    - level 5a—right or left hepatic duct
    - level 5b—right sectorial duct but bile duct still in continuity

  Type and extent of injury—Occlusion (O) or Division (D), either complete (c) or partial (P); loss of substance (LS)
  Vasculobiliary injury—VBI (RHA—right hepatic artery, LHA left hepatic artery, CHA common hepatic artery, PV portal vein, MV marginal vessels)
  Time of detection

  - Ei—early intraoperative
  - Ep—early postoperative
  - L—late

  Mechanism

  - Me—mechanical
  - ED—energy driven

In addition to our retrospective analysis, we have done a literature review on the reported use of the ATOM classification for bile duct injuries, by searching several databases: Pubmed, Scopus, Embase. A comprehensive review of the medical literature has been performed, using the terms "ATOM," "bile duct injury," and "EAES classification." We included original articles, either prospective or retrospective studies, written in English. We excluded articles that discussed the use of other classification systems

Table 1 Demographic characteristics (age, sex) and the signs/symptoms experienced at detection of the BDI

Sex	Male	37 (37%)
	Female	63 (63%)
Age	Mean ± Standard deviation	52.84 ± 16.04
	Minimum	20
	Maximum	87
Symptoms/Signs	Jaundice	35 (35%)
	Abdominal pain	46 (46%)
	Bile leakage	50 (50%)
	Fever	9 (9%)
	Altered general state	9 (9%)
	Nausea	11 (11%)

Table 2 The operative indication for the laparoscopic cholecystectomy

Indication	Unknown		36 (36%)
	Elective surgery	Chronic cholecystitis	18 (18%)
		Sclerotic-atrophic cholecystitis	2 (2%)
	Emergency surgery	Acute cholecystitis	22 (22%)
		Phlegmonous cholecystitis	6 (6%)
		Gangrenous cholecystitis	16 (16%)

or did not focus on the potential utility of the ATOM classification in clinical practice.

Results

One hundred patients with BDI were treated in our department in the respective 10 year period. In 15 cases (15%), the LC was performed in our institution, while in the other 85 cases (85%), the LC was performed in other hospitals and the patients were transferred to our department for definitive treatment of the BDI. A total of 14,544 LC were performed in our clinic between 2011 and 2020; therefore, the incidence of BDI in our institution was 0.1%: 15 BDI out of 14,544 LC.

The demographic characteristics, symptoms, and signs experienced after the BDI are presented in Table 1.

Fifty-eight (58%) patients were diagnosed with BDI in less than 2 weeks after the LC, out of which 39 (39%) were diagnosed with BDI in the first postoperative week. The presentation in our department occurred after more than 3 months from the LC in the case of 14 patients (14%). We did not have information regarding the time interval between the LC and the detection of the BDI for two patients (2%).

The indication for LC is presented in Table2. All patients had biliary lithiasis as the main indication for surgery, but we here referred to the type of cholecystitis for which LC was performed. In 36% of patients (36 patients), the gallbladder walls and aspect were not specifically described by the primary surgeon, and only "biliary lithiasis" was mentioned as the indication for surgery, although this implies that a chronic cholecystitis might have been the case.

Conversion to open cholecystectomy occurred in 18 of these cases; in five cases, the LC was performed for gangrenous cholecystitis, in seven cases, the LC was done for acute cholecystitis, in two cases, the LC was done for chronic cholecystitis, while in four cases, the indication for surgery was not mentioned. The reason for conversion was the following: intraoperative recognition of the BDI in seven cases, hemorrhage from the cystic artery in one case, and in the rest of the cases (10 patients), difficulty of dissection with inability of proper identification of the biliary anatomy prompted to conversion to open surgery.

Regarding the diagnosis workup, in only 32 patients (32%), MRCP was done, in 59 patients (59%), ERCP was done, in one case (1%), an endoscopic ultrasound was done, a CT scan was done in 18 patients (18%), while an abdominal ultrasound was done in 39 patients (39%). Eighteen patients (18%) had done both an ERCP and a MRCP. Twenty-seven patients (27%) did not undergo neither MRCP nor ERCP.

