

Endoscopic retrograde cholangiopancreatography induced splenic injury: comprehensive analysis and new perspectives based on a case report

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Abstract: Splenic injury is an extremely rare complication of endoscopic retrograde cholangiopancreatography (ERCP). There are only 34 cases reported in the literature up to now. Based on a case of a 72-year-old man, who after ERCP due to choledocholithiasis developed a large perisplenic and subcapsular hematoma, we carried out an extensive review of all cases of ERCP-induced splenic injury found in the literature. We searched PubMed/Medline and Google Scholar till 15 April 2023, for published case reports and series using the following terms: splenic injury after ERCP, ERCP-induced splenic injury, and post-ERCP splenic trauma. The case reports included were in English, Spanish, and German literature. We attempt to discuss the possible clinical image, the available diagnostic methods, the potential treatment alternatives, and predisposing factors related to this entity. Furthermore, a theory of a possible mechanism of this injury is discussed and supported schematically. The ERCP-induced splenic injury is rare and a high index of suspicion is needed for diagnosis. Therefore, we present two diagnostic algorithms, which according to our opinion may assist the evaluation of this complication and lead to early accurate diagnosis and appropriate management. Collectively, our findings support that although ERCP-induced splenic injury is an unexpected/unusual complication of ERCP, following the proper steps can be timely diagnosed and treated.

Keywords: endoscopic retrograde cholangiopancreatography, endoscopy, ERCP complications, hemoperitoneum, splenic injury, splenic trauma

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Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) is a golden standard, renowned, world widely applied technique used for the diagnosis and treatment of a wide range of hepatobiliary and pancreatic disorders. Over the years, and despite the undoubtable benefits, ERCP as an interventional procedure has been reported to be associated with complications. Some of the reported complications are very common (acute pancreatitis, infection, hemorrhage, and duodenal perforation)¹ while others are more infrequent, such as cardiovascular or anesthesia-related effects/complications,² pneumothorax, hepatic

hematoma, and air embolism.³ Splenic injury is a rare complication that should be taken into consideration and included in differential diagnosis. Post-ERCP splenic injury was first reported by Trondsen *et al.*⁴ in 1989 and only 34 cases have been reported since then. To the best of our knowledge, no one has tried to speculate a step-by-step approach to explain the mechanism of the injury.

Methods

We searched PubMed/Medline and Google Scholar till 15 April 2023, for published case

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Figure 1. Dilated common bile duct and hepatic ducts in pre-operative evaluation with MRCP. Arrows are pointing at two gallstones in the common bile duct (choledocholithiasis). MRCP, magnetic resonance cholangiopancreatography.

reports and case series using the following terms: ‘splenic injury after ERCP’, ‘ERCP-induced splenic injury’, ‘post-ERCP splenic trauma’. The case reports included were in English, Spanish, and German literature. We further searched the bibliography of each published case to find relevant studies. The patient provided written informed consent for the anonymous publication of his medical data and images, so all personal patient details were de-identified. The reporting of this study conforms to the CARE statement.⁴⁶

Case

A 72-year-old man was admitted to the hospital with right upper quadrant pain and jaundice. His

past medical history was unknown. Laboratory tests and imaging evaluation were consistent with acute cholecystitis due to choledocholithiasis accurately depicted with magnetic resonance cholangiopancreatography (Figure 1). An ERCP was followed, with relative ease, and no difficulties and complications were noticed. ERCP confirmed the diagnosis and combined it with endoscopic retrograde stone removal and sphincterotomy. Immediately after the intervention, the patient complained of left upper quadrant pain. Furthermore, the patient became hypotensive, developed tachycardia, and a hemoglobin and hematocrit drop was noticed (from 10 to 8.1 mg/dL and from 29.5% to 24.5%, accordingly). Mild leukocytosis was present. Serum amylase was normal and total bilirubin had been decreasing. The following abdominal ultrasound scan revealed free peritoneal fluid perisplenic, subdiaphragmatic as well as subhepatic with some echogenic foci, especially in the splenonephric pouch (Figure 2). As stone removal and sphincterotomy were uneventful, all the above raised the suspicion of splenic laceration. A CT scan with intravenous contrast administration confirmed hemoperitoneum due to splenic rupture with subcapsular and perisplenic hematoma as well as active bleeding (Figure 3). No other visceral organ or other pathology was found. A splenectomy was performed and the patient was resuscitated with blood transfusion and blood products. The postoperative course was uneventful and the patient was discharged 10 days after in good condition.

Discussion

Splenic injury following ERCP is considered to be a rare complication. Up to now, a total number of



Figure 2. Ultrasound images: (a) perisplenic fluid with internal echoes (star), (b) subhepatic/perihepatic fluid with internal echoes (star), and (c) air-filled intrahepatic bile ducts (arrow). gb, gallbladder; pt, pancreatic tail; s, spleen.

