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Original Article

Laparosc Endosc Surg Sci 2024;31(1):1-7
DOI: 10.14744/less.2024.05658

Impact of thoracic outlet diameter on surgical outcomes in laparoscopic cholecystectomy

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ABSTRACT

Introduction: This study assesses the influence of inferior thoracic aperture dimensions on the outcomes of laparoscopic cholecystectomy for cholelithiasis. It aims to determine if the size of the thoracic outlet, akin to pelvic measurements in obstetrics, can predict surgical complexity and complications.

Materials and Methods: In this prospective anatomical and clinical study, 32 patients who underwent laparoscopic cholecystectomy between April 2014 and December 2015 at Bursa Yuksek Ihtisas Research and Training Hospital were evaluated. Anteroposterior (AP) and laterolateral (LL) diameters of the inferior thoracic aperture were measured using CT or MRI. The study focused on dissection time and intraoperative blood loss, quantitatively.

Results: Twenty-three of 32 patients (71.9%) were female, and 9 (28.1%) were male. The mean age of the patients was 57.97±16.11 years (min: 29; max: 85). The mean overall dissection time was 1,172.43±427.58 seconds (min: 550; max: 2,157), and the median amount of intraoperative hemorrhage was 6.5 cc (min: 1; max: 23). The mean LL diameter of the patients was 26.02±2.29 cm (min: 21.50; max: 31.50), and the median value of the AP diameter was found to be 11.35 cm (min: 9.40; max: 19.40). A positive relationship was found between the LL and AP diameters (r=0.574; p=0.001). There was a negative relationship between operational time and both LL and AP diameters (r=-0.418; p=0.017 and r=-0.405; p=0.022).

Conclusion: Findings suggest that narrower thoracic apertures can prolong the standard 4-port-access laparoscopic cholecystectomy procedure. This study underscores the importance of measuring thoracic outlet diameters for anticipating surgical difficulty in general surgery, analogous to pelvic measurements in obstetrics. Such measurements could be pivotal in preoperative planning and in improving surgical outcomes.

Keywords: Cholelithiasis, Inferior Thoracic Aperture, Laparoscopic Cholecystectomy, Thoracic Outlet, Thorax Anatomy

Introduction

Cholelithiasis, a prevalent gastrointestinal condition, is categorized into cholesterol stones, pigment stones, and mixed stones, based on its structural features.[1,2] Cholesterol stones affect approximately 10-20% of the global population, with prevalence rates ranging from 10-15% in Western countries to 3-15% in Eastern countries.[3]

Received: 04.01.2024 **Revision:** 31.03.2024 **Accepted:** 31.03.2024
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Cholelithiasis presents asymptomatically in approximately 25% of patients; however, the development of inflammation can lead to severe complications, including biliary pancreatitis, cholecystitis, and cholangitis.[4,5]

Laparoscopic cholecystectomy has been recognized as the most effective treatment for gallstone disease, although its complication rate ranges from 6.8% to 7.7%.[6] Major complications of this procedure include bile leakage, occurring at a rate of 1%; gastrointestinal organ injury, occurring at a rate of 0.2%; massive hemorrhage, occurring at a rate of 0.1%; and injury to the common bile duct, occurring at a rate of 0.2-0.4%.[6,7]

The inferior thoracic aperture, defined by the twelfth thoracic vertebral body, the eleventh and twelfth ribs, their connected costal cartilages, and the xiphisternal joint, serves as the lower boundary of the thoracic cavity. Its importance lies not only in separating the thoracic cavity from the abdomen but also in its role in influencing respiratory mechanics and the positioning of abdominal organs such as the liver and gallbladder.[8,9]

This study investigated the potential significance of the inferior apertura thorica as a predictive parameter for the outcomes of laparoscopic cholecystectomy, based on its ability to reflect the anatomical position of the gallbladder. Surgical outcomes were assessed by considering the duration of surgery, the estimated amount of blood loss, and the presence or absence of gallbladder perforation during surgery.