In 73 cases, no classification system was used for the BDI, while 23 patients were classified using the Strasberg system, and three patients were classified using the Bismuth classification and only one patient was classified by the ATOM classification. All patients were retrospectively classified by the ATOM guidelines, at the time of this study. The characteristics of the BDI, by the ATOM classification are presented in Table 3.

The correlation between each injury types, based on the retrospective reclassification of the three systems used in our study (Strasberg, Hannover, ATOM), is presented in Table 4. Since the Strasberg classification is the simplest classification out of the three used systems, the comparison was based on the Strasberg type, as a point of reference.

Nine percent (nine cases) of the BDI were detected intraoperatively, one of these injuries was encountered in a case in which the LC was done in our center. Immediate surgical treatment, during the same intervention, was performed in seven cases: one of these cases was the case where the injury occurred in our center and the other six of these cases, were postoperatively transferred in our center, where reintervention with definitive treatment was done (Table 5).

Thirty-one patients (31%) had surgical interventions or other interventions (the primary treatment) for the BDI done in the hospital in which the LC was performed, before being transferred to our department. The primary treatment included the following interventions: in seven patients, bile duct stenting through ERCP was done; in seven patients,

Table 3 Classification of the bile duct injuries based on the ATOM system

Anatomical characteristics							Time of detection			Mechanism		Total
Anatomic level	Type and extent of injury					VBI	Ei	Ep	L	Me	ED	
	O		D									
	C	P	C	P	LS							
MBD												
1	6	12	4	5	2		1	19	9	27	2	29 (29%)
2	2	9	5	5	2	2 (1 RHA, 1CHA)	5	14	4	17	6	23 (23%)
3	5	7	1	2	2	3 (2 RHA, 1 MV)	3	11	3	17		17 (17%)
4			1	1				2		2		2 (2%)
5a	2	1	1					2	2	3	1	4 (4%)
5b				1				1		1		1 (1%)
NMBD			9	15		1 (MV)		23	1	17	7	24 (24%)
Total	15 (15%)	29 (29%)	21 (21%)	29 (29%)	6 (6%)	6 (6%)	9 (9%)	72 (72%)	19 (19%)	84 (84%)	16 (16%)	

Anatomic level: *MBD* main bile duct. Level 1—more than 2 cm from lower border of superior biliary confluent, level 2—less than 2 cm from lower border of superior biliary confluent, level 3—injury involves the superior biliary confluent, but communication right left is preserved, level 4—the injury involves superior biliary confluent, but communication right left is interrupted, level 5a—right or left hepatic duct, level 5b—right sectorial duct but bile duct still in continuity

Type and extent of injury *O* occlusion, *D* division, *C* complete, *P* partial, *LS* – loss of substance, *VBI* vasculo-biliary injury, *RHA* right hepatic artery, *CHA* common hepatic artery, *MV* marginal vessels. Time of detection *Ei* early intraoperative, *Ep* early postoperative, *L* late, Mechanism: *Me* mechanical, *ED* energy drive.

NMBD – nonmain bile duct

Table 4 Correlation between the Strasberg, Hannover, and ATOM classifications on the patients included in our study