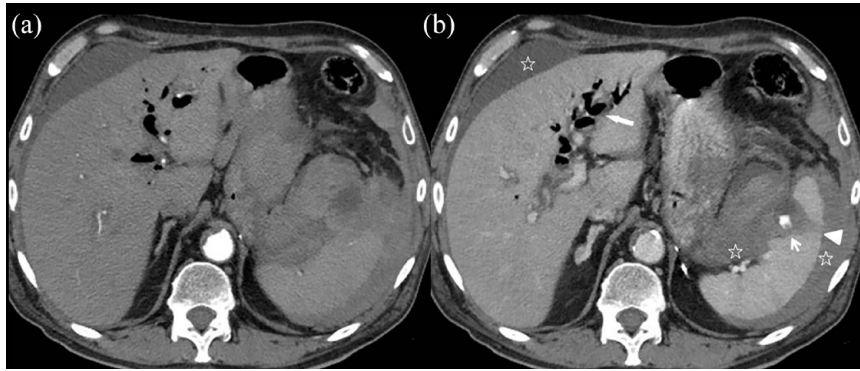


Figure 3. Contrast-enhanced CT scan: (a) arterial phase and (b) venous phase. Stars, intra-abdominal free fluid (perihepatic and perisplenic); thick arrow, air-filled intrahepatic bile ducts; thin arrow, splenic active bleeding; triangle, splenic capsule rupture.

34 cases have been reported in the literature with female predominance (n : 21). The age of the patients differs from 29 to 86 years old (mean age: 58.8). We created two tables (Tables 1 and 2) based on CT *versus* non-CT first approach, where we refer information about each of these cases such as age, gender, type of intervention, time to symptoms onset, clinical presentation and blood test results, imaging findings, laparotomy and pathologic findings, type of treatment, risk factors and difficulties, and other noteworthy data.

The symptoms that are related to post-ERCP splenic injury include progressive left upper quadrant pain radiating to the back and/or left shoulder, peritoneal irritation, tachycardia, hypotension, marked abdominal distention, vague tenderness, paleness, nausea, vomiting, and shock. Weaver *et al.*⁵ also describe numbness in the patient's leg and absent Doppler signal probably due to hypotension induced by splenic injury and the patient's severe arterial disease. Furman and Morgenstern⁶ and Subramanian *et al.*⁷ reported that the pain was confused with the pain of pancreatitis and thus high awareness is needed. Grammatopoulos *et al.*⁸ mentioned that tachycardia was absent from their patient despite the patient's intra-abdominal bleeding probably due to previous β -blockers treatment. Hemoglobin and hematocrit drop, rise in inflammatory markers and in some cases, mild leukocytosis were referred. The time interval between ERCP and the first symptom appearance is also worth mentioning. In most cases, symptoms appeared immediately after ERCP or a few hours postoperatively but in some cases, symptoms appeared 1, 2,^{9,10} 4 days later,¹¹ or even 6 days later.¹² The

later the symptoms appear, the higher the index of suspicion needed to achieve the correct diagnosis.

In the literature cases, after a physical examination and laboratory tests, 27/34 patients had an abdominal CT scan conducted. Only in 5/34 cases,^{9,13–16} instead of a CT scan, laparotomy was performed, with abdominal exploration leading to the diagnosis. Two patients revealed hemoperitoneum and splenic bleeding unexpectedly when they were prepared for laparoscopic surgery after ERCP.^{17,18} In four cases^{4,16,19,20} (as in our case), abdominal ultrasound was also used with good results. Based on our case, we might suggest the use of ultrasound especially in hemodynamically stable patients. Another potentially useful diagnostic tool that is increasingly used with great results in abdominal trauma is contrast-enhanced ultrasound (CEUS).²¹ In CT scans, findings include free abdominal fluid, splenic rupture and/or laceration, subcapsular hematoma, and capsular avulsion. In two cases,^{7,22} CT scan was not diagnostic for splenic injury. In the first case, one more CT scan was needed 24 h after the first to reveal the free fluid and the splenic rupture and in the second case CT scan was suggestive of post-procedure pancreatitis. Even CT scan is considered the golden standard someone must keep in mind that sometimes it might not highlight the real cause of the symptoms. Laparotomy and pathological findings in the vast majority of cases came to confirm the CT findings.

In 24/34 cases, splenectomy was performed. In the rest^{6,7,10,12,23–25} (7/34), conservative management with frequent follow-ups (with CT while

Table 1. Literature review of cases with post-ERCP splenic injury with CT used as the first approach.

