World J Surg (2019) 43:207–213
https://doi.org/10.1007/s00268-018-4770-z

ORIGINAL SCIENTIFIC REPORT WITH VIDEO

Hepatic Pedicle Occlusion with the Pringle Maneuver During Difficult Laparoscopic Cholecystectomy Reduces the Conversion Rate

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Published online: 28 September 2018
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Abstract

Background In the presence of cholecystitis or portal hypertension, hemorrhage is common during laparoscopic cholecystectomy (LC) because the vessels of Calot's triangle are fragile and tortuous. Bleeding can obstruct surgical field visibility and increase conversion rates and risk of common bile duct injury. The Pringle maneuver is a simple occlusion approach that could limit blood flow from the hepatic pedicle, thus controlling bleeding to provide a clear surgical field to reduce conversion rate. In this study, we aimed to investigate the feasibility, effectiveness and safety of hepatic pedicle occlusion with the Pringle maneuver during difficult LC.

Methods From 2011 to 2015, LC with hepatic pedicle occlusion by the Pringle maneuver was performed in 67 patients (Pringle group). Another group of 67 cases with matched clinical parameters where LC was performed without the Pringle maneuver (non-Pringle group) was retrieved from a database to serve as the control group.

Results The Pringle group had a significantly lower conversion rate (1.49% vs. 11.9%; $P = 0.038$), less blood loss (37.5 ± 24.1 mL vs. 94.5 ± 67.8 mL; $P = 0.002$), shorter postoperative hospitalization (2.5 ± 1.4 days vs. 3.5 ± 2.5 days; $P = 0.005$), and lower cost (\$1343 ± \$751 USD vs. \$1674 ± \$609 USD; $P = 0.024$) than non-Pringle group. There was one case each of bile duct injury and readmission within 30 days because of bile leakage in the non-Pringle group, but none in the Pringle group.

Conclusions Hepatic pedicle occlusion could provide a clear surgical field and enable the recognition of structures during LC. The Pringle maneuver offers a feasible and safe approach to lower conversion rates in difficult LC.

Introduction

Laparoscopic cholecystectomy (LC) has become the gold standard surgical approach for benign gallbladder diseases on account of its shorter hospital stay, faster recovery, and better cosmetic outcomes than conventional open cholecystectomy [1–3]. However, in some difficult cases, LC needs to be converted to an open procedure to ensure patient safety. Continuous bleeding during the dissection of Calot's triangle of the gallbladder with extensive inflammation, as well as dense adhesions, can make recognition of the biliary anatomy difficult. In particular, in the presence of acute inflammation, the surrounding tissues may become edematous and fragile; thus, even gentle manipulation of dissection may lead to bleeding, thereby obscuring

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00268-018-4770-z) contains supplementary material, which is available to authorized users.

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the vision of the surgeon and increasing the risk of structure damage. Consequently, conversion to laparotomy is an inevitable choice in some cases [4]. On the other hand, in cases accompanied with portal cavernous transformation or portal hypertension, the vessels of Calot's triangle tend to be enlarged and tortuous, and the vascular network distribution is richer than usual [5, 6]. An attempt of dissection at the Calot's triangle may lead to bleeding during LC, which makes conversion to open surgery extremely possible, because of lack of clear visualization. Under these circumstances, compression at the Calot's triangle with gauze always fails to achieve hemostasis. In addition, the hasty use of electrocoagulation is generally avoided for the fear of common bile duct (CBD) damage. Therefore, conversion rates of LC in such difficult situations have been reported to range from 10 to 20% [7].

The Pringle maneuver, which was first described in 1908 [8], is probably the simplest method of limiting blood inflow of porta hepatis and can easily be performed laparoscopically [9, 10]. Occluding blood flow from the hepatic pedicle can effectively limit the pooling of blood in Calot's triangle and create a bloodless operating field. In addition, it enables the recognition of structures and may reduce the risk of damage to the CBD and structures in the hepatic hilum. Therefore, it is a novel approach for difficult cholecystectomy that has not been reported in previous studies.

The present study aimed to investigate the feasibility, effectiveness, and safety of hepatic pedicle occlusion with the Pringle maneuver during difficult LC.