Strasberg	Hannover	ATOM
A (24)	A1 (14)	NMBD Dp VBI−Ep Me (12)
		NMBD Dp VBI−L Me (1)
		NMBD Dc VBI−Ep Me (1)
	A2 (10)	NMBD Dc VBI−Ep ED (5)
		NMBD Dc VBI−Ep Me (3)
		NMBD Dp VBI−Ep ED (1)
		NMBD Dc VBI + MV Ep ED (1)
B (3)	B2 (1)	MBD 5a Oc VBI−Ep Me (1)
	D3 (1)	MBD 5a Op VBI−L Me (1)
	E4 (1)	MBD 5a Oc VBI−L ED (1)
C (2)	D4 (2)	MBD 5a Dc VBI−Ep Me (1)
		MBD 5b Dp VBI−Ep Me (1)
D (7)	C1 (3)	MBD 1 Dp VBI−Ep Me (2)
		MBD 2 Dp VBI−Ep ED (1)
	C2 (4)	MBD 1 Dp VBI−Ep ED (1)
		MBD 1 Dp VBI−L ED (1)
		MBD 2 Dp VBI−Ei ED (2)
E1 (27)	B1 (5)	MBD 1 OP VBI−Ep Me (3)
		MBD 1 Op VBI−L Me (1)
		MBD 2 Op VBI−L Me (1)
	B2 (2)	MBD 1 Oc VBI−Ep Me (1)
		MBD 1 Oc VBI−L Me (1)
	C1 (1)	MBD 1 Dp VBI−Ep Me (1)
	C2 (2)	MBD 1 DLS VBI−Ep (1)
		MBD 1 DLS VBI−Me (1)
	D1 (3)	MBD 1 Dc VBI−Ep Me (2)
		MBD 1 Oc VBI−Ep Me (1)
	D2 (6)	MBD 1 Dc VBI−Ep Me (2)
		MBD 1 Oc VBI−Ei Me (1)
		MBD 1 Oc VBI− Ep Me (2)
		MBD 2 DLS VBI−Ep Me (1)
	E1 (6)	MBD 1 Op VBI−Ep Me (2)
		MBD 1 Op VBI−L Me (4)
	E2 (2)	MBD 1 Op VBI−L Me (2)
E2 (17)	B1 (4)	MBD 2 OP VBI−Ep Me (2)
		MBD 2 Op VBI−L Me (1)
		MBD 2 Op VBI−L ED (1)
	B2 (1)	MBD 2 Oc VBI−Ep Me (1)
	C1(2)	MBD 2 Dp VBI−Ep Me (1)
	D1 (2)	MBD 2 Dc VBI−Ei Me (1)
		MBD 2 Op VBI−Ep Me (1)
	D2 (5)	MBD 2 Dc VBI−Ep Me (1)
		MBD 2 Dc VBI−Ei Me (1)
		MBD 2 Dc VBI + CHA Ep Me (1)
		MBD 2 Dc VBI + RHA Ei Me (1)
		MBD 2 DLS VBI−Ep ED (1)
	E2 (3)	MBD 2 Op VBI−Ep ED (1)
		MBD 2 Op VBI−Ep Me (1)
		MBD 2 Op VBI−L Me (1)
E3 (17)	B1 (4)	MBD 3 Op VBI−Ep Me (1)
		MBD 3 Op vbi−L Me (1)
		MBD 3 Op VBI + MV Ei Me (1)
		MBD 3 Op VBI + RHA Ep Me (1)
	B2 (4)	MBD 3 Oc VBI−EI Me (1)
		MBD 3 Oc VBI−Ep Me (2)
		MBD 3 Oc VBI + RHA Ep Me (1)
	C3 (2)	MBD 3 Dp VBI−Ep Me (2)
	D3 (3)	MBD 3 Dc VBI−Ei Me (1)
		MBD 3 DLS VBI−Ep Me (2)
	E3 (4)	MBD 3 Oc VBI−Ep Me (1)
		MBD 3 Op VBI−Ep Me (2)
		MBD 3 Op VBI−L Me (1)
E4 (2)	C3 (1)	MBD 4 Dp VBI−Ep Me (1)
	D3 (1)	MBD 4 Dc VBI−Ep Me (1)
E5 (1)	B2 (1)	MBD 2 Oc VBI− Ep Me + NMBD Dc VBI−Ep ED (1)

The table presents the type of injury and the number of injuries classified such, in brackets. Anatomic level: *MBD* main bile duct, level 1—more than 2 cm from lower border of superior biliary confluent, level 2—less than 2 cm from lower border of superior biliary confluent, level 3—injury involves the superior biliary confluent, but communication right left is preserved, level 4—the injury involves superior biliary confluent, but communication right left is interrupted, level 5a—right or left hepatic duct, level 5b—right sectorial duct but bile duct still in continuity

