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CT characterization of retractor related liver injuries after pancreaticoduodenectomy: Retrospective analysis of a single institution experience

William Law [a], Robert Percarpio [b], Qingyuan Song [c], Kerrington D. Smith [d], Eric K. Hoffer [b], Nancy McNulty [b,*]

[a] Department of Surgery, Rhode Island Hospital, Brown University, 593 Eddy Street, APC 429, Providence, RI 02903, United States
[b] Geisel School of Medicine at Dartmouth, Department of Radiology, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH 03756, United States
[c] Geisel School of Medicine, Department of Biomedical Data Science, Dartmouth College, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH 03756, United States
[d] Geisel School of Medicine at Dartmouth, Department of Surgery, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH 03756, United States

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ABSTRACT

Purpose: Retractor related liver injuries (RRLI) are reported after upper gastrointestinal tract surgeries; most commonly laparoscopic cholecystectomy and gastric surgeries. The aim of this study was to characterize the incidence, identification, type, severity, clinical features and risk factors for RRLI after open and robotic pancreaticoduodenectomy.

Methods: A 6-year retrospective study of 230 patients was performed. Clinical data was extracted from the electronic medical record. Post-operative imaging was reviewed and graded using the American Association for the Surgery of Trauma (AAST) liver injury scale.

Results: 109 patients met eligibility criteria. RRLI occurred in 23/109 (21.1%), with a higher incidence in the robotic/combinedapproach (4/9) compared with open (19/100). Most common injury was an intraparenchymal hematoma (56.5%), grade II (78.3%), located in segments II/III (77%). 39.1% of injuries were not reported on the CT interpretation. There was a statistically significant elevation of postoperative AST/ALT in the RRLI group [median AST 219.5 vs. 72.0 ($p < 0.001$), ALT 203.0 vs. 69.0 ($p < 0.001$)]. Trends toward lower preoperative platelet counts and longer operations were observed in the RRLI group. No significant difference in hospital length of stay or post-operative pain scores were noted.

Conclusion: RRLI occurred frequently after pancreaticoduodenectomy, however most injuries were low grade and the only clinical significance was a transient increase in transaminases. A trend toward higher injury rates was observed in robotic cases. In this population, RRLI was often unrecognized on postoperative imaging.

1. Introduction

Retractor related liver injuries (RRLI) are reported after various open and laparoscopic abdominal surgeries, and are thought to occur due to blunt trauma caused by the compressive force a retractor places upon the liver. Acute pressure on the liver parenchyma can produce tissue fracture or tears, and if prolonged, may produce parenchymal congestion or contusion, and if sustained, an infarction.[1–4] Laparoscopic cholecystectomy and gastric surgery associated RRLIs have been the most widely reported.[3–16]

RRLI is most often diagnosed after elevated transaminases or pain prompt imaging that identifies a characteristic oval, triangular or linear hepatic hypodensity that extends to the liver capsule.[1,4,17] The enzyme and imaging abnormalities were most often transient and therefore consistent with a post-compressive contusion. However, more serious complications have been reported with RRLI-related readmission for pain,[6] increased level of care with ICU admission or reoperations,[7–9] focal infarct,[4] liver failure,[2] and even death.[3] Although these severe consequences are infrequent, CT evidence of RRLI after surgery is important to recognize and document as it may account for clinical signs or symptoms and it is essential to differentiate it from a metastatic lesion or abscess.[4,17]

* Corresponding author.
E-mail address: Nancy.J.McNulty@hitchcock.org (N. McNulty).