Materials and methods

Patients

From September 2011 to February 2015, patients who underwent LC with the Pringle maneuver (Pringle-LC; Pringle group) at West China Hospital were retrospectively investigated. The decision to perform Pringle-LC was made intraoperatively for difficult LC cases, which was defined as the presence of inflammation or adhesions in Calot's triangle, or portal cavernous transformation, or portal hypertension. The Pringle maneuver was considered in the following cases: (1) Severe bleeding threatens the safety of the patient; (2) continuous and mild bleeding seriously obscures recognition of structures and cannot be limited easily. In total, LC with hepatic pedicle occlusion by the Pringle maneuver was performed in 67 patients (Pringle group). For comparison, a historical control group comprising 67 difficult LC cases in which conventional LC without the Pringle maneuver (non-Pringle group) was performed were selected from a cohort of 6228 patients registered in a database by a computerized randomization program according to age, gender, and "reason for being difficult" (i.e., inflammation, adhesion, portal hypertension, and portal cavernous transformation); these cases were matched with the Pringle group. In the database, the degree of inflammation and adhesion was recorded as "slight, moderate, or severe," which was evaluated by two experienced surgeons. The criterion to grade the degree of inflammation is as follows: (1) severe: gall bladder wall thickness of 5 mm or greater; (2) moderate: gall bladder wall thickness of 2–4 mm; (3) slight: gall bladder wall thickness of less than 2 mm. The criterion to grade the degree of adhesion is as follows: (1) severe: gall bladder is completely covered by the omenta or surrounding tissues and it cannot be seen at all; (2) moderate: more than 50% of the gall bladder is covered, but part of the gall bladder wall can still be seen; (3) slight: less than 50% of the gall bladder is covered and most of the gall bladder wall can be seen. Preoperative examinations, such as blood tests and abdominal ultrasound, were routinely performed in all patients. Ultrasound and magnetic resonance cholangiopancreatography (MRCP) were used when anatomic variations were suspected or when the location of gallstones needed to be confirmed. The costs were obtained from West China Hospital by consulting the medical records, and the total cost included examination fee, operation fee, medicine fee, and hospitalization fee. This study was approved by the Research Ethics Committee of West China Hospital (Chengdu, China).

Surgical technique

A standard laparoscopic approach was employed [11]. Once a pneumoperitoneum was established, two 12-mm and one 5-mm trocars were inserted. Then, the gallbladder neck and the Calot's triangle were dissected. After being skeletonized, the cystic duct and cystic artery were ligated with clips. When unremitting bleeding was encountered during dissection of the gallbladder neck and Calot's triangle, the bleeding site was compressed with gauze for hemostasis. If this did not work, the Pringle maneuver was employed. But in some cases, the Pringle maneuver was employed empirically at the beginning of an operation, as follows: (1) existence of severe portal hypertension or portal cavernous transformation; (2) two experienced surgeons who could perform LC independently considered the inflammation or adhesion to be extremely severe and predicted that continuous bleeding was highly likely to occur.

The extracorporeal Pringle maneuver was performed as follows [12]: First, the pars flaccida of the gastrohepatic ligament was opened using hook electrocautery. After placing a 5-mm trocar along the axillary line in the right flank, a grasper was inserted behind the hepatic pedicle