ATOM Classification, Type, and extent of injury *O* occlusion, *D* division, *C* complete, *P* partial, *LS* loss of substance, *VBI* vasculo-biliary injury, *RHA* right hepatic artery, *CHA* common hepatic artery, *MV* marginal vessels, Time of detection *Ei* early intraoperative, *Ep* early postoperative, *L* late, Mechanism *Me* mechanical, *ED* energy drive, *NMBD* nonmain bile duct

reintervention with lavage and drainage of the abdominal cavity was done; in five patients, a bilio-digestive anastomosis was performed; in eight cases, an external biliary drainage was placed; in two cases, the primary suture of the main hepatic duct was performed; and in two other cases, the ligature of a hepatic duct was performed. Table 5 presents the interventions done in the local hospitals (primary treatment), compared to the intervention done in our center, as a definitive treatment of these BDI, as well as the postoperative complications encountered after the definitive treatment.

The 100 cases included in this study underwent the definitive surgical, interventional, or conservative treatment in our tertiary center; we will present the choices of management for each of these cases. A hepaticojejunal anastomosis was performed in 59 cases (59%), while a hepaticoduodenal anastomosis was performed in one case

Table 5 The BDI that underwent interventional or surgical procedures prior to the presentation in our department: their primary treatment, the definitive treatment performed in our center, and the postoperative complications encountered after the definitive treatment

ATOM classification	Primary treatment	Definitive treatment	Complications
MBD 2 Op VBI−L Me	ERCP – bile duct stenting	Bilio-digestive anastomosis	Hepatic abscess
MBD 2 Op VBI− L Me		Bilio-digestive anastomosis	
MBD 2 Op VBI−L ED		Bilio-digestive anastomosis	
MBD 1 Op VBI−L Me		External biliary drainage	Biliary fistula (Bilio-digestive anastomosis)
MBD 1 Op VBI−L Me		Bilio-digestive anastomosis	
MBD 1 Op VBI−L Me		ERCP—bile duct stenting	
MBD 1 Op VBI−Ep Me		ERCP—bile duct stenting	Late bile duct stenosis (Bilio-digestive anastomosis)
NMBD Dc VBI−Ep ED	Abdominal cavity lavage and drainage	Suture of the accessory bile duct	
NMBD Dp VBI−Ep Me		ERCP—bile duct stenting	
MBD 1 Oc VBI− Ep Me		Bilio-digestive anastomosis	
MBD 2 Dp VBI− Ep Me		Bilio-digestive anastomosis	
MBD 3 Oc VBI + RHA Ep Me		Bilio-digestive anastomosis	
MBD 3 DLS VBI− Ep Me		Bilio-digestive anastomosis	Wound infection
MBD 5a Op VBI− L ME		Bilio-digestive anastomosis	
MBD 1 Dc VBI−Ep Me	Bilio-digestive anastomosis	Bilio-digestive anastomosis	Biliary fistula (Bilio-digestive anastomosis)
MBD 2 Dc VBI− Ei Me		Bilio-digestive anastomosis	
MBD 2 Dc VBI−Ei Me		Bilio-digestive anastomosis	
MBD 3 Dp VBI− Ep Me		External biliary drainage	
MBD 3 Op VBI− EP Me		External biliary drainage	Biliary fistula (Bilio-digestive anastomosis)
MBD 1 Oc VBI−Ei Me	External biliary drainage	Bilio-digestive anastomosis	
MBD 1 Op VBI−L Me		Bilio-digestive anastomosis	
MBD 2 Dp VBI−Ei ED		Bilio-digestive anastomosis	
MBD 2 Op VBI−Ep Me		Primary suture of the main bile duct	
MBD 3 Dc VBI−Ei Me		Bilio-digestive anastomosis	
MBD 3 Oc VBI−Ep Me		Bilio-digestive anastomosis	
MBD 3 Dp VBI−Ep Me		Bilio-digestive anastomosis	
MBD 3 Op VBI + MV Ei Me		Bilio-digestive anastomosis	
MBD 2 Oc VBI−Ep Me	Ligature of a hepatic duct	Bilio-digestive anastomosis	
MBD 5A Dc VBI−Ep Me		Bilio-digestive anastomosis	
MBD 1 Dc VBI−Ep Me	Primary repair of the main hepatic duct	Bilio-digestive anastomosis	
MBD 4 Dp VBI− Ep Me		Bilio-digestive anastomosis	