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	CT findings	Pathologic findings	Therapy	Risk factors and difficulties
Agarwal, <i>J Belg Soc Radiol</i> , 2022	63, M	ERCP, sphincterotomy, hilar stricturoplasty, stenting	4 days	Severe LUQ abdominal pain, hypotension, altered mental status, anemia	Subcapsular splenic hematoma with active contrast extravasation, hemoperitoneum	Splenic hematoma, hemoperitoneum	Splenic artery embolization	The patient's history is unknown, and no information was given about ERCP's difficulty and duration
Cebrián García, <i>J Gastroenterol Hepatol</i> , 2021	83, M	ERCP, sphincterotomy, stent placement	6 h	Hemodynamically unstable, Hct drop	Hemoperitoneum, splenic rupture, perisplenic hematoma	2 L hemoperitoneum, spleen with notable vascular congestion in contiguity with a partially organized hematoma and a bloody surface at the level of the splenic hilum, splenic rupture	Splenectomy	History of bulbar stenosis, difficulty accessing the papilla due to the described bulbar stenosis, greater exploration time with greater endoscopic manipulation
Nasereddin, <i>Am J Gastroenterol</i> , 2020	86, M	ERCP, sphincterotomy, stenting	6 h	Altered mental status, unresponsive, abdominal tenderness, low BP, bradycardia, decreased bowel sounds, Hgb drop	Active hemorrhage along the posteromedial aspect of the spleen with adjacent blood, hemoperitoneum	Splenic laceration and decapsulation	Splenic artery embolization	Uneventful ERCP, unknown surgical history
Bajwa, <i>J Clin Gastroenterol Treat</i> , 2020	83, F	ERCP, sphincterotomy	The following day	Hgb drop, stable vital signs	Grade 3 splenic laceration with intraparenchymal and subcapsular hematoma with moderate peritoneal free fluid	Grade 3 splenic laceration with intraparenchymal and subcapsular hematoma with moderate peritoneal free fluid	Conservative	Prior appendectomy, cholecystectomy and ventral hernia repair, use of anticoagulants
Lubikowski, <i>Eur J Gastroenterol Hepatol</i> , 2020	31, F	ERCP and biliary stenting twice	After procedure	Severe upper abdominal pain with Hgb drop	Huge perisplenic fluid collection, splenic rupture	Spleen rupture (major splenic injury)	Splenectomy	Previous abdominal surgery (left hepatectomy), suboptimal sedation on second ERCP resulting in patient discomfort, non-compliance, and abrupt movements against the endoscope (ERCP conducted on left lateral position)
Wang, <i>Laparosc Endosc Robot Surg</i> , 2020	74, F	ERCP, endoscopic nasobiliary drainage	3 h	Dizziness and excessive sweating without abdominal pain, no abdominal tenderness, tachycardia, hypotension, a notable Hgb drop	Large hemoperitoneum and contrast extravasation in the spleen, U/S findings: significant amount of ascites, intra-abdominal bleeding was suspected	Multiple lacerations with active bleeding on the aspect gastrosplenic ligament of the spleen, hemoperitoneum (3L). Histology: splenic laceration	Splenectomy	Difficult cannulation because of papillary edema, the endoscope was bowed in the long position to obtain successful cannulation, previous open cholecystectomy and open cholangiography, intra-abdominal adhesions noted on exploration (ERCP in prone position)

(Continued)

Table 1. (Continued)

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	CT findings	Pathologic findings	Therapy	Risk factors and difficulties
Pamudurthy, <i>Endosc Int Open</i> , 2018	60, F	ERCP, sphincterotomy, stent placement	8 h	Sharp epigastric pain radiating to the left shoulder and chest, hypotension, Hgb drop	Large left perisplenic hematoma consistent with acute hemorrhage in the region of the splenic hilum, displacement of the spleen inferiorly, moderate amount of abdominal and pelvic ascites consistent with hemorrhage	Decapsulated spleen with splenic rupture (splenic capsular avulsion), 3L of hemoperitoneum, and clots	Splenectomy	No potential etiological factors or technical difficulties with the procedure
Al Momani, <i>J Investig Med High Impact Case Rep</i> , 2018	44, F	ERCP, sphincterotomy	Few hours postoperatively	Severe epigastric and LUQ abdominal pain radiating to the back, hypotension, Hgb drop	Large splenic subcapsular hematoma and peripancreatic stranding	Large splenic subcapsular hematoma	Conservative	Patient with a gastric sleeve (gastrectomy) and remote laparoscopic cholecystectomy
Lee, <i>Case Rep Gastroenterol</i> , 2017	59, F	ERCP, stenting	4 h	Hypotension, no abdominal pain, no abdominal tenderness, or signs of peritonitis, the next morning Hgb drop	Peri-splenic hematoma and moderate volume of hemoperitoneum	Peri-splenic hematoma and hemoperitoneum	Conservative	Previous ERCP and stenting, hepatitis C without cirrhosis, alcohol abuse, previous laparotomy for ovarian cystectomy, intravenous drug use, the procedure was technically difficult requiring a sustained long scope position to achieve biliary cannulation and stent placement, Mirizzi syndrome, adhesions from prior abdominal surgery
Montenovo, <i>Exp Clin Transplant</i> , 2017	41, F	ERCP, papillotomy (sphincterotomy), stenting	Mild symptoms in the recovery room, 8 h later more serious symptoms	Hypotension, tachycardia, Hct drop, tenderness in the epigastrium, and LUQ of the abdomen	Large subcapsular splenic hematoma with a significant amount of ascites but no hemoperitoneum	Big subcapsular hematoma on the dome of the spleen, and the stomach was compressed between the large spleen and the left lobe of the liver	Embolization of the splenic artery and splenectomy	History of end-stage liver disease and uneventful orthotopic liver transplant, ascites, large spleen, difficulty for abdominal re-exploration secondary to the potential amount of adhesions
Ahmad, <i>Clin Case Rep</i> , 2016	76, M	ERCP, sphincterotomy, balloon trawl	30 min	Abdominal pain, tachycardia, hypotension, tender epigastrium, Hgb drop	Hemoperitoneum	Capsular tear in the splenic hilum, subcapsular hematoma, hemoperitoneum, and clots along with fresh bleeding	Splenectomy	No difficulty was reported, normal sized spleen
Weaver, <i>Am Surg</i> , 2014	66, M	ERCP (for intra- and extrahepatic duct dilation)	Overnight	Hypotension at night, next morning the patient reported numbness in his left leg, no Doppler signals below his femoral pulse, and unable to move or feel his left foot	Large perisplenic hematoma with significant hemoperitoneum (severe arterial disease)	Evacuation of 1.5L blood from the abdomen, perisplenic hematoma	Splenectomy	Fibrosis from chronic pancreatitis

(Continued)

