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Evaluation of the Common bile duct (CBD) Diameter After Laparoscopic Cholecystectomy (LC) and Laparoscopic Common Bile Duct Exploration (LCBDE): A Retrospective Study

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Background: Common Bile duct (CBD) measurement is a crucial aspect in the evaluation of the biliary tree. Whether the CBD undergoes any compensatory change in diameter after laparoscopic cholecystectomy or laparoscopic common bile duct exploration is still up for discussion. The aim of this study was to investigate CBD diameter changes after laparoscopic cholecystectomy (LC) and laparoscopic common bile duct exploration (LCBDE) on magnetic resonance cholangiopancreatography (MRCP).

Materials and Methods: Our retrospective study is divided into 2 sections. The first part assessing CBD diameter changes after laparoscopic cholecystectomy due to gallstones or gallbladder polyps, involved 85 patients, who underwent MRCP procedures. These patients aged between 30 and 85 were divided into an interval LC group (group A, n = 56) and a remote LC group (group B, n = 29). In group A, the common CBD diameters were measured at their widest portions on MRCP obtained before and after laparoscopic cholecystectomy. Measurements of the CBD diameters were repeated on MRCP obtained twice after the surgery in group B. Section 2 consisted of 38 patients who had choledocholithiasis and were treated with laparoscopic CBD exploration and T-tube placement. These patients aged 26 to 86 formed the interval LCBDE group (group C). The CBD widest diameters were measured on MRCP before LCBDE and after T-tube cholangiography for these individuals. Patients in groups A and C were further divided into 5 and those in group B into 4 age-related subgroups to facilitate statistical analysis. The Pearson correlation test was performed to find any relationship between CBD diameters and age in groups A and B. Paired sample T test was used to compare the significant difference between the 2 sets of CBD diameters in each study group and their subgroups.

Results: In the interval LC group, the post-LC mean CBD diameter was significantly wider when compared with the preoperative mean diameter ($P < 0.05$). There was a significant difference between the first and second post-LC means CBD diameter in the remote LC group ($P < 0.05$). In group C, the mean CBD diameter measured on T-tube cholangiography after LCBDE was significantly smaller than the preoperative dilated mean diameter ($P < 0.05$).

Conclusions: This study demonstrated significant dilation occurring in the common bile duct diameter after laparoscopic cholecystectomy. Furthermore, our remote LC group also supported that claim by showing significant dilation between the first and second post-cholecystectomy CBD diameter values. And lastly, our interval LCBDE sample's initial dilation of the CBD diameters was reduced after surgery and stone extraction.

Key Words: common bile duct, common hepatic duct, diameter, laparoscopic cholecystectomy, laparoscopic common bile duct exploration, magnetic resonance cholangiopancreatography

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Dilation of the common bile duct (CBD) is usually caused by obstructive changes such as CBD stones or strictures, gallbladder or pancreatic tumors, previous surgical interventions, and periampullary diverticulum.[1–3] Other causes include increasing age[4–7]; and cholecystectomy.[8–12] Post-cholecystectomy dilation was first highlighted in 1887 by Oddi.[8] Later some studies supported this statement by claiming that physiological compensation occurs due to the loss of the gallbladder's reservoir function.[10,11,13]

Since then, this theory in humans has been promptly debated and remains controversial in the radiologic, surgical, and sonographic literature, necessitating further examinations.[10] While some studies showed a significant dilation in the CBD diameter after cholecystectomy,[14–17] others denied such results.[18–20] Following cholecystectomy, CBD diameter dilation has been observed in ultrasonography (US), computed tomography (CT), and magnetic resonance cholangiopancreatography (MRCP) studies.[10,11,13,15]

Magnetic resonance cholangiopancreatography is a noninvasive "gold standard" method that uses T2 sequence magnetic resonance imagery for assessing gallbladder and CBD diseases. It is used to examine intrahepatic and extrahepatic bile ducts.[21,22] To our knowledge, MRCP has high sensitivity and specificity in detecting choledocholithiasis.[23] But so far, only 1 study has utilized MRCP to assess post-laparoscopic cholecystectomy CBD dilatation.[15]

Our research investigated the CBD diameters retrospectively in both the postlaparoscopic cholecystectomy

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population (section 1) and the postlaparoscopic CBD exploration population (section 2). Section 1 of this study has 2 samples of post-LC patients. In sample 1 (interval LC), we evaluated any significant change in the CBD diameters measured on MRCP before and after laparoscopic cholecystectomy. In sample 2 (remote LC), we investigated if there was a significant change in diameter between 2 post-LC CBD diameters.