Anatomic level: *MBD* main bile duct, *NMBD* nonmain bile duct, level 1—more than 2 cm from lower border of superior biliary confluent, level 2—less than 2 cm from lower border of superior biliary confluent, level 3—injury involves the superior biliary confluent, but communication right left is preserved, level 4—the injury involves superior biliary confluent, but communication right left is interrupted, level 5a—right or left hepatic duct, level 5b—right sectorial duct but bile duct still in continuity

ERCP endoscopic retrograde cholangiopancreatography, ATOM classification, Type and extent of injury: *O* occlusion, *D* division, *C* complete, *P* partial, *LS* loss of substance, *VBI* vasculo-biliary injury, *RHA* right hepatic artery, *CHA* common hepatic artery, *MV* marginal vessels, Time of detection: *Ei* early intraoperative, *Ep* early postoperative, *L* late, Mechanism: *Me* mechanical, *ED* energy drive

(1%). An external biliary drainage, with placement of a Kehr tube, was done in 6 patients (6%). Primary repair of the main bile duct was done in two cases (2%). In 10 cases (10%), the suturing of the cystic or aberrant duct was performed. In 19 cases (19%), main bile duct stenting through ERCP was the choice of treatment; two of these cases also needed reintervention with laparoscopic lavage and drainage of the abdominal cavity. In three cases of nonmain bile duct injuries, conservative treatment was chosen (3%); these cases still had the subhepatic drainage in place after the LC, with a low debit of bile leakage (less than 200 ml per 24 h). Table 6 will detail the surgical intervention performed and the correlation with the type of injury, based on the ATOM classification.

Table 6 The definitive treatment of the bile duct injuries, based on the ATOM classification

	Bilio-digestive anastomosis	Primary repair of bile ducts	Closure of a small bile duct	External biliary drainage	ERCP—bile duct stenting	Conservative treatment
MBD 1 DC	3				1	
MBD 1 DP	2				3	
MBD 1 D LS	1			1		
MBD 1 OC	6					
MBD 1 OP	8			1*	3	
MBD 2 DC	5					
MBD 2 DP	4			1		
MBD 2 D LS	2					
MBD 2 OC	2					
MBD 2 OP	8	1				
MBD 3 DC	1					
MBD 3 DP	1			1		
MBD 3 D LS	2					
MBD 3 OC	5					
MBD 3 OP	6			1*		
MBD 4 DC	1					
MBD 4 DP	1					
MBD 5A DC	1					
MBD 5A OC		1*		1		
MBD 5A OP	1					
MBD 5B DP					1	
NMBD			10		11	3
Total	60 (60%)	2 (2%)	10 (10%)	6 (6%)	19 (19%)	3 (3%)

Anatomic level: *MBD* main bile duct, level 1—more than 2 cm from lower border of superior biliary confluent, level 2—less than 2 cm from lower border of superior biliary confluent, level 3—injury involves the superior biliary confluent, but communication right left is preserved, level 4—the injury involves superior biliary confluent, but communication right left is interrupted, level 5a—right or left hepatic duct, level 5b—right sectorial duct but bile duct still in continuity

ATOM classification, Type and extent of injury: *O* occlusion, *D* division, *C* complete, *P* partial, *LS* loss of substance, *VBI* vasculo-biliary injury, *RHA* right hepatic artery, *CHA* common hepatic artery, *MV* marginal vessels, Time of detection: *Ei* early intraoperative, *Ep* early postoperative, *L* late, Mechanism: *Me* mechanical, *ED* energy drive

*Reintervention, with bilio-digestive anastomosis was necessary, due to postoperative complications

A minimally invasive approach was chosen in 6% of the interventions (six cases): two cases of laparoscopic lavage and draining and four cases of laparoscopic suturing of the cystic duct or aberrant hepatic duct.