Table 1. (Continued)

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	CT findings	Pathologic findings	Therapy	Risk factors and difficulties
Grammatopoulos, <i>Ann Gastroenterol</i> , 2014	64, M	ERCP, stent placement	6 h	Epigastric pain, soft abdomen with mild tenderness over the epigastrium and the LUQ without peritoneal signs, Hgb drop, mild leukocytosis, absence of tachycardia due to β-blocker treatment	Homogeneous mass lesion of the left subdiaphragmatic region (splenic hematoma), hemoperitoneum	Rupture at the splenic hilum	Splenectomy	Prolonged procedure [(1) to bypass the duodenal stenosis a balloon dilatation was necessary, (2) to achieve cannulation of the bile duct, prolonged manipulations of the side-view endoscope within the edematous and deformed duodenum had to be performed], mass at the head of the pancreas, duodenal stenosis
Geddoia, <i>CRSLS MIS Case Rep SLS</i> , 2014	75, M	ERCP, stenting, sphincterotomy	Next morning	Dizziness, altered level of consciousness, state of shock (hypotension and tachycardia), Hgb drop, and inflammatory markers were raised	Splenic rupture and abdominal free fluid	Splenic capsular tear with a large amount of hemoperitoneum but no injury to the splenic hilum. Histology: splenic capsular rupture (13 mm)	Splenectomy	Multiple OGDs and ERCPs (2), challenging ERCP because of looping of the endoscope in the stomach and a subsequent inability to reduce the loop, inflammatory pyloric stenosis
Geddoia, <i>CRSLS MIS Case Rep SLS</i> , 2014	72, F	ERCP	Soon after her ERCP procedure	Acute onset of dull and constant abdominal pain associated with nausea and vomiting, mild tenderness in the LUQ with muscular guarding and evidence of peritonism, Hgb low, inflammatory markers were raised	The first CT was clear, second CT after 24+ h showed free intrapertoneal fluid and a ruptured spleen	Full-thickness laceration at the inferior pole with active blood oozing, no vascular injury at the splenic hilum, large amount of free blood and clots. Histology: stripped splenic capsule	Splenectomy	Recorded as difficult because the patient was restless during the procedure, no technical difficulties during the procedure
Gaffney, <i>Case Rep Gastroenterol</i> , 2012	48, M	ERCP, stent exchange	6 days	Progressive localized LUQ abdominal pain, Hgb drop, no tachycardia or hypotension, vague tenderness along the LUQ with radiation to the left shoulder	Splenic laceration with associated subcapsular hematoma	Splenic laceration with associated subcapsular hematoma	Conservative	Chronic alcoholic pancreatitis, common bile duct stricture, previous pancreatic duct stent, multiple previous ERCPs, ampullary cannulation was performed without difficulty, extensive pancreatic calcifications (and dilated common bile duct)
Taheri, <i>SAGES</i> , 2011	55, F	ERCP, sphincterotomy	12 h	Generalized abdominal pain soon after the procedure, hypotension, tachycardia, rigid abdomen, Hgb drop	A large amount of free fluid, capsular avulsion of the spleen	Ruptured spleen	Splenectomy	Past medical and surgical history and cholecystectomy 6 days ago
Cortiñas Sáenz, <i>Rev Española Enfermedades Dig Organo of Soc Española Patol Dig</i> , 2010	82, F	ERCP	Immediately after ERCP	Hemodynamic and respiratory unstable	2 L hemoperitoneum, hyperdense area on the anterior pole of the spleen, free intra- abdominal fluid mainly on perisplenic region	Splenic rupture (histology: splenic laceration)	Splenectomy	ERCP was recorded as difficult; ERCP's duration was 150 min, use of anticoagulants

(Continued)

Table 1. (Continued)