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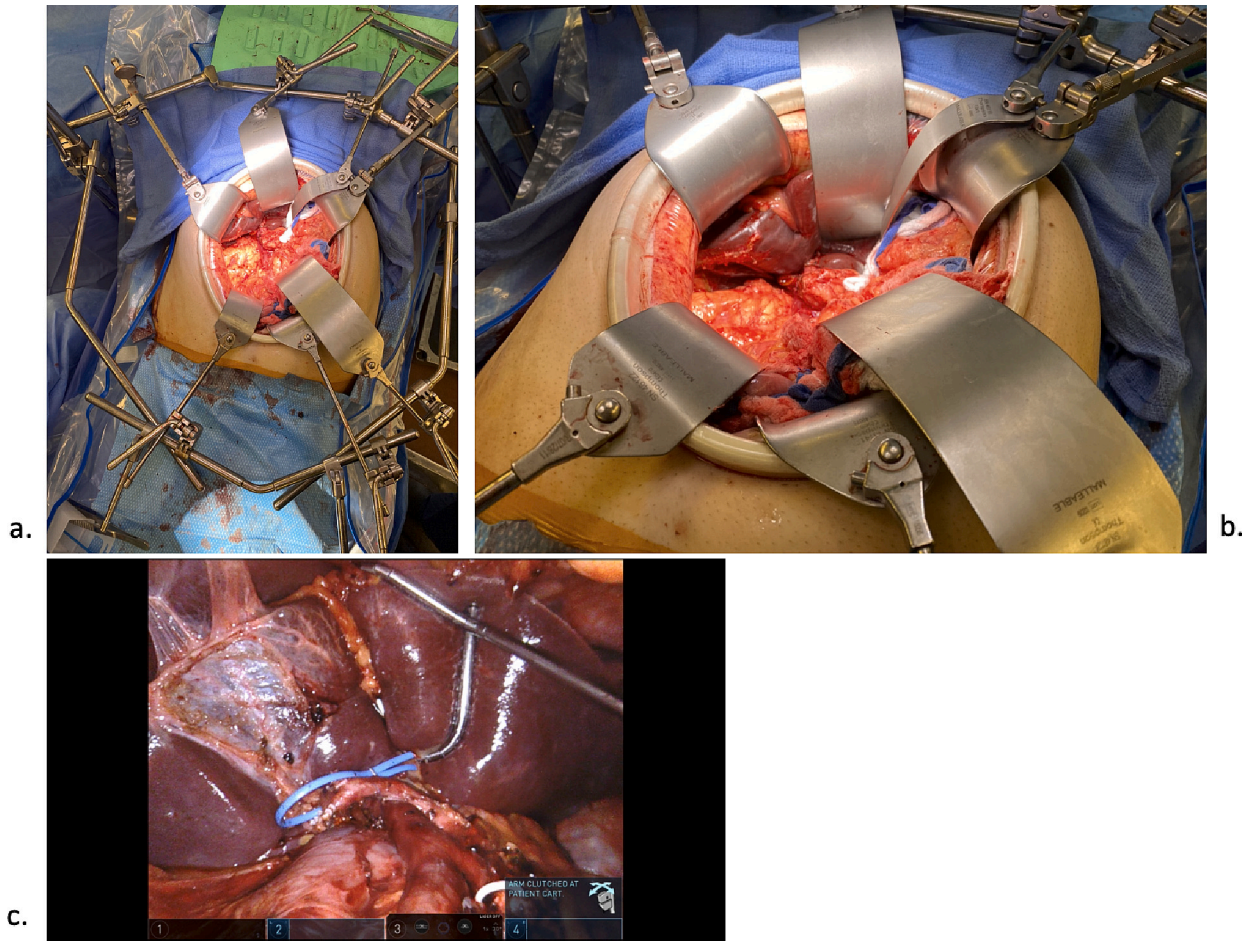

Fig. 1. Liver retractors, intraoperative images. a) Thompson retractor full view, b) Thompson retractor liver view, c) Snake flexible retractor on Martin arm liver view.