The average in-hospital stay in our institution was 15.22 days, with a minimum of 3 days and a maximum of 6 months. Twenty-four patients were also admitted in the intensive care unit, with an average stay of 10.5 days. The in-hospital mortality rate was 0 in our cohort of patients.

There were 14 postoperative complications that occurred after the definitive treatment performed in our institution—14% morbidity rate: 10 cases of biliary fistula, one case of hepatic abscesses, two cases of wound infection, and one case of postoperative acute pancreatitis. Seven reinterventions (7%) were registered: two cases of bilio-digestive anastomosis after external biliary drainage, one case of bilio-digestive anastomosis after primary suturing of the main hepatic duct, two cases of redo of the hepaticojejunal anastomosis (in one of these cases an associated hepatic resection being needed), one case of drainage of the hepatic abscesses, and one case of re-suturing of the aberrant hepatic duct.

Late complications that occurred after discharge, were encountered in 12 cases (12%): four cases of anastomotic stenosis, one case of bile duct stenosis—after primary repair of the main hepatic duct, one case of recurrent angiocolitis, two cases of hepatic abscesses, and four cases of incisional hernias.

The PubMed search returned 4 results, the Embase search returned 13 results, while the Scopus search returned 4 results: a total of 21 articles being identified. After removal of duplicates (8 articles), 13 studies were analyzed for eligibility. Two full-text articles [14, 15], and 9 conference abstracts that analyzed the use of the ATOM classification in clinical practice were identified.

Discussion

The introduction of laparoscopic cholecystectomy in surgical practice, as a routine procedure, marked a new milestone and a new era, of minimally invasive surgery [16]. Although it first encountered skepticism, LC has soon proven its benefits, mainly shorter postoperative recovery, and lower postoperative pain [1, 17]. LC is the most performed abdominal surgical intervention; therefore, a careful assessment of the training needs for performing a safe procedure and the correct management of the possible complications, including their prevention, early diagnosis, and treatment, is essential. The complication rate after LC is low, the encountered complications varying from wound infections, conversion to open surgery, to bile duct injuries [18, 19]. An increase in the incidence of BDI has been observed since the introduction of LC [10]; BDI are the most serios complication of this surgical intervention, and they bring a significant increase in both morbidity and mortality rate [20].

The symptoms related to BDI are often nonspecific, abdominal pain being the most prevalent symptom in our case series; on the other hand, postoperative bile leakage or intraabdominal collections, as well as jaundice can indicate the occurrence of a BDI [9, 21].

Most injuries (44%) occurred during emergency surgery for acute cholecystitis, but still an important percentage (20%) occurred during elective surgery. While the risk of BDI is higher in acute cholecystitis, a significant number of injuries also occur in routine LC [22–24]. This reiterates once again the importance of performing a safe cholecystectomy and taking all the measures to prevent BDI, like using the critical view of safety, performing bailout procedures (fundus-first approach or subtotal cholecystectomy) when the biliary anatomy cannot be clearly defined or by using intraoperative cholangiography, including indocyanine green fluorescence cholangiography, whenever needed [9].

When we observe the patterns of the preoperative diagnostic procedures, we see that the percentage of MRCPs performed is still low (32%), ERCP being more often preferred (59% of cases). We can only assume that the preference of the ERCP as a first choice might come from a desire to combine a diagnostic tool with a therapeutic procedure. However, the possible complications of ERCP do not recommend it as a diagnostic procedure and the balance should be turned toward performing more MRCPs. We believe that we need to address the fact that a considerable number of patients did not undergo a bile-duct-specific imagistic examination (MRCP and ERCP); we believe that this practice is not recommended, and care should be taken in the management of future cases.