Materials and Methods

This prospective anatomical and clinical study was approved by the Ethics Committee of Bursa Yuksek Ihtisas Research and Training Hospital (Approval Number: 2014/07-01) and was conducted in the Department of General Surgery at Bursa Yuksek Ihtisas Research and Training Hospital. Written informed consent was obtained from all patients who underwent surgery.

Thirty-two patients who were evaluated by computed tomography (CT) or magnetic resonance imaging (MRI) for several additional reasons, such as uncertain comorbidities and suspicion of concomitant common bile duct stones, and who underwent laparoscopic cholecystectomy (LC) between April 2014 and December 2015, were included in the study. We hypothesized that as the diameter of the inferior thoracic aperture narrows, there will be an increase in surgery time, blood loss, and frequency of gallbladder perforation. To minimize errors, 17 patients were excluded from the study due to concomitant pathologies: one patient with extra-hepatic biliary tract anomalies, four patients with intraabdominal adhesions because of previous upper abdominal surgeries, six patients with perihepatic adhesions due to several acute relapses of cholecystitis, and six patients with inconvenient anatomy due to acute or chronic cholecystitis, which may affect the dissection time and distort the results. Additionally, two patients were excluded from the study because of cooperation deficiencies with the radiology technician. Patients were also excluded if their ASA score was ≥3 and if their body mass index was ≥30 kg/m^2.

To ensure the homogeneity of the study, patients underwent a standard 4-port-access laparoscopic cholecystectomy performed by a single surgeon who had already performed more than 500 laparoscopic cholecystectomy procedures. Patients were placed in the supine position during the surgical procedure. The trocars were placed as follows: a 10-mm port for the camera was inserted just below the umbilicus, a 10-mm right-hand port was inserted approximately 2 cm below the xiphoid process, a 5-mm left-hand port was inserted approximately 1 cm below the intersection of the midclavicular line and the right costal margin, and a 5-mm traction port was inserted 1 cm below the intersection of the right anterior axillary line and the right costal arc.

The age and sex of all patients were evaluated. The period between the placement of all four trocars and the completion of gallbladder dissection from the liver bed was considered the operational (overall dissection) time. During surgery, the overall dissection time was measured using a digital chronometer. The amount of aspirated blood in the subhepatic space was measured with the help of an injector for the quantitative evaluation of perioperative bleeding. In addition, the gallbladder perforation rate during dissection was investigated as a minor intraoperative complication.

From cross-sections of pre-surgical CT or MRI scans, two diameters of the patients' inferior thoracic apertures were measured at the end of the surgery:

- Anteroposterior (AP) diameter: from the anterior edge of the 10th thoracic vertebra's body to the xiphoid process tip (Fig. 1).
- Transverse or laterolateral (LL) diameter: between the midpoints of the right and left 9th costal bodies (Fig. 2).

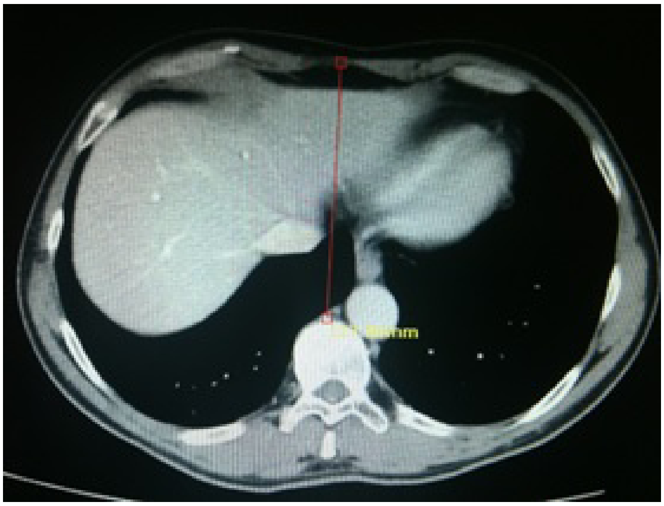

Figure 1. Anteroposterior (AP) diameter: from the anterior edge of 10th thoracic vertebra's body to xiphoid process tip.