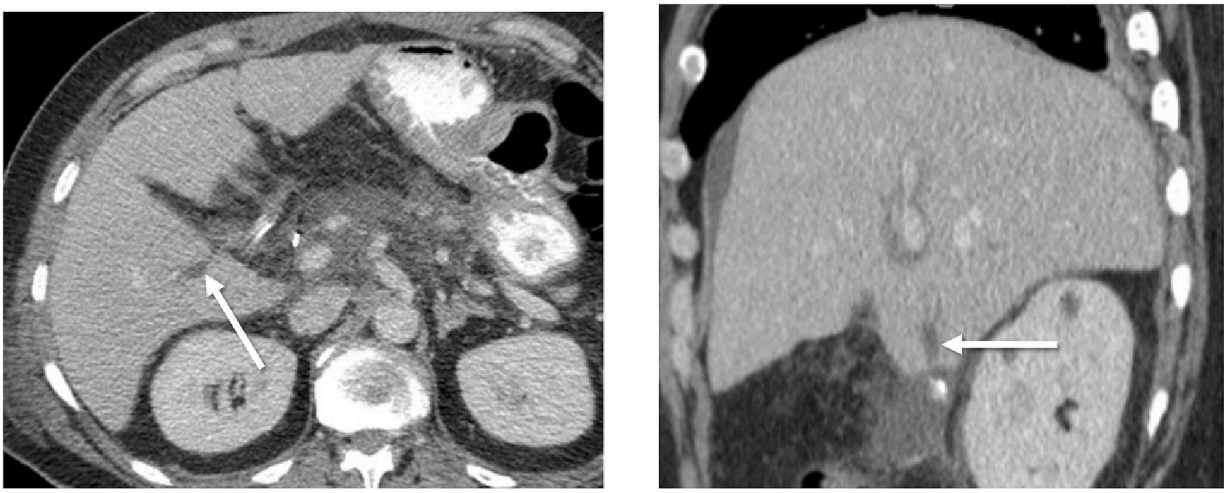

Fig. 2. Rouviere's sulcus – Axial and sagittal images from a post-operative contrast enhanced CT in the portal venous phase demonstrate a smooth, linear, cleft-like low density extending inward from the liver capsule in the expected location of Rouviere's sulcus.

This differentiation is salient in pancreaticoduodenectomy, a procedure associated with prolonged retractor compression of liver parenchyma, for which there are few studies of RRLI.[17] This study is a retrospective analysis of consecutive pancreaticoduodenectomies performed at a single center to determine the incidence of RRLI, identify predisposing factors, characterize the clinical and imaging features, and determine outcomes associated with these injuries.

2. Methods

Approval was obtained through the Committee for Protection of Human Subjects (CPHS) with a waiver of informed consent. All

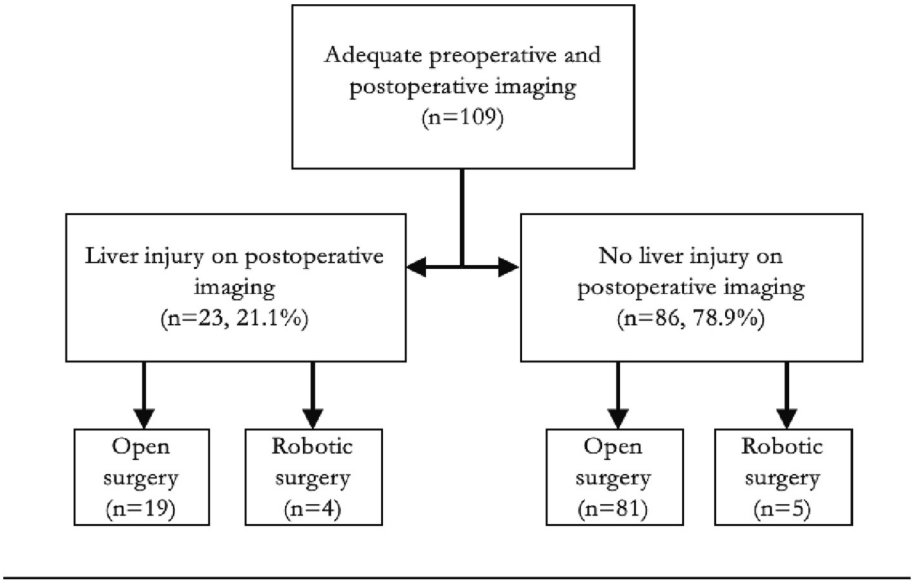

Fig. 3. RRLI rates by surgical approach.