In section 2, the CBD diameters in post-LCBDE patients were assessed using MRCP. Two sets of CBD diameters measured before LCBDE and after T-tube cholangiography were recorded and compared (interval LCBDE). This study aims to measure the CBD diameters in the same patients using MRCP images to see whether there are any changes in the common bile duct diameter after (1) laparoscopic cholecystectomy and (2) laparoscopic common bile duct exploration.

MATERIALS AND METHODS

Ethics Statement

This retrospective study was performed in the Department of General Surgery of the Nanjing First Hospital, Nanjing Medical University. This manuscript has been reviewed and approved by the ethics committee of Nanjing First Hospital affiliated with Nanjing Medical University.

Data Research

In section 1 of this study, we researched MRCP images in the MRI database of the Nanjing First Hospital affiliated with Nanjing Medical University, China, between January 2011 to November 2021. Using the keyword "post-cholecystectomy", 861 MRCPs were identified. Each post-cholecystectomy MRCP was examined using the same database by cross-matching name, gender, age, and diagnosis to find a corresponding pre-cholecystectomy MRCP image. Furthermore, we also recorded patients having a second post-cholecystectomy MRCP.

The second part of the research was conducted by searching the term "T-tube" and 260 T-tube cholangiography were registered. We recorded T-tube cholangiography firstly as it is the most appropriate method to obtain images to measure the CBD diameters after LCBDE for our retrospective study. All the T-tube cholangiography were then assessed using the same method mentioned above to find their corresponding pre-LCBDE MRCP images, resulting in 44 cases.

Inclusion and Exclusion Criteria

Laparoscopic Cholecystectomy Sample

The LC sample was assembled by recruiting patients with the following conditions: 2 MRCP images (interval: pre-LC vs. post-LC and remote: post-LC vs. post-LC) and laparoscopic cholecystectomy due to gallstones or gallbladder polyps.

Our exclusion criteria included: Open cholecystectomy; Conversion from laparoscopic to open surgery; Extrahepatic/intrahepatic bile ducts stones; Acute cholecystitis; Cholangitis; Abnormal LFTs; Gallbladder carcinoma; Liver carcinoma; Cholangiocarcinoma; Gas accumulation or infection in the CBD; CBD stenosis; CBD injury; and Chronic or necrotizing pancreatitis. Patients were also excluded if their stones or polyps were diagnosed on CT or US without MRCP examinations.

Laparoscopic Common Bile Duct Exploration Sample

Inclusion criteria for selecting the LCBDE sample were if patients had 1 MRCP imaging before and 1 T-tube cholangiography after LCBDE, common bile duct stones, and LCBDE with stones extraction.

The exclusion criteria for this sample were open CBD exploration (OCBDE), conversion from LCBDE to OCBDE, patients with chronic pancreatitis, recurrence of choledocholithiasis, LCBDE without T-tube placement, post-LCBDE common bile duct infection, and unclear T-tube cholangiography.

Patients Grouping

Data collected were assessed using the criteria mentioned above, and the final cohort investigating any change in CBD diameter after LC included 85 patients and were divided into 2 groups (section 1). The interval LC group (group A) consisted of 56 patients aged 30 to 85 years old with 1 MRCP before and one after surgery.

The remaining 29 patients formed the remote LC group (group B), ranging from 41 to 79 years old. These patients had 2 MRCP after cholecystectomy (no MRCP was found before surgery). MRCP was performed for these patients after LC due to abdominal discomfort to check for any CBD pathology, but none was found.