Figure 2. Transverse or laterolateral (LL) diameter: between the midpoint of right and left 9th costal bodies.

All patients' CT or MRI scans were performed by the same devices, with high resolution, in the same training and research hospital's radiology department. Images were captured during the deep breath-holding phase.

The relationships between total operation time, intraoperative gallbladder perforation rate, total amount of blood loss during surgery, and the AP-LL diameters of the thoracic outlet were examined.

No early major complications, such as massive bleeding requiring re-laparotomy, biliary fistula, or surgical site infections, were detected in any of the patients included in the study.

Statistical Analyses

Statistical analyses were performed using SPSS (Statistical Package for the Social Sciences, ver. 21.0; SPSS Inc., Chicago, Illinois, USA). The Shapiro-Wilk test was used to analyze normality because the number of samples was less than 50. In descriptive analyses, the mean±standard deviation was used for data following normal distribution, and median and minimum-maximum values for non-parametric data. Pearson and Spearman correlation coefficients were used to calculate the relationships between inferior thoracic aperture diameters and other variables. In all statistical tests conducted as part of the study, α values of 0.05 and p-values of less than 0.05 were considered statistically significant.

Results

Of the 32 patients, 23 (71.9%) were female, and 9 (28.1%) were male. The mean age of the patients was 57.97±16.11 years (min: 29; max: 85). Eight patients' radiologic measurements were performed using magnetic resonance cross-sectional imaging, and 24 patients (75%) underwent CT (Table 1).

Table 1. Descriptive statistics

Age	57.97±16.11		
Gender, n (%)			
Male	9 (28.1)	32 (100)	
Female	23 (71.9)		
Radiodiagnostic modality, n (%)			
CT	24 (75)	32 (100)	
MRI	8 (25)		
Operational time (second)	1172.43±427.58	p=0.285	Between male and female patients
Hemorrhage (cc)	6.5 (Min: 1; Max: 23)	p=0.376	
LL diameter (cm)	26.02±2.29	**p=0.006**	
AP diameter (cm)	11.35 (Min: 9.40; Max:19.40)	p=0.356	

The mean operative time was 1172.43±427.58 (min:550; max:2157) seconds, and the median amount of intraoperative blood loss was 6.5 cc (min: 1; max: 23) (Table 1). During dissection, gallbladder perforation occurred in four patients (12.5%). No statistically significant difference was found between the sexes in terms of the duration of surgery and intraoperative bleeding (p=0.285 and p=0.376) (Table 1).

The mean LL diameter of the patients was 26.02±2.29 cm (min: 21.50; max: 31.50), and the median value of the AP diameter was 11.35 cm (min: 9.40; max: 19.40) (Table 1 and Fig. 3).

As expected, a positive relationship was found between the LL and AP diameters (r=0.574; p=0.001). There was a negative relationship between operational time and both the LL and AP diameters (r=-0.418; p=0.017 and r=-0.405; p=0.022, respectively). The relationship between hemorrhage and diameter was not significant. Although no statistically significant correlation was found between perioperative bleeding and LL diameter, the p-value of the Spearman correlation analysis was just above the α value (r=-0.346; p=0.052). Correlation coefficients (r) and p-values for the correlation coefficients were calculated, and the results are presented in Table 2. Statistically significant relationships are shown in Figures 4-6.

Although the difference between the LL diameter and perforation was not statistically significant, the difference between sex and LL diameter was statistically significant. The laterolateral diameter of the inferior thoracic aperture was wider in male patients (p=0.006). Comparisons between the AP diameter and other parameters were not statistically significant (Table 3).