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	CT findings	Pathologic findings	Therapy	Risk factors and difficulties
Subramanian, SAGES, 2009	29, F	ERCP, sphincterotomy, choledocholithotomy	Post-procedure	Abdominal pain, thought it was postoperative pancreatitis	No CT findings (the diagnostic workup was suggestive of post- procedure pancreatitis)	Hemoperitoneum, 2–3 cm tear in the capsule of the spleen. Tear had been contained completely with the clot and omentum and there was no evidence of bleeding at this point	Conservative	ERCP without difficulties, suspected gallstone pancreatitis when referred
Cho, <i>Hong Kong Med J</i> , 2008	63, F	ERCP, papillotomy	18 h	Hypotension, epigastric pain, nausea, mild epigastric and LUQ tenderness without peritoneal signs, shock, Hct drop, absence of tachycardia due to β - blocker treatment	Large hemoperitoneum and extravasation of contrast in the splenic region	4 L of fresh blood and clots, active bleeding from a laceration on the superoposterior aspect of the spleen, this quarter completely avulsed from the rest of spleen. Histology: splenic tear and subcapsular hematoma but otherwise normal spleen	Splenectomy	Difficulties when trying to cannulate the common bile duct, the pancreatic duct was the only duct successfully cannulated, the endoscope was bowed in the 'long' position in an attempt to cannulate the common bile duct, features of chronic pancreatitis, no adhesions were noticed despite previous laparotomy
Dixon, <i>JSLs</i> , 2004	38, M	ERCP (investigation for LUQ abdominal pain, acute exacerbation of alcohol-induced chronic pancreatitis)	Immediately after ERCP	LUQ abdominal discomfort with associated left shoulder tip pain, tachycardia, vague tenderness, and later signs of peritonitis	Large amount of free fluid surrounding both the liver and spleen, and no evidence of solid organ splenic or liver injury	Major splenic capsular tear/disruption (the spleen was of normal size and consistency, with no evidence of splenomegaly or splenic vein thrombosis), 2000 cc of hemoperitoneum	Splenectomy	ERCP was technically difficult (pancreatogram could not be obtained), dense adhesions between the tail of the pancreas, the stomach, and the spleen as well as the transverse colon and splenic flexure (these adhesions were the result of chronic pancreatitis), alcohol- induced chronic pancreatitis, intervention for a <i>prior</i> pseudocyst (percutaneously drained)
Zyromski, <i>Am Surg</i> , 2004	33, F	ERCP, sphincterotomy	First post-ERCP day	Epigastric and LUQ pain with tenderness, tachycardia. 3.5 days later: hypotension, syncopal episode, palleness, tachycardia, signs of diffuse peritonitis, Hgb drop	Large hematoma on the LUQ and a large amount of free fluid in the abdomen	2.5 L of blood, active bleeding from the upper pole of the spleen and proximal greater curvature of the stomach, avulsion of short gastric vessels	Splenectomy	Past medical history was unremarkable, ERCP was not noted to be remarkably difficult, laparoscopic cholecystectomy 2 days ago reported to be difficult because of a short cystic duct and intrahepatic gallbladder
Deist, <i>Z Gastroenterol</i> , 2003	52, F	ERCP, sphincterotomy	8 h	Cramp-like upper abdominal pain without peritoneal signs, the next morning laboratory tests showed the acute hemorrhage, Hgb, and Hct drop	CT for pancreatitis suspicion showed perisplenic and perihepatic fluid, U/S showed free abdominal fluid	Splenic rupture	Splenectomy	History of pyelonephritis and cholecystectomy

(Continued)

Table 1. (Continued)

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	CT findings	Pathologic findings	Therapy	Risk factors and difficulties
Kingsley, <i>JSL</i> , 2001*	54, F	ERCP with stent revision for pancreas divisum	24 h	Hypotension with marked abdominal distension	Ruptured spleen	Splenic rupture associated with massive hemoperitoneum	Splenectomy	Hepatitis C, cirrhosis, chronic pancreatitis, previous pancreatic stenting for pancreas divisum
Lo, <i>Surg Endosc</i> , 1994	79, M	ERCP, sphincterotomy	48 h	Severe LUQ pain, Hgb drop in the 72 h between ERCP and the CT scan but hemodynamically stable	Large splenic subcapsular hematoma	Large splenic subcapsular hematoma	Conservative	(Small residual gastric pouch), Billroth I anastomosis 14 years ago, previous subtotal gastrectomy may have resulted in adhesion formation
Furman, <i>Surg Endosc</i> , 1993	63, F	ERCP, papillotomy	Following the papillotomy, a CT scan for pancreatitis was done that showed the hematoma	Abdominal pain that was masked or confused with the pain due to pancreatitis	10-cm lateral subcapsular splenic hematoma, 10 days later splenic abscess and splenic subcapsular collection increased to 15 cm displacing the spleen medially	Subcapsular splenic hematoma, the splenic injury was further complicated by splenic abscess	Conservative, abscess percutaneous drainage	No obvious predisposing factor, nor was there any difficulty reported during ERCP. Authors suggest that it is possible that a branch of one of the highest of the short gastric vessels (which according to the author are the shortest) was stretched and torn as it entered the splenic capsule, previous cholecystectomy, pancreatitis after ERCP
Trondsen, <i>Acta Chir Scand</i> , 1989	46, F	ERCP (for evaluation of acute pancreatitis), sphincterotomy	5 or 15 h (ambiguity of the literature)	LUQ pain	Splenic rupture, U/S was also used	Splenic rupture/ decapsulated spleen (histologically normal), hemoperitoneum	Splenectomy	Acute pancreatitis and manipulation of the patient on the X-ray table, patient obese and heavy, difficult cannulation, ERCP reported as 'difficult'

*Died on postoperative day 40 of multiple organ failure.

BP, blood pressure; ERCP, endoscopic retrograde cholangiopancreatography; Hct, hematocrit, Hgb, hemoglobin; LUQ, left upper quadrant; CT, Computed Tomography; OGD, oesophago-gastro-duodenoscopy.

Table 2. Literature review of cases with post-ERCP splenic injury with a non-CT first approach.