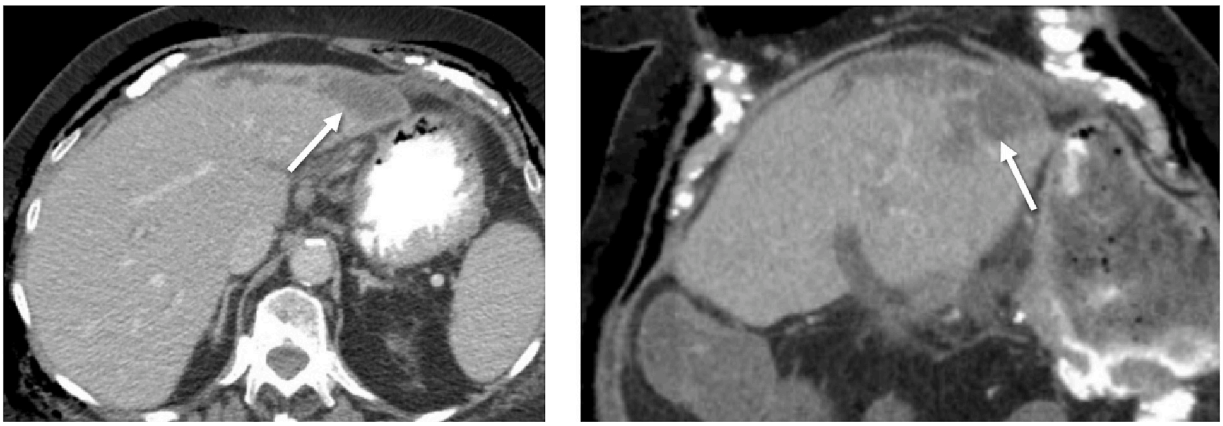

Fig. 4. Intraparenchymal and subcapsular hematoma – Axial and coronal images from a post-operative contrast enhanced CT in the portal venous phase demonstrate an irregular, low to intermediate attenuation, ill-defined abnormality superficially and deeper within segment 2, representing a grade II intraparenchymal and subcapsular hematoma.

pancreaticoduodenectomy cases performed at a 400-bed academic medical center from 1/2014 to 12/2019 were identified using the National Surgical Quality Improvement Program (NSQIP) database (all cases at our institution are reported to the database). The inclusion criteria were a preoperative CT or MRI of the abdomen performed within 1 year of surgery and contrast enhanced CT or MRI of the abdomen performed within 30 days postoperatively. Data was extracted from the NSQIP database and electronic medical record, including patient demographics, pre- and post-operative laboratory values, and procedure details, and outcomes. Post-operative labs were included if performed within 1 week of operation, and the earliest results obtained were used. The first postoperative pain score after a patient was on floor status and within three days after surgery was extracted from a nursing or acute pain service note.

Data obtained from the operative report included the retractor type, segmental location of any intraoperative liver biopsies performed, operating surgeon, and specific operative risk factors (areas of adhesion dissection or blood vessel injury).

During open surgeries, retraction was obtained by a mechanical arm anchored to the bedside with Thompson © Ratcheting retractors (Thompson Surgical Instruments) placed on the liver with laparotomy towels for cushioning. In robotic cases, the Martin Arm (PretzelFlex TM, Surgical Innovations) was used to anchor a flexible retractor which was inserted into the abdomen under camera visualization. The arm was tightened to achieve retraction shape and applied to the underside of the left lobe of liver for retraction (Fig. 1).

Pre- and postoperative CT scans were performed on 16–64 slice Multidetector CTs, and when intravenous contrast was administered, portal venous phase images were obtained. Imaging was reviewed by two radiologists with 6 years (Percarpio) and 19 years (McNulty) reading experience. Hepatic steatosis was diagnosed based on averaged Hounsfield unit (HU) measurements of <40 Hounsfield units (HU) on a CT without contrast, and <80 HU on portal venous phase contrast enhanced CT.[18] On 1.5 T and 3 T MRI scans steatosis was diagnosed on T1 weighted in and out of phase axial images by a phase difference of >100.[19]

Any new low-density region in the liver on post-operative CT not secondary to a pre-existing liver lesion or attributable to an intraoperative biopsy or wedge resection was deemed positive for liver injury, and categorized as a laceration, intraparenchymal hemorrhage or contusion, or subcapsular hematoma. These were graded according to the American Association for the Surgery of Trauma (AAST) liver injury

Fig. 5. Coronal and axial images from a post-operative contrast enhanced CT scan in the portal venous phase demonstrate a >3 cm depth, linear low attenuation region extending from anterior to posterior through segment 3, representing a grade III laceration.