Discussion

According to the literature, the mean operational time of standardized four-port laparoscopic cholecystectomy is approximately 29.56 to 63.9 minutes.[10-12] In our study, we found the mean operational time to be 1172.43±427.58 seconds (~19.5±7.13 minutes). Our results seem shorter than those reported in the literature because we excluded the time spent on peritoneal insufflation, placement of the trocars, removal of the gallbladder from the abdom-

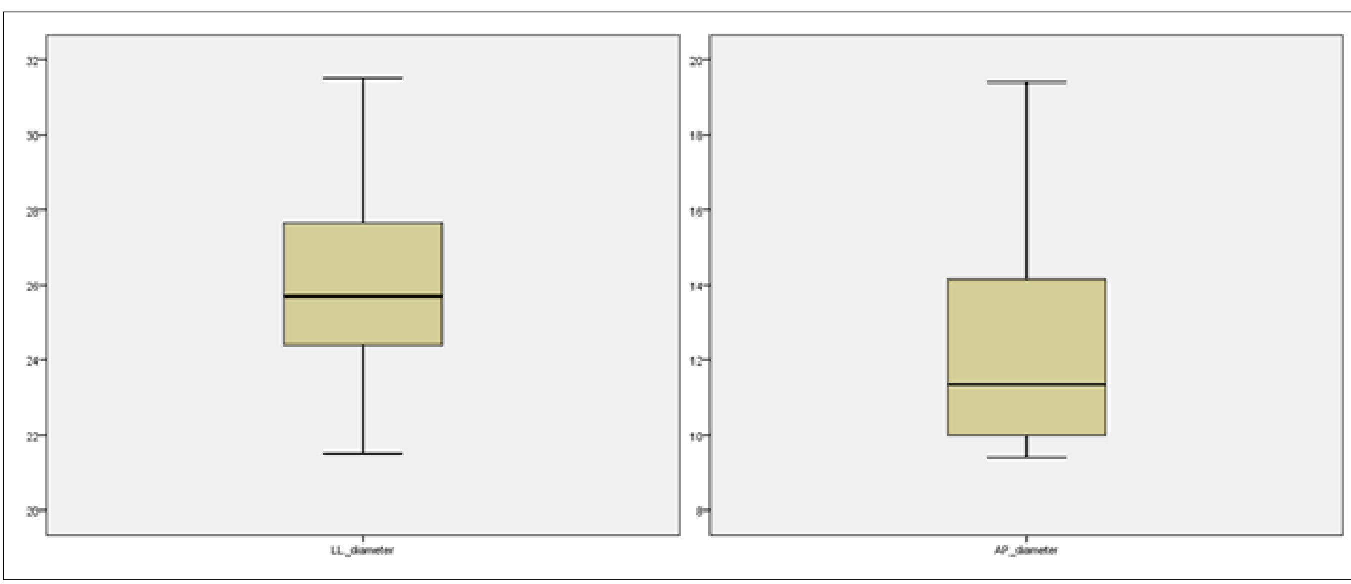

Figure 3. Boxplot graphics of LL and AP diameters.

Table 2. Correlations between diameters and other variables

	LL diameter			AP diameter		
	n	r	p	n	r	p
Operational time	32	-0.418	0.017	32	-0.405	0.022
Hemorrhage	32	-0.346	0.052	32	-0.288	0.110
AP diameter	32	0.574	0.001	-	-	-

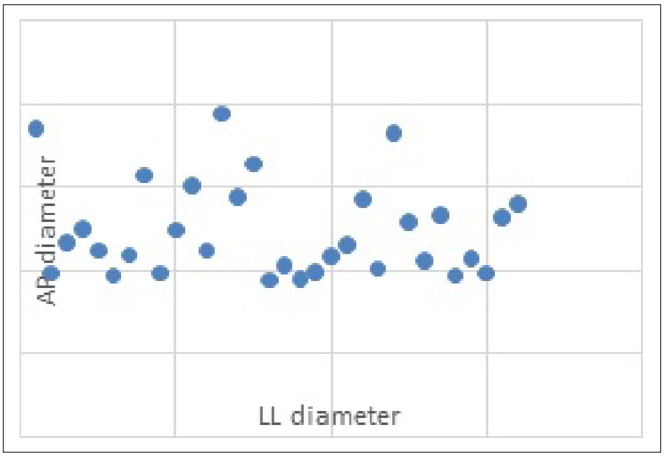

Figure 4. LL diameter and AP diameter relationship.