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	First approach	Pathologic findings	Therapy	Risk factors and difficulties
Polman, <i>Case Rep Gastroenterol</i> , 2020	52, M	ERCP, stenting	Bleeding found by chance observation during surgery immediately after ERCP	Hypotension, Hgb drop (first time after the arrival on the ICU and overnight (second time))	Diagnosis made unexpectedly at the laparoscopic surgery after ERCP*	Hemoperitoneum, disruption of the anterior and superior splenic poles	Splenic artery embolization	Difficulty in cannulating hepato-pancreatic ampulla, requiring a prolonged procedure time
Villalobos-Garita, <i>Endoscopy</i> , 2014	74, M	ERCP, sphincterotomy	2 h	Hypotension, mild diffuse abdominal pain, and mild abdominal distention without peritoneal signs, 4 h later Hgb drop	Abdominal U/S (findings: large intraperitoneal fluid around liver and spleen, important gas distention)	2 L of hemoperitoneum and multiple clots, decapsulated spleen with large clots, and active bleeding from a laceration	Splenectomy	Mild pancreatitis with grade of severity Balthazar C without necrosis, changes in peripancreatic fat tissue, cannulation without difficulty (pancreatitis may lead to calcification and fibrosis of the supporting ligaments of the spleen)
Paredes, <i>Endoscopy</i> , 2013	39, F	ERCP, sphincterotomy, stenting	1 h	Tachycardia, hypotension, persistent abdominal pain, Hgb drop	Emergency laparotomy	4-cm angled laceration at the apex of the spleen, >1 L of fresh blood and clot in the LUQ of the abdomen	Splenectomy	Smaller than usual intra-abdominal cavity, limiting the amount of space available during the normal maneuvers that transmit pressure and force across the greater curvature of the stomach, technically difficult laparoscopic cholecystectomy due to adherent omentum 3 days ago complicated also by bile leak (initial attempts of cannulation selectively cannulated the central pancreatic duct, which was deeply cannulated after repositioning of the cannula), ERCP 90 min
Badaoui, <i>Can J Anaesth</i> , 2002	42, M	ERCP (intermittent epigastric pain)	20 min	Diffuse abdominal pain soon after the procedure, hypotension but treated, 1 h later hypotension again and Hct drop	Emergency laparotomy	Splenic laceration, hemoperitoneum (2 L)	Conservative surgery-splenectomy	Past medical history was unremarkable, and ERCP performed with relative ease

(Continued)

Table 2. (Continued)

Study	Age, years/ gender	Intervention	Time to symptoms	Symptoms and blood tests	First approach	Pathologic findings	Therapy	Risk factors and difficulties
Wu, <i>Gastrointestinal Endosc</i> , 1993	57, F	ERCP (concern for choledocholithiasis or obstructive lesion)	60 h	Progressive LUQ abdominal pain radiating to the back and left shoulder, over 8 h-period shock, peritoneal irritation, Hgb, and Hct drop	Emergency laparotomy	A large amount of hemorrhagic fluid in the LUQ and lesser sac. The spleen was completely avulsed from the capsule, which was attached to the anterior abdominal wall. Furthermore, hepatic laceration was found	Splenectomy	Common bile duct cannulation was challenging and required numerous attempts. Previous cholecystectomy, lysis of abdominal adhesions that had resulted in partial small bowel obstruction, pelvic surgery for a tubal pregnancy, adhesions were noted during laparotomy, obese patient, at the time of ERCP patient had undiagnosed liver disorder, type of endoscope used, use of anticoagulants, patient was changed from left lateral to prone position during ERCP
Ong, <i>Endoscopy</i> , 1991	55, F	ERCP (intermittent epigastric pain)	Diffuse abdominal pain after the procedure but considered non-significant, 2 days after ERCP found	Diffuse abdominal pain, vital signs, and physical examination were unremarkable	Diagnosis made by chance observation during surgery for the primary disease condition	Old and fresh blood was found in the abdomen, and splenic laceration was the source of bleeding	Splenectomy	First ERCP failed: cascade stomach predisposes to looping of the lateral viewing instrument, obese patient
Lewis, <i>Gastrointestinal Endosc</i> , 1991	63, F	ERCP (distal common bile duct stricture and biopsies of duodenal mass/pancreatic mass), stent placement	Hypotension after 20 min, 9 h later found	Hypotension, 9 h later Hct was found at 18%	Emergency laparotomy	Avulsion of the short gastric vessels from the splenic hilum, hemoperitoneum (2L)	Splenectomy	Bowing of the endoscope in the stomach during attempts to pass the large endoscopes through the narrowed duodenum (pancreatic head mass), attempt to cannulate the papilla on the long position

*Post-procedural CT of the abdomen and pelvis was conducted showing a large splenic hematoma. BP, blood pressure; ERCP, endoscopic retrograde cholangiopancreatography; Hct, hematocrit; Hgb, hemoglobin; LUQ, left upper quadrant.

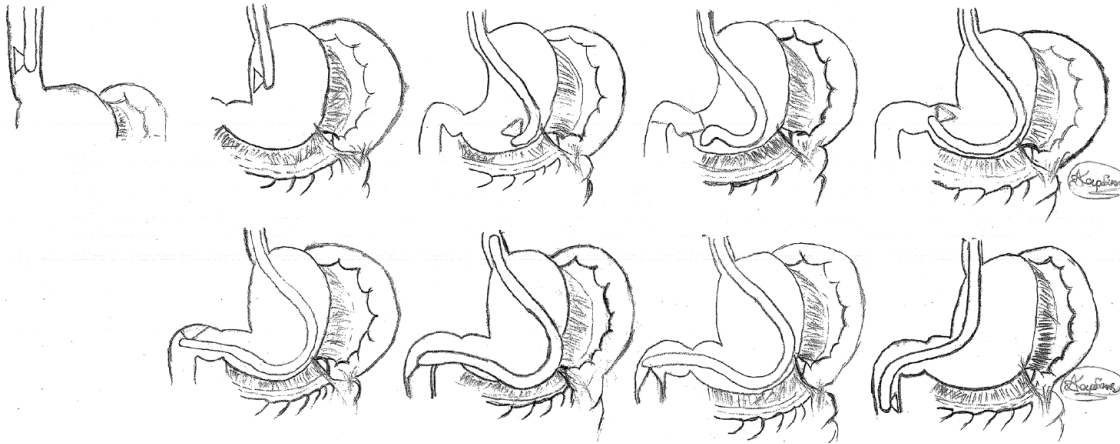


Figure 4. Illustration of the process approaching the ampulla of Vater during ERCP. Step-by-step approach from the esophagus to the ampulla of Vater and endoscope's maneuvers are recognized.