scale as RRLI are considered a manifestation of blunt trauma.[4,17,20,21] Liver lacerations were defined by linear, triangular or stellate low to intermediate density areas, typically extending inward from the liver capsule. Accessory sulci were differentiated from lacerations by their characteristic location and appearance as smooth linear or ovoid fluid density lesion with well-defined margins. In particular Rouviere's sulcus was identified by a linear low density extending inward from the infero-medial liver surface adjacent to the gallbladder fossa, following the capsular contour.[22] Though ideally confirmed on pre-operative imaging, the sulcus was often more evident post operatively due to fluid tracking into it from the nearby surgical resection bed (Fig. 2). Hepatic contusion or hematoma were non-enhancing rounded, ovoid, or irregular areas of low to intermediate density. Correlation of lesion location with the operative report allowed differentiation from a site of intraoperative liver biopsy. If two injuries were present, the primary categorization was granted to the more severe injury.

Radiology reports were reviewed to assess for prospective identification and reporting of the RRLI. If the liver abnormalities were described in the report and deemed secondary to trauma or injury, they were considered positive. If only the term 'post-operative changes' was included in the report, this was not considered prospective identification, as RRLI is not an expected post-operative finding.

Data analysis was performed in R and consisted of Shapiro Wilk test to assess normality and summary statistics (mean, standard deviation, median, interquartile range). For continuous variables, independent sample *t*-test or Mann-Whitney test based on normality were used and for categorical variables Fisher's exact test was used. Surgery type was dichotomized into open versus combined and/or robotic. Combined surgeries were initially robotic that were converted to open, and these were included in the robotic surgery group as both experienced the robotic surgery type retraction. A *p*-value of less than or equal to 0.05 was considered significant. Missing values were excluded from the analysis of corresponding variables.

Fig. 6. Axial and coronal images from a post-operative contrast enhanced CT scan in the portal venous phase demonstrate an intermediate density, ovoid, intraparenchymal abnormality in segment 7, representing a grade II intraparenchymal hematoma.

Table 1
CT characterization and reporting of RRLI

Injury grade	1	2 (8.7%)
	2	18 (78.3%)
	3	3 (13.0%)
	4	0
	5	0
Injury type	Laceration	9 (39.1%)
	Subcapsular hematoma	1 (4.3%)
	Intraparenchymal hematoma	13 (56.5%)
Liver segment involved[a]	1	0
	2	8
	3	15
	4	2
	5	2
	6	1
	7	2
	8	0
More than one site of liver injury	Yes	4 (17.4%)
	No	19 (82.6%)
Injury reported on CT	Yes	14 (60.9%)
	No	9 (39.1%)

[a] Some injuries involved multiple segments. Percentages not calculated.

3. Results

Of 230 pancreaticoduodenectomies performed during the study period, 121 did not have the necessary pre or postoperative imaging and were excluded. 109 patients met inclusion criteria. The indications for surgery included malignancy, pancreatitis, mesenteric fibrosis with hemorrhagic conversion, duodenal adenoma, and gastrinoma. Operations were performed by one of 5 surgeons, and there were 100 open (91.7%), 6 robotic (5.5%), and 3 combined (2.8%) approaches. No laparoscopic surgeries were performed during the study period. No postoperative MRI scans were performed; all included subjects had post-operative contrast enhanced CT scans.

RRLI was identified in 23/109 (21.1%) of patients; 19/23 (82.6%) were in the open group and 4/23 (17.4%) in the robotic group (Fig. 3). The original CT interpretation reported the RRLI in 14 of 23 (60.9%) cases. Of the 23 RRLI identified on post-operative imaging, intraparenchymal hematoma was found in 56.5% of injuries, followed by laceration, 39.1% and subcapsular hematoma, 4.4% (Figs. 4, 5, 6). The injuries were predominantly low grade; 87% were grade I or II. Only 3