The second section evaluating CBD diameter after LCBDE consisted of 44 patients with 1 MRCP before surgery and 1 T-tube cholangiography after LCBDE. Six were excluded due to CBD stones recurrence after further analysis of these patients' medical reports. And The final cohort in the interval LCBDE group (group C) involved 38 patients aged 26 to 86 years old. A general description of the 3 study groups is shown below (Fig. 1).

Time Interval Between Two MRCP

Preoperative MRCP was performed within 3 days or the same day before laparoscopic cholecystectomy and laparoscopic CBD exploration for patients in groups A and C. The Postoperative MRCP for group A's patients ranged from 3 to 1008 days after LC. Patients in group B had the 2 MRCPs done after LC with time interval between them ranging from 164 to 3448 days. Group C's patients had their T-tube cholangiography done between 2 to 610 days after LCBDE.

Measuring CBD Diameters on MRCP

All participants fasted for 6 to 8 hours before MRCP to minimize fluid secretions within the stomach, the duodenum, and diminished bowel peristalsis. Each patient's first and second MRCP illustrations were displayed simultaneously to facilitate CBD diameter measurements (Fig. 2). The inner diameter of each patient's CBD was digitally estimated from perpendicular cross-sections at a certain position on the biliary tree by positioning an electronic caliper perpendicular to the long axis at the widest visible area of the CBD on MRCP for all the patients, and the values were recorded (Fig. 3).[7,24]

Recorded Information and Age Subgroups

For every patient: age, gender, 2 CBD diameters, and the time interval in days between the images were recorded for this study. All patients in the 3 study groups were stratified into age-related subgroups, regardless of gender. Group A yielded 5 subgroups: (1) 40 years or younger; (2) 41 to 50 years; (3) 51 to 60 years; (4) 61 to 70 years, and (5)

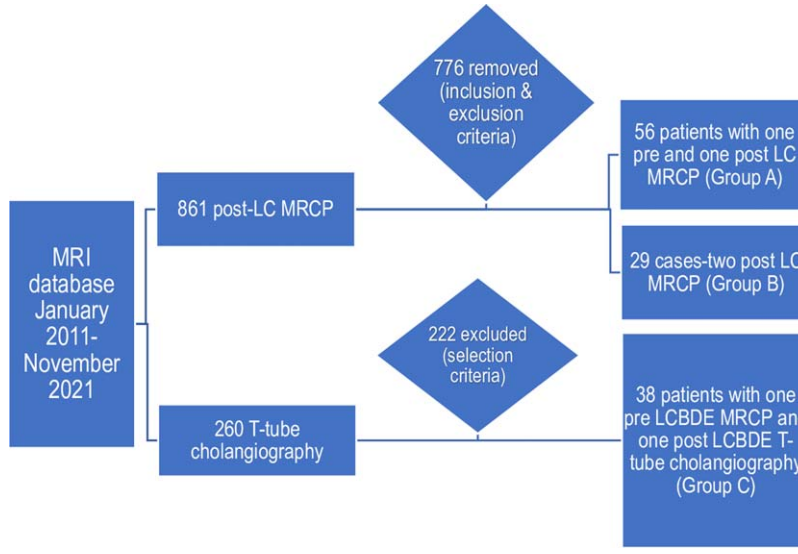

FIGURE 1. Classification of the final interval LC (group A), remote LC (group B), and interval LCBDE (group C) groups.

71 years or older. Due to zero patients under the age of 40 in group B and a small number of patients under 40 years old in group C, stratifications for groups B and C were as follows: (1) 50 years or younger, (2) 51 to 60 years, (3) 61 to 70 years and (4) 71 years or older; and (1) 50 years or younger, (2) 51 to 60 years, (3) 61 to 70 years, (4) 71 to 80 years and (5) 81 years or older, respectively. The collected data's evaluation and statistical interpretation were performed independently for each study group and their corresponding age subgroups.