CEUS could be a promising alternative method)²¹ was followed due to the patients' hemodynamically stable condition. Recently, the evolvement of interventional radiology broadened the horizons of trauma management with selective splenic artery embolization in hemodynamically stable patients playing an important role in post-ERCP splenic injury. Selective splenic artery embolization was used in four cases (4/34).^{11,18,26,27} Montenegro *et al.*²⁶ used splenic artery embolization as a bridge therapy for splenectomy while Polman *et al.*¹⁸ used it as final treatment.

The exact cause of splenic injury during ERCP remains unknown. A possible mechanism is the endoscope passing maneuvers (Figure 4), which transmit direct forces to the spleen through the gastrosplenic ligament as speculated by the majority of the authors.

Forces during ERCP

In Figure 5(a) (scheme), the distal tip of the endoscope is facing the upper wall of the duodenum. After rotating the scope, the distal tip is now facing the second part of the duodenum, allowing us to locate the ampulla of Vater [Figure 5(b) scheme]. The scope's rotation creates torque/rotational force which is perpendicular to the plane of F_A . Torque/rotational force is defined as $\tau = F_A * r$, where F_A is the force applied on the stomach wall by the scope and r is the radius of the insertion tube, since it is in direct contact with the stomach wall. With that rotation, the insertion tube of the endoscope which is already in contact with the greater curvature of the stomach

in the 'long scope' position, applies F_A on the stomach wall. This force is transmitted across the greater curvature of the stomach, to the gastrosplenic ligament. The total force transmitted to the gastrosplenic ligament by the stomach is

$$F_{\text{lig}} = \sqrt{F_{\text{stom}}^2 + F_A^2 + 2 * F_{\text{stom}} * F_A * \cos\varphi^\circ}.$$

The forces that are applied to the spleen's steady state are as follows: F_{spl} (spleen), F_{col} (colon), F_{dia} (diaphragm), and F_{ren} (renal). With this new transmitted force, the total force (F_{tot}) applied to the spleen by the gastrosplenic ligament is $F_{\text{tot}} = \sqrt{F_{\text{spl}}^2 + F_{\text{lig}}^2 + 2 * F_{\text{spl}} * F_{\text{lig}} * \cos\theta^\circ}$. This force causes the avulsion of the splenic vessels in the splenic hilum.

Predisposing factors

From all reviewed cases, many predisposing factors are referred to play an important role in post-ERCP splenic injury. These factors include altered anatomy from previous major surgeries such as left hepatectomy,²⁸ sleeve gastrectomy,²⁴ liver transplant,²⁶ Billroth I gastrectomy,¹⁰ or other anatomic reasons such as cascade stomach¹⁷ and small intra-abdominal cavity,¹⁵ pancreatic head masses^{8,13} and duodenal masses narrowing the duodenum lumen, pyloric stenosis,^{8,22,29} and requirement of prolonged loop position to achieve cannulation.²⁵ The referred factors act by reducing the available space for endoscopic movements, increasing the duration of ERCP, multiplying the number of maneuvers needed for

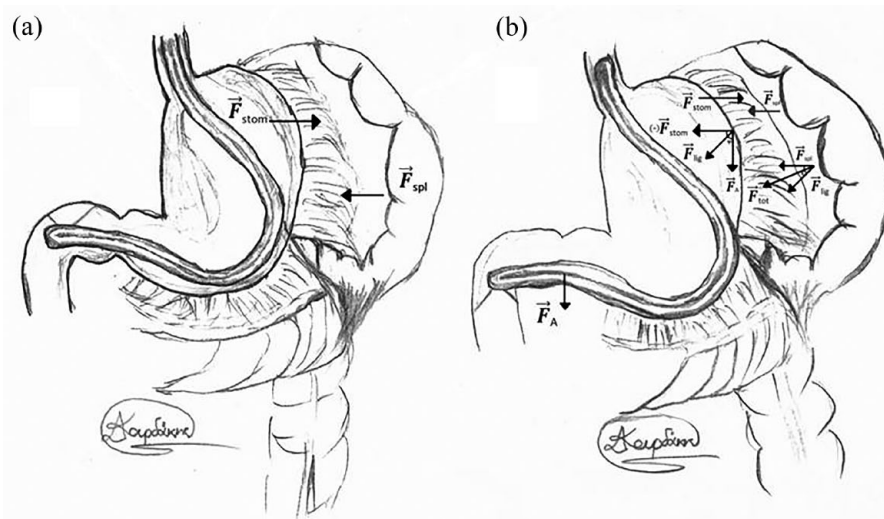


Figure 5. Illustration of the forces exerted before (a) and after (b) the rotation of the endoscope in 'the long scope' position
 \vec{F}_{spl} , force applied by a gastrosplenic ligament to the spleen; \vec{F}_{stom} , force applied by a gastrosplenic ligament to the stomach
 $[F_{col}$, force applied by a splenocolic ligament to the spleen; F_{dia} , force applied by a phrenicocolic ligament to the spleen;
 F_{ren} , force applied by a splenorenal ligament to the spleen. These forces are not shown in the figure because the stomach–ligament–spleen is considered a closed system for simplification purposes].