BDIs are dangerous complications after LC that may present in various forms: they can affect minor bile ducts or the main hepatic ducts, they can be represented by either occlusion or transection of a duct on different lengths and parts of their circumference and can even be translated into long-term complications, like biliary strictures [21]. Given the diversity of BDI, providing an inclusive and unanimously accepted classification is of great importance, to assure a common subject when discussing the correct management of this pathology. Several classifications have been developed along the years, each of them with their own limitations. The Strasberg classification is one of the most well-known systems, simple to use, but with an important disadvantage: it cannot properly describe the complexity of a BDI, without mentioning any vascular involvement and omitting other essential details. The Hannover classification is a more complex system that highlights more aspects regarding the pattern of the BDI; however, it still does not encompass the time of detection and the pathogenesis of the BDI. The EAES developed the ATOM classification, which was able to overcome the downsides of the other available systems; however, this classification has not been easily adopted into clinical practice, only a few studies reporting its use [12, 14, 15].

Our retrospective single-center analysis intended to focus on the advantages of routinely using a comprehensive and uniform classification in the management of BDI; also, we assessed the use of different classifications of BDI in our clinic. In our study, 73% of the BDI were not classified by any system at the time of treatment; the most used classification was the Strasberg system, only one BDI being described according to the ATOM guidelines.

When comparing the Strasberg, Hannover, and ATOM classification systems, we can observe that the first two, and especially the Strasberg classification over-simplifies the injury, many types of BDI, with different characteristics being included in the same category. (Table 4) As we can see, a Strasberg lesion E1 corresponds to eight different Hannover injury types; moreover, for each Hannover lesion, we can see a broader spectrum of ATOM classifications, clearly showing that even a complex system such as Hannover cannot fully describe a BDI. The ATOM classification has been dimmed as being too complex and difficult to use; we wanted to emphasize the fact that a surgeon can gather a lot of information from simply reading the ATOM classification for a certain BDI, since the used abbreviations are easy to understand. For example, more essential information can be deducted from the syntagm "MBD 2 Dc VBI- Ei Me" than from a type D1 Hannover BDI. Therefore, we believe that the characterization of the ATOM classification as being hard to use in

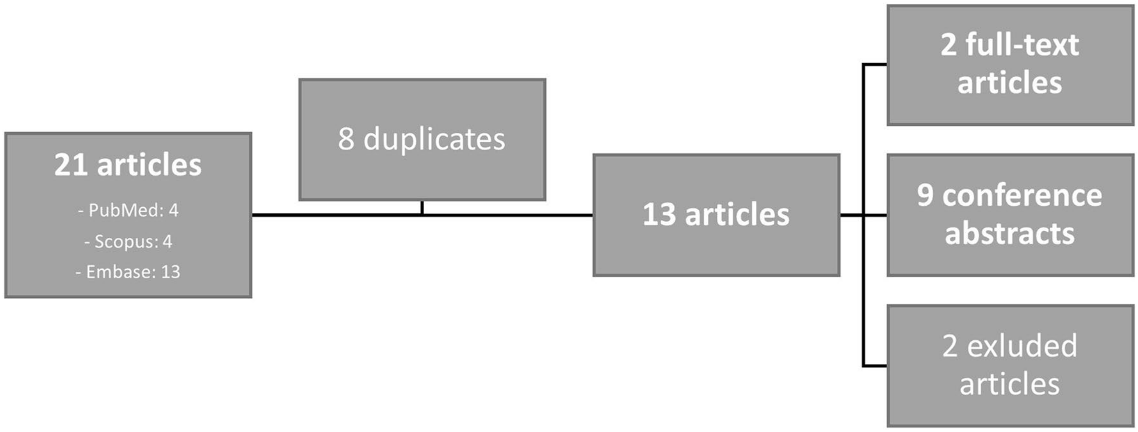

Fig. 1 The search strategy of the medical literature databases

day-to-day practice is too harsh, since it has the ability to create a common language, with full sentences describing all the important details of the BDI, a task that the other classification systems have failed at.