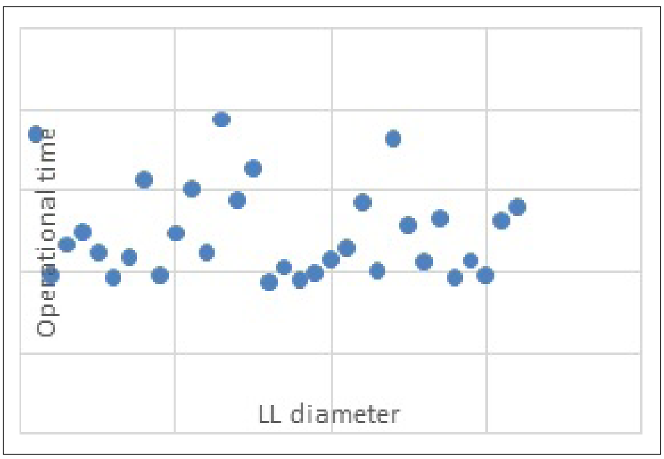

Figure 5. LL diameter and operational time relationship.

inal cavity, and measured only the dissection time (cystic artery, cystic duct, and fossa vesica).

According to our findings, the median amount of intraoperative blood loss was 6.5 cc (min: 1; max: 23) and the gallbladder perforation ratio during dissection was 12.5%. The incidence of gallbladder perforation was 4% in the Bari et al.[13] series and 16% in the case series by Sharma et al.[14] In a systematic review and meta-analysis of the literature published in 2020 by Lyu et al.,[15] the intraoperative

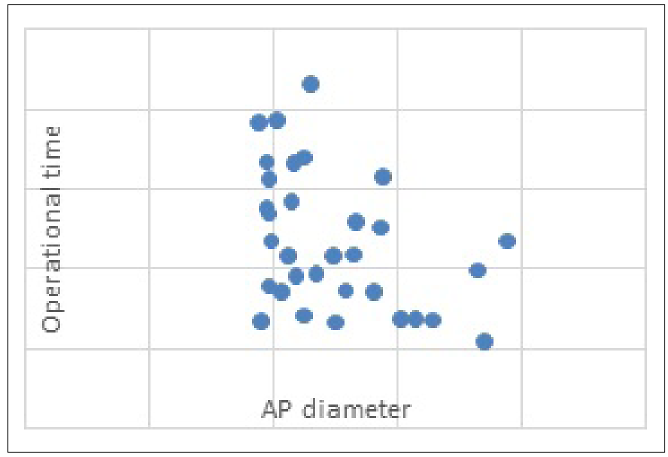

Figure 6. AP diameter and operational time relationship.

blood loss volume varied between 7.69 and 44 cc. Our perioperative "minor" complication results were concordant with the literature.

Several studies evaluating the surgical difficulties of cholecystectomy and related problems, such as blood loss due to difficult dissection or prolonged surgical time, have been reported. The main factors include inflammation or necrosis of the gallbladder wall, including Mirizzi syndrome, intraperitoneal fibrotic adhesions due to previous cholecystitis exacerbations or surgeries, conversion to an open operation, and anatomical variations/abnormalities of the extrahepatic biliary tract.[16,17] In 2021, Asai et al.[18] created a scoring system to predict problematic laparoscopic cholecystectomies, which includes criteria such as inflammation of the gallbladder, appearance of the Calot triangle, appearance of the gallbladder bed, findings regarding the surroundings of the gallbladder (abscess formation, cholecystoenteric fistula, etc.), and intraabdominal factors unrelated to inflammation (excessive visceral fat, adhesions around the gallbladder, anomalous bile duct, etc.).