the proper cannulation, and increasing the direct forces transmitted to the surrounding tissues resulting in increased chances of a splenic injury. Moreover, the anticoagulation therapy^{9,23,27,30} (4/34) and stomach insufflation/overinflation during ERCP^{6,31} appear to escalate the danger of ERCP-induced splenic trauma. Pancreatitis,^{4,16} especially chronic pancreatitis,^{5,12,31–33} (7/34) is also referred to as a possible risk factor. Chronic pancreatitis is thought to cause fibrosis and calcification on the surrounding ligaments, becoming less flexible. Another risk factor could be the presence of adhesions due to previous abdominal surgeries. Adhesions^{6,9,10,15,19,20,23–26,28,34} (12/34) decrease the mobility of abdominal organs and ligaments, making them more vulnerable to trauma. Patients' general condition appears also to play a significant role. Insufficient sedation^{22,28} could lead to the patient's discomfort and abrupt moves against the endoscope. Caution is needed on obese patients' manipulation on the operating table^{4,9,17} because obesity has been associated with the development of post-ERCP complications³⁵ and with prolonged sedation with standard agents.³⁶ Another possible factor contributing to the injury could be the type of the endoscope.⁹ Deist and Freytag¹⁹ also presented a very interesting theory about a possible correlation between the level of estrogens and splenic rupture induced by ERCP. High level of estrogens has been associated with ligament and tendon trauma (anterior

cruciate ligament).^{37,38} Estrogen receptors (ER)- β can be prevalent in the tissue of tendons and ligaments.³⁷ These receptors are present also in many human organs as the spleen, ovaries, testicles, and thymus.^{37,39} However, it has not been scientifically proven yet that ER- β receptors can be found especially in splenic ligaments, and if so, how estrogen levels could affect them. Another possible predisposing factor could be age-related changes in the spleen's ligament system. Ligaments consist mainly of Collagen Type I (80%).⁴⁰ These changes are related to altered collagen structure, increased stiffness, and decreased fibril diameter of the ligaments resulting in increased risk for trauma, as was described for the anterior cruciate ligament.⁴¹ Further evaluation is needed to determine whether these age-related changes involve the splenic ligaments. Also, someone can speculate that chronic liver dysfunction (cirrhosis) could affect the 'quality' of the body ligaments making them more prone to trauma. Some possible mechanisms could be malnutrition, insufficient blood supply, hypoalbuminemia causing alteration in the ligament composition, and collagen fiber degeneration. A cohort study in Taiwan showed that incidence rates of internal derangement of knees were higher in patients with chronic liver disease.⁴² However, additional research is needed on the effects of chronic liver disease on the visceral ligament system.

Although many possible predisposing factors seem to contribute to post-ERCP splenic injury, some cases are more complicated with no difficulties or known predisposing factors.^{14,43–45} In our case, the endoscopist was skilled, and ERCP was performed without any difficulties. Furthermore, no risk factor was known. Thus, in such cases, the possible mechanism could be the forces transmitted by the endoscope in the long position or the direct trauma. Furman and Morgenstern⁶ suggest that the highest of the short gastric vessels, which are very short, are the most vulnerable to injury as they are stretched and torn when entering the splenic capsule.

In this paper, we presented a rare case of a patient with post-ERCP splenic injury as well as an in-depth literature review. After having examined closely all previously published cases, we gathered and evaluated the most interesting – in our opinion – characteristics and predisposing factors. Furthermore, we presented a step-by-step approach to the mechanism of this complicated injury. As far as we are aware, nobody before tried to support his theory neither scientifically nor schematically. Due to the lack of a clear practical diagnostic approach available in the literature, we designed two diagnostic algorithms, the first one for the differential diagnosis of ERCP's most common and uncommon complications and the second one for the diagnosis and management of the post-ERCP splenic injury. (Both algorithms are available and can be found as Supplemental Material.) Lastly, we first suggested the use of CEUS as a promising new alternative diagnostic tool in post-ERCP splenic injury.

Conclusion

Splenic injury is a very rare but possibly life-threatening complication that should always be on the expert's mind and differential diagnosis to be managed appropriately and on time. Post-ERCP symptoms such as progressive left upper quadrant pain, tachycardia, and hypotension should additionally raise the suspicion of splenic rupture. The time interval between ERCP and clinical manifestations can vary from minutes to many days. By the time of potential symptoms manifestation, an abdominal ultrasound could be helpful. CT scan is the method of choice for the diagnosis in the vast majority of cases with CEUS being a promising and encouraging

alternative. If not, laparotomy will solve the problem. A high index of suspicion and clinical awareness are required, to establish the proper diagnosis, especially when symptoms appear days later. Alertness is needed during the ERCP procedure on patients with suspicious and/or known predisposing factors.

Declarations

Ethics approval and consent to participate

Not applicable (there is no identification material in our images and/or in the whole manuscript). Furthermore, written informed consent to treatment was obtained from the participants included in the study.

Consent for publication

The patient involved in this study gave written informed consent for the anonymous publication of his medical data and images. The patient's personal information was removed from text, images, and figures.

Author contributions

Dimitrios S. Kourdakis: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

Savvas P. Deftereos: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing.

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Supplemental material

Supplemental material for this article is available online.

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