Statistical Analysis

Data collected were statistically analyzed using Statistical Package for the Social Sciences for Windows (SPSS Version 26.0, IBM). Percentages and frequencies are used to express categorical data. Numerical data such as ages and CBD diameters were computed as mean, SD and range. Time intervals between the 2 MRCPs were recorded in days as mean, SD, and range. The means of CBD diameter in the study groups were recorded twice. The Pearson correlation test was used to evaluate any relationship between CBD diameters and age in the interval LC (group A) and remote LC groups (group B). Significance of difference in CBD diameters before and after surgery in both groups A and C; and between the first postoperative and second postoperative CBD diameters in group B were performed using Paired samples T test. Next, the means of common bile duct diameter for each subgroup were recorded for further evaluation. And the paired sample T test was used again to assess the significance of the difference by comparing the first values of the CBD diameter to their corresponding second values for each subgroup. $P < 0.05$ was considered statistically significant.

RESULT

Our study comprises 123 patients who had surgery and MRCP examinations in our hospital.

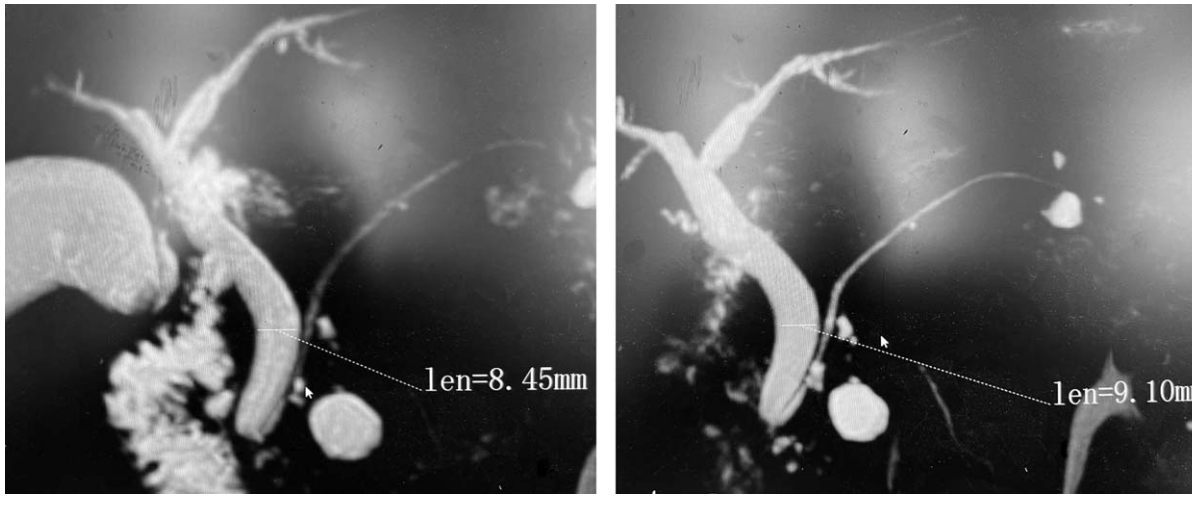

FIGURE 2. Pre (left) and post (right) laparoscopic cholecystectomy MRCPs of a 67-year-old patient while measuring CBD diameters.

FIGURE 3. By placing an electronic caliper perpendicular to the long axis at the widest estimated portion to measure the CBD diameters on MRCP in a patient.

Section One: CBD Diameter Dilation After Laparoscopic Cholecystectomy

The laparoscopic cholecystectomy sample was divided into the interval LC (group A) (65.88%) and remote LC (group B) (34.12%) groups.

The interval LC group (group A) consisted of 56 patients (40 or 71.43% females) with a mean age of 60.57 ± 13.176, and the average time interval between the 2 MRCPs was 424.07 ± 257.103 days. The Pearson correlation test was significant between pre-LC CBD diameters and age (Table 1). However, after LC there was no correlation between CBD diameters and age (in Table 2).

Pre-LC mean CBD diameter was 6.90 ± 2.14866 mm and post-LC mean CBD diameter was 8.20 ± 2.45692 mm. A statistically significant increase was present between the preoperative mean CBD diameter and the postoperative mean CBD diameter ($t = 2.004$, $P < 0.05$). Means of preoperative and postoperative CBD diameters of the subgroups were also compared with investigate any statistical differences in the interval LC sample. There was significant dilation in CBD diameters after LC, as shown in Table 3.