Table 2
Pre and post-operative factors in patients without/with RRLI

	No injury (n = 86)	Injury (n = 23)	p-Value
Mean age (SD)	65.0 (11.8)	64.0 (9.3)	0.706
Male sex (%)	54 (62.8)	11 (47.8)	0.235
BMI, median (IQR), (kg/m2)	26.3 [23.0, 29.5]	29.3 [23.2, 31.1]	0.195
Hepatic steatosis (%)	9 (10.5)	3 (13.0)	0.720
Preoperative labs			
Hematocrit, mean, (SD)	37.6 (4.4)	39.0 (4.7)	0.205
WBC, median (IQR), (1000/uL)	7.6 [6.1, 9.3]	7.4 [5.5, 8.5]	0.441
Platelet count, median (IQR), (1000/uL)	249.0 [204.8, 305.0]	220.0 [193.8, 241.3]	0.054
AST, median (IQR), (U/L)	24.0 [17.8, 34.3]	21.0 [18.0, 31.0]	0.776
Alkaline phosphatase, median (IQR), (U/L)	105.5 [69.5, 160.8]	103.0 [77.0, 179.0]	0.958
Total bilirubin, median (IQR), (mg/dL)	0.4 [0.3, 0.9]	0.5 [0.4, 0.6]	0.668
Albumin, median (IQR), (g/dL)	4.0 [3.7, 4.3]	4.1 [3.8, 4.3]	0.283
INR, median (IQR)	1.0 [0.9, 1.1]	1.0 [1.0, 1.1]	0.705
PTT, mean, (SD), (seconds)	31.8 (5.3)	29.3 (4.7)	0.487
Postoperative findings			
Hospital length of stay, median (IQR), (days)	13.0 [9.0, 17.0]	13.0 [8.5, 15.0]	0.854
Pain score, median (IQR)	5.0 [3.0, 7.0]	5.0 [3.0, 7.0]	0.705
AST, median (IQR), (U/L)	72.0 [47.0, 103.5]	219.5 [97.8, 378.0]	<0.001
ALT, median (IQR), (U/L)	69.0 [40.0, 105.0]	203.0 [86.0, 375.0]	<0.001
Total bilirubin, median (IQR), (mg/dL)	0.8 [0.5, 1.2]	0.6 [0.5, 1.1]	0.380
Direct bilirubin, median (IQR), (mg/dL)	0.2 [0.1, 0.4]	0.4 [0.2, 0.8]	0.375
Total protein, median (IQR), (g/dL)	5.1 [4.6, 5.3]	5.0 [4.4, 5.4]	0.848
Albumin, mean (SD) (g/dL)	2.7 (0.4)	2.8 (0.4)	0.632

BMI (body mass index), WBC (white blood cell count), AST (aspartate aminotransferase), ALT (alanine aminotransferase), INR (international normalized ratio), PTT (partial thromboplastin time).

Table 3
Intraoperative factors in patients without/with RRLI

Technique	No injury	Injury	p-Value
Open approach ($n = 100$)	81 (81.0%)	19 (19.0%)	0.092
Robotic/combined Approach ($n = 9$)	5 (55.6%)	4 (44.4%)	
Duration of surgery (minutes), mean (SD)	498.1 (90.6)	539.0 (90.5)	0.057

grade III injuries occurred, and there were no grade IV or V injuries. Four patients (17.4%) had RRLI in more than one location. Of the 30 total injuries that were identified, 25 occurred in the left lobe, and only five in the right lobe (Table 1).

There was no significant difference between the injury and non-injury groups with respect to age, sex, BMI, or hepatic steatosis. Pre-operative platelet counts were lower in patients with injuries (220.0 versus 249.0, $p = 0.054$) (Table 2).

Postoperative AST (U/L) and ALT (U/L) were significantly elevated in patients with injury versus those without [median AST 219.5 versus 72.0 ($p < 0.001$) and ALT 203.0 versus 69.0 ($p < 0.001$)]. No significant difference in hospital length of stay or post-operative pain scores were identified (Table 2). There was one death within 30 days in the non-injury group.

Regarding operative factors, there was a higher rate of liver injury in the robotic/combined approach (4 out of 9, 44.4%) compared with open approach (19 out of 100, 19.0%), and in those with longer operative durations (mean 539.0 min versus 498.1 min), although these were not statistically significant (Table 3).