Surgeons must prioritize preoperative assessment of the technical challenges associated with laparoscopic chole-

Table 3. Comparions between diameters and other variables

	LL diameter (cm)			AP diameter (cm)		
Perforation	n		p	n		p
Positive	4	26.30 (23.10-28.30)	0.842	4	9.75 (9.40-18.50)	0.169
Negative	28	26.03±2.29		28	11.60 (9.50-19.40)	
Gender	n		p	n		p
Male	9	28.20 (25.20-31.50)	0.006	9	13.30 (9.50-18.50)	0.356
Female	23	25.32±2.01		23	11.20 (9.40-19.40)	

cystectomy.[19] As mentioned, some authors have focused on the presurgical assessment of procedural difficulties. However, very few studies have examined the relationship between normal anatomical structures and cholecystectomy time. For instance, Shinozaki et al.[20] reported an assessment of the gallbladder bed's height and width. They defined a "gallbladder bed pocket score" with the help of CT imaging for presurgical estimation of the difficulties in dissecting the gallbladder from the gallbladder fossa vesica biliaris. The authors concluded that while the height and width of the gallbladder fossa did not affect the amount of intraoperative bleeding, they did influence dissection time, suggesting that cases with a "gallbladder bed pocket score" less than 0.4 were more suitable for general surgery residents at the beginning of their learning curve.

Daradkeh published another study, concluding that gallbladder and liver size affect the overall difficulty score as perceived by the patient. Increased liver and/or gallbladder size makes the operation more challenging.[21] Sakuramoto et al.[22] investigated another parameter, the anatomic neck position of the gallbladder. However, they did not find any significant correlation between the gallbladder neck's anatomy and the technical challenges and complications during laparoscopic cholecystectomy. Kapoor et al.[23] conducted a study on the identification of adhesions using preoperative ultrasonography during laparoscopic cholecystectomy. Their findings showed that the presence of preoperative adhesions detected by ultrasonography can predict challenging cholecystectomies.

The major limitation of this study was the relatively small number of patients. However, there might be an ethical conflict in irradiating patients with tomography before cholecystectomy without any suspicion, such as comorbidity. Magnetic resonance imaging (MRI) is a radiation-free imaging modality, yet it is challenging for patients to tolerate the noise and feelings of claustrophobia without any indication for radiological scanning methods other than ultrasonography. Thus, we evaluated only patients who required CT or MRI scans.

Another limitation is the lack of assessment of patients with comorbidities and a high body mass index (BMI). Additionally, other anatomical parameters, such as liver volume, should be evaluated in future studies. More detailed studies conducted using subgroup and multivariate analyses with larger series may provide more accurate results in the future.

Numerous publications in the literature have documented that laparoscopic cholecystectomy has become more challenging due to anatomical difficulties. Thus, it is important to anticipate these difficulties and estimate the risks before surgery.

It is evident that many factors influence the difficulties and potential complication rate of minimally invasive cholecystectomy. Likewise, it appears that cholecystectomy can take a much longer time in patients with a narrow thoracic outlet, which may be considered an anatomical difficulty.

Conclusion

In our opinion, this study has revealed the importance of the thoracic outlet aperture and its influence on the minimally invasive cholecystectomy procedure. We believe that the diameter of the inferior thoracic aperture might be considered one of the many predictive factors for a challenging laparoscopic cholecystectomy. The measurements of these diameters could be clinically useful in general surgery, akin to the use of pelvic diameters in obstetrics.

Disclosures

Ethichs Committee Approval: This prospective anatomical and clinical study was approved by the Ethics Committee of Bursa Yuksek Ihtisas Research and Training Hospital (Approval Number: 2014/07-01) and was conducted in the Department of General Surgery at Bursa Yuksek Ihtisas Research and Training Hospital.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – D.T.; Design – D.T., M.I.K., D.T.; Supervision – D.T.; Materials – E.B.; Data collection and processing – F.E.C., O.F.A.; Analysis and interpretation – D.T., O.F.A.; Literature search – D.T., O.F.A.; Writing – O.F.A.; Critical review – D.T., M.I.K., E.B.

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