The remote LC group (group B) included 29 patients (22 or 75.86% females) with a mean age of 59.59 ± 11.262. The mean time interval between the 2 MRCPs was 2107.59 ± 837.582 days. The Pearson correlation showed no relationship between CBD diameters and age after LC ($r = 0.240$ and $r = 0.278$ for the first and second post-LC CBD diameters, respectively). The total means of the 1st post-cholecystectomy and 2nd post-cholecystectomy CBD diameter were 8.58 ± 3.73408 mm and 9.89 ± 4.19521 mm, respectively. When comparing CBD diameters, a statistically significant dilation is found between the 2 postoperative CBD diameters ($t = 2.048$, $P < 0.05$). Results for each age subgroup are detailed in Table 4.

TABLE 1. The Pearson Correlation Test Shows the Relationship Between CBD Diameters and Age Before Laparoscopic Cholecystectomy in the Interval LC Group

Correlations		
	Age	**Pre-LC CBD diameters**
Age		
Pearson correlation	1	0.285*
Sig. (2-tailed)		0.033
N	56	56
Pre-LC CBD diameters		
Pearson correlation	0.285*	1
Sig. (2-tailed)	0.033	
N	56	56

*Correlation is significant at the 0.05 level (2-tailed).

TABLE 2. Pearson Correlation Test Demonstrates No Relationship Between Post-LC CBD Diameters and Age After Laparoscopic Cholecystectomy in the Interval LC Group

Correlations		
	Age	**Post-LC CBD diameters**
Age		
Pearson Correlation	1	0.259
Sig. (2-tailed)		0.054
N	56	56
Post-LC CBD diameters		
Pearson correlation	0.259	1
Sig. (2-tailed)	0.054	
N	56	56

Section Two: The Dilated CBD Diameter Reduced After LCBDE

The change in the dilated CBD diameter after laparoscopic common bile duct exploration with the interval LCBDE group (group C), involved 38 patients (20 or 54.05% males) with a mean age of 64.24 ± 16.643. The average time interval between the 2 imaging modalities was 94.76 ± 153.542 days. The pre-LCBDE mean CBD diameter on MRCP was 10.54 ± 3.51492 mm, and the post-LCBDE mean CBD diameter on T-tube cholangiography was 8.70 ± 2.92332 mm.

There was a statistically significant reduction in post-LCBDE CBD diameters when compared with pre-LCBDE CBD diameters ($t = 2.2026$, $P < 0.05$). Hence, all patients below the age of 81 had a significant difference between their post-LCBDE CBD diameters and their preoperative CBD diameters. However, patients aged 81 and above showed no statistical difference between the 2 CBD diameters ($P = 0.071$). Table 5 shows details for each age subgroup in the interval LCBDE sample.

DISCUSSION

The CBD diameter values vary according to the measuring techniques used. For instance, US measurements are slightly lower than those obtained on CT. The CBD diameter is measured from the inner-wall to the inner-wall on ultrasonography, in contrast to CT, which is done from the outer-wall to the outer-wall.[13,25] An increase in pressure caused by the injection of contrast medium in the CBD when performing ERCP may result in a larger CBD diameter value.[26,27] Two previous studies by McArthur et al and Valkovic et al reported that the CHD and the CBD could not be separately evaluated because they are not easily differentiated on sonography.[10,13] Also, because the cystic duct is too small to be visible on either US or CT, special attention must be paid to not include the cystic duct in the CBD diameter measurements.[28]

TABLE 3. Comparing Pre-LC and Post-LC CBD Diameters (Mean ± SD) in the Interval LC Group (Group A)

Age Groups in years	No. Patients	Pre-LC Mean CBD diameter in mm	Post-LC Mean CBD diameter in mm	*P*
≤40	5	6.24 ± 0.79878	8.97 ± 1.29084	0.033
41-50	10	6.36 ± 0.48747	7.38 ± 0.54663	0.006
51-60	10	6.51 ± 0.62331	6.99 ± 0.51237	0.014
61-70	19	6.78 ± 0.56448	7.97 ± 0.62939	< 0.0001
≥71	12	8.14 ± 0.61815	9.95 ± 0.62015	< 0.0001
TOTAL	56	6.90 ± 2.14866	8.20 ± 2.45692	< 0.0001