4. Discussion

RRLI, identified by a new hypodense lesion abutting the liver edge, was identified in 21% of patients that had CT after open or robotic pancreaticoduodenectomy, with clinical manifestation limited to a transient rise in alanine and aspartate transaminases, consistent with prior reports.[1,4,17,23] The recognition of RRLI allows differentiation from metastases or infection, which highlights the lack of identification in 39.1% of the prospective reports in this cohort. The frequently unrecognized or underreported RRLI in our population may be due to lack of radiologist's awareness or the inclusion of an unclear finding as "post-operative change." However, blunt injury to an organ is not a typical postoperative finding, and given that an injury may have clinical impact, or be misinterpreted as a metastasis or infection on subsequent imaging, it is important to clearly report them.

RRLI occur during upper gastrointestinal surgeries; open, laparoscopic, and in this report, robotic.[1,4,17] Typically, these injuries are only recognized when they cause clinical symptoms or altered laboratory results that lead to postoperative imaging, or are identified on routine postoperative imaging[1–17] An 11% incidence of RRLI was reported after open pancreaticoduodenectomy in a population with mean operation time of a comparable 541 min, where postoperative imaging was routinely obtained for all patients.[17] The higher 21.1% incidence in the current report likely reflects a selection bias in our clinical practice, where imaging was limited to symptomatic patients. However, that rate is within the range of other retrospective cohorts where RRLI was diagnosed when imaging was obtained for post-operative symptoms or enzyme elevation.[1,4,15]

This study uniquely involved robotic surgeries, albeit a relatively small number (9 robotic/combined vs 100 open), where the incidence of RRLI was 44.4%, compared to 19.0% for open surgeries. This difference did not reach significance, possibly due to the small total number of those cases. In the evaluation of open vs laparoscopic gastrectomy, a similar increased incidence of RRLI was reported.[14,15] If demonstrated in a larger population, the use of a table-anchored flexible retractor, fixed in relation to the patient, may account for this. In reports of laparoscopic urologic procedures, RRLI was thought to be influenced by "passive systems…unable to respond to anatomical shifts caused by changes in organ manipulation.".[2,24]

The reported incidence of RRLI varies based on the definition (enzyme elevation or imaging abnormality) and surgery performed (retractor type and duration). The surgical literature often employed mean enzyme elevation alone to assess RRLI reduction methods through retractor repositioning, retractors that spread the force of retraction and retractors that accommodate patient movement during surgery.[25,26] Radiological literature has focused on the recognition of imaging evidence of postoperative liver injury. Future research toward prediction of the rare RRLI with clinically significant sequalae[2–5,7–9] may benefit from the classification by AAST grade in conjunction with enzymatic elevation.

Although the majority of RRLI occurred in the left hepatic segments 2 and 3, consistent with prior reports and those being the usual site of compression by both the Thompson and Snake retractors,[1,4,17] right lobe injuries were found in this cohort as well. Also identified in this cohort were several CT reports that incorrectly identified a RRLI in the right hepatic lobe, that on review met criteria for Rouviere's sulcus.[22]

Our study had several limitations. Being retrospective, postoperative labs and imaging were inconsistently collected, and time points varied. Since only patients who underwent postoperative imaging (obtained for pain or laboratory abnormalities) were included in the study, this introduces a selection bias for patients with complications, and falsely elevates the true incidence of retractor related liver injury. The relatively small number of robotic/combined cases limits the ability to determine if RRLI occurs significantly more frequently in that subgroup, although we did note a trend. As this was a single center study, the retractor type used was consistent. The generalizability of these results may be limited, as results may be dependent upon the retractor types used at other institutions.

This study identified a 21% incidence of RRLI in a large group of patients who had undergone pancreaticoduodenectomy. The character and incidence were similar to that reported for these iatrogenic injuries in other upper gastrointestinal surgeries: they were low grade contusions or lacerations, associated with transient AST and ALT elevation, predominantly located in the left lobe, and were not associated with increased hospital length of stay or post-operative pain. The initial, limited data on robotic pancreaticoduodenectomy suggested an increased risk of RRLI versus an open surgery. Review of the radiology reports found a deficit in the reporting of this surgical complication, which provides an opportunity for education and improved performance.

Declaration of competing interest

The authors did not receive support from any organization for the submitted work.

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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