A big advantage of the ATOM classification is the fact that it highlights the time of detection of the BDI—only 9% of cases were identified intraoperatively, most of the cases being identified in the early postoperative period (72%), with an important percentage (19%) of patients being diagnosed late after the LC. Regarding the BDI detected intraoperatively, one was done in our clinic, with immediate treatment, while the other 8 were done in other hospitals; in 6 patients, a first treatment was done in the primary hospital and needed definitive treatment in our institution. The current guidelines recommend that the treatment of a BDI should not be conducted by the primary surgeon and should be instead managed by an experienced hepatobiliary surgeon, with better results [25]. Our data reiterates this idea, since we have encountered in our series that these six cases in which a reintervention was needed in our department, after a primary treatment attempt. Moreover, an important percentage (31%) of the admitted cases in our center had a surgical or interventional procedure performed in the hospital in which the LC was done; all of them needed reintervention in our department, for a definitive treatment of the BDI.

Regarding the level of the injury, most injuries were located either on the nonmain bile ducts (24%), either on the low—type 1 (29%) and middle—type 2 (23%) portion of the main bile duct. Higher lesions were less common, especially lesions on the left or right hepatic ducts, which were exceptions. The prevalent mechanism of injury was mechanical (84%), especially in main bile duct lesions; in nonmain bile duct injuries, the mechanical mechanism still prevailed, but energy driven lesions also had an important part. The type and extent of the BDI varied greatly, but the injuries with loss of substance were the least frequent (6%).

Six patients had associated vascular injuries: 1 had an injury at the level of the common hepatic artery (MBD 2), 3 had an injury at the level of the right hepatic artery (MBD 3 in 3 cases and MBD 2 in one case), while 2 others had lesions of the cystic artery (MBD 3 and NMBD). Given the fact that no type 1 lesion was associated with vascular lesions, we can observe that higher injuries on the main bile duct are at risk of associating vascular injuries (Fig. 1).

Avoiding a correct classification of BDI creates confusion especially when discussing the adopted definitive treatment. For each scenario, when a complete and correct description of the BDI is done, a preferred treatment, which offers the best results, can be identified. Nonmain bile duct injuries were treated either endoscopically, through sphincterotomy and bile duct stenting or by primary closure of the bile duct; a few well-selected cases (subhepatic drainage placed during the LC still in place with low-debit biliary leakage) could be managed conservatively, but with a careful monitorization. Bilio-digestive anastomosis was the treatment of choice in most main bile duct injuries, with bile duct stenting through ERCP being an option for a few selected cases of type 1 injuries. In 2 of the cases with type 1 injuries of the MBD, a primary treatment with bile duct stenting through ERCP was performed in the hospital in which the BDI was done, with insufficient control of the problem; however, an ERCP with a bile duct stenting in our center was the definitive treatment of the BDI. This shows that non-operative treatments should not be too quickly dismissed, and an ERCP procedure in a tertiary center might be worth a try in the pursuit of avoiding major surgery.

The literature review on the use of the ATOM classification showed scarce results, with only two full-text articles. Both studies [14, 15] clearly prove the utility of the ATOM system in providing a common language when discussing BDI, while showing that it encompasses all the important details for describing a BDI.

Our study has the advantage of analyzing a large number of patients, treated in a tertiary center by experienced biliary surgeons—we used the ATOM classification and each of its aspects to guide our retrospective analysis, therefore, proving once again the complexity and utility of this classification. The retrospective design, with the retrospective classification of the BDI, is the biggest limitation of our study; however, we hope that the positive results shown on this retrospective analysis will encourage other centers not only to adopt the routine use of the ATOM classification, but to also conduct prospective studies on the topic.

Conclusion

The EAES ATOM classification is an exhaustive classification system that is able to grasp the complexity of BDI, assuring the standardization of definitions and offering a good template for discussing the correct management of BDI. However, its complexity brings skepticism in the adoption of this classification in routine surgical practice; tertiary centers that specialize in treating hepatobiliopancreatic diseases should make efforts in adopting the use of the ATOM classification.

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