In our study, we used MRCP, which has a high sensitivity (93%) and high specificity (94%), to detect choledocholithiasis when evaluating the biliary tree.[29] We excluded patients who had open surgery or conversion from laparoscopic to open surgery due to the fact that in our own experiences, we found that patients who have had previous "open abdominal surgeries" usually present with adhesions from the peritoneum to abdominal organs because of incisions made. These adhesions usually create tension in the CBD and could affect the normal size of the CBD diameters. Patients using medications that contribute to CBD dilation in both sections were also excluded, and those with CBD stones found on MRCP and recurrence of choledocholithiasis on T-tube cholangiography after LC and LCBDE, respectively. And measurement of the extrahepatic bile ducts' inner diameter on MRCP after the section where the cystic duct joins the CHD to form the CBD contributes to our study's data accuracy.

Two previous studies conducted on CBD diameter changes after LC by Pavlovic et al and Valkovic et al had a choledocholithiasis rate of 1% and 2%, respectively[10,15]; however, in our study, the rate of CBD stones when evaluating the CBD diameter was zero as patients with postoperative stones development or recurrence were excluded.

The CBD diameter significantly increased for the whole sample in the interval LC group after cholecystectomy ($P < 0.05$). Several studies have reported similar results where the CBD diameter increased after removing the gallbladder.[10–13,15,17,30] The latter physiologically acts as a tension bulb to maintain steady bile pressure in the biliary tree when the sphincter of Oddi is closed.[31] And, the absence of this reservoir-acting sac causes a compensatory increase in CBD diameter to withstand the biliary pressure.

On the other hand, Valkovic et al[10] stated that there is no immediate CBD dilation occurring in the early postcholecystectomy period and no need to measure the CBD diameter. However, our study found that the CBD dilated immediately after LC. Where in 2 patients, we found an increase of 1.25 and 1.27 mm in their initial pre-LC CBD diameter values, which were recorded at 3 and 5 days after surgery, respectively.

For our remote laparoscopic cholecystectomy patients, a statistically significant dilatation was found between the first and second post-LC CBD diameters ($P < 0.05$). This group included 9 patients who were diagnosed with gallstones on CT and US before LC. Our study did not include these patients in the interval LC group due to the lack of their pre-LC CBD diameters. Also, we ensured that the Liver function tests (LFTs) of all the 85 patients included in this section were normal. As high values of γ-aminotransferase (> 90 U/L) and ALP increases the possibility of choledocholithiasis.[11,32–37]

The postcholecystectomy mean CBD diameter values in both the interval (8.20 ± 2.45692 mm) and remote cholecystectomy (9.89 ± 4.19521 mm) samples are within <10 mm, which is consistent with the study done by Park et al.[11] Therefore, we can confirm a threshold upper limit of CBD diameter of 10 mm after laparoscopic cholecystectomy. The remote LC group of our study shows statistically significant differences in CBD diameters among all age groups when comparing the 2 post-cholecystectomy CBD diameters (Table 4). It also indicates that the CBD continues to dilate after cholecystectomy as time goes by.

In section 1 of our research, the interval LC group showed that the CBD undergoes a compensatory mechanism postgallbladder removal. The significant difference in our 2 post-LC values (remote LC group) begs whether this phenomenon is caused by an adaptive response of the CBD in the absence of the gallbladder or whether the increase in our second post-LC CBD diameters is due to a physiological dilation. We found no studies inquiring about this mechanism, thus opening the door for future studies. However, the Pearson correlation test demonstrated that post-LC CBD diameters in both the interval and remote LC groups have no relationship with age.

After stones extraction through an incision made in the CBD during the LCBDE procedure, many surgeons opt to insert a T-tube in the cut before stitching up the CBD.[38] The T-tube allows the drainage of residual stones which may have been undetected or impossible to extract during the surgery.[39,40] Other reasons include decompression of the CBD, incision support, prevention of bile building up due to temporary swelling, and its leakage through the incision.[39,40] T-tube cholangiography also helps us to obtain CBD images after LCBDE, whereas for primary closure after LCBDE usually needs us to do MRCP again to obtain the images, which is costly in real-world clinical settings.

In section 2, we measured the CBD diameter on MRCP obtained before LCBDE and after LCBDE with T-tube insertion to assess whether, postsurgery, the dilated CBD diameter reverted back to under the accepted upper limit set by previous studies.[5,7,41] The difference between the pre-LCBDE and the post-LCBDE CBD diameter was statistically significant for the whole sample (Table 5)

TABLE 4. Comparison of CBD Diameters (mean ± SD) Between the 2 Post-LC Values in the Remote LC Group (Group B)

Age Groups (years)	No. Patients	First Post-LC mean CBD diameter in mm	Second Post-LC mean CBD diameter in mm	*P*
≤50	7	6.50 ± 1.43743	7.16 ± 1.43320	0.030
51-60	8	9.74 ± 1.27398	11.46 ± 1.57350	0.017
61-70	8	8.19 ± 1.13595	9.25 ± 1.04831	0.035
≥71	6	9.96 ± 1.70154	11.83 ± 1.90357	0.007
TOTAL	29	8.58 ± 3.73408	9.89 ± 4.19521	< 0.0001

TABLE 5. Statistical Differences in CBD Diameters (mean ± SD) of the Different age Subgroups in the Interval LCBDE Group (Group C)

Age groups (years)	No. Patients	Pre-LCBDE mean CBD diameter in mm	T-tube cholangiography mean CBD diameter in mm	*P*
≤ 50	8	8.19 ± 0.74385	6.10 ± 0.55819	0.024
51-60	7	9.99 ± 0.93295	8.32 ± 0.77738	0.019
61-70	7	13.03 ± 1.91610	9.85 ± 1.30846	0.028
71-80	9	11.52 ± 0.97771	10.23 ± 0.75832	0.041
≥ 81	7	10.05 ± 1.25739	8.95 ± 1.32741	0.071
Total	38	10.54 ± 3.51492	8.70 ± 2.92332	< 0.0001

($P < 0.05$), proving a significant decrease of the dilated CBD diameter size after LCBDE.

However, in analyzing by subgroups, we found no statistically significant decrease between the 2 CBD diameter values ($P = 0.071$) in patients above 81 years old. It is known that longitudinal smooth muscle bands and their intervening connective tissue breaks with increasing age and are accompanied by loss of the ductal wall reticuloendothelial network.[42] Therefore, this inability in our eldest group of patients to experience a significant reversion in CBD diameter can be theorized due to the loss of the ductal wall's reticuloendothelial network with increasing age. In such a situation, it can be hypothesized that the CBD diameter change in older patients post-LCBDE is age-related rather than being surgically-related.

The first section of our study suggests that CBD undergoes a potential compensatory adaptive mechanism in response to the removal of the gallbladder. Although this likeliest phenomenon is supported by our results, future studies involving methods evaluating the intraductal pressure changes pre-LC and post-LC will help strengthen the compensatory adaptive theory.

The limitations in our study include a nondefined time interval between the 2 images. However, as this study is being performed retrospectively, we recorded the longest time interval to be 3448 days which is within 10 years, as Wu et al[5] mentioned that the CBD physiologically increases by 1 mm every decade. In addition, the common bile duct diameter was measured at a single point, being the widest estimated portion of the extrahepatic bile ducts. Next, we did not consider the respiratory phase during data collection. And finally, this investigation was conducted in a single-center environment, with only Chinese participants. This result may be different in people with different ethnic backgrounds.

CONCLUSION

In conclusion, this study demonstrated that the CBD diameter dilates after laparoscopic cholecystectomy. In the interval laparoscopic cholecystectomy group, we found the increase in CBD diameters after LC to be significant, and we concluded that this dilation was due to the compensatory adaptation of the CBD in the absence of the gallbladder.

The increase in our remote LC subgroups further supports the claim of an increase in CBD diameters post-LC. However, this could also be an effect of the physiological dilation of the CBD as one ages.

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