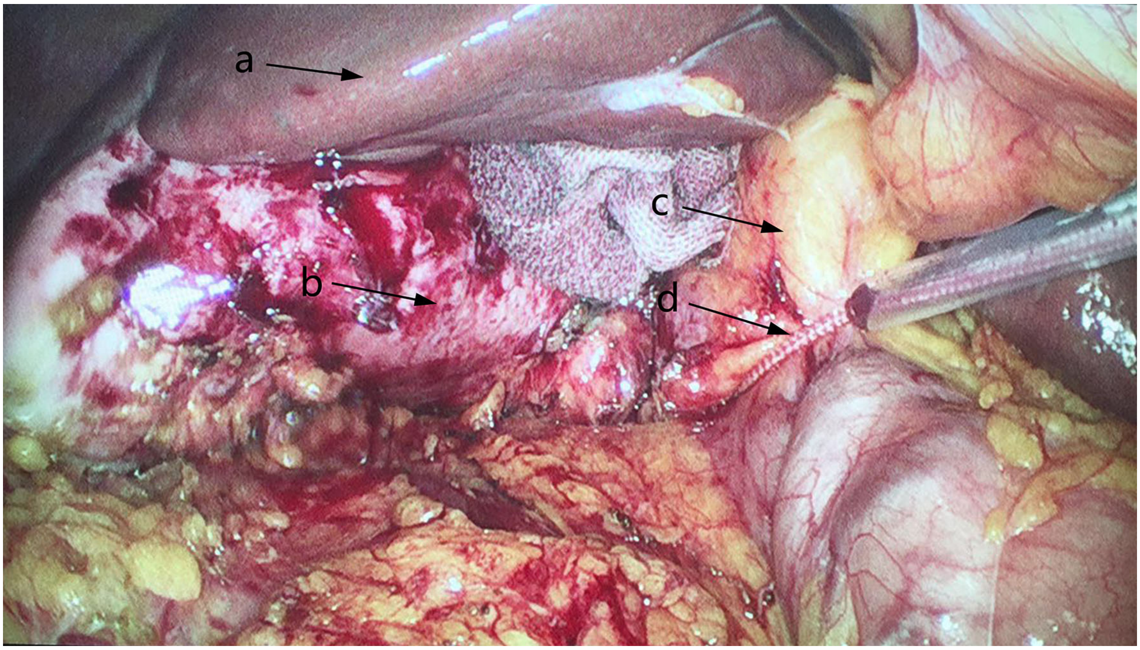

Fig. 1 Laparoscopic cholecystectomy with hepatic pedicle occlusion. (a) Liver. (b) Gall bladder. (c) Hepatic pedicle. (d) Occlusion tape. The hepatic pedicle could be occluded by tightening the tape and pushing the tube toward the pedicle

through the foramen of Winslow, which was then covered with a cotton tape. Next, both ends of the tape were exteriorized through the 5-mm trocar. This trocar was removed, and both ends of the cotton tape were threaded through a 16-F plastic aspirator tube. The internal end was left against the pedicle, while the external end remained outside the patient. To occlude blood flow, a tourniquet was tightened around the hepatoduodenal ligament with a clamp under direct vision (Fig. 1). But in some cases, the omentum gastrohepaticum could not be penetrated due to severe adhesion, so the occlusion tape could not cross behind the hepatic pedicle, and an atraumatic hemostatic clamp was used to accomplish occlusion (Video 1).

For the intracorporeal Pringle maneuver, the procedure of the placement of a cotton tape around the hepatic pedicle was the same as that described for the extracorporeal Pringle maneuver. The ends of the cotton tape were pulled out of the 12-mm trocar located above the optic trocar. Then, the ends were threaded through a 16-F, 5-cm-long plastic tube. Subsequently, the tube was pushed into the abdominal cavity, and clips were placed at the ends of the tape. Occlusion was achieved by clipping the hemlock on the tape to tighten the tube against the hepatic pedicle while simultaneously gripping the tail of the tape.

Once the hemorrhage was controlled and the view of Calot's triangle was clear, dissection of the gallbladder neck and Calot's triangle was continued. If the Pringle maneuver did not work or if inflammation of Calot's triangle was too severe, conversion to laparotomy cholecystectomy or subtotal cholecystectomy was adopted.

Statistical methods

All statistical analyses were performed using SPSS 19.0 statistical software (IBM SPSS, Somers, NY, USA). For the comparison of classification variables, Pearson's Chi square test and Fisher's exact test were used, as appropriate. In case of continuous numerical data, independent samples *t* test and the Mann–Whitney U test were used for data that were normally and non-normally distributed, respectively. A P value of less than 0.05 was considered statistically significant.

Results

Preoperative characteristics of patients

During the study period, 67 patients who underwent Pringle-LC were enrolled. Their median age was 50.1 years (range, 28–73 years), and the median American Society of Anesthesiology (ASA) classification was 2 (Table 1). There were no significant differences between the groups in terms of age ($P = 0.251$), gender ($P = 0.591$), ASA scores ($P = 0.436$), BMI ($P = 0.886$), admission ($P = 0.612$), accompanied diseases ($P = 1.000$), and reason for LC being difficult ($P = 0.741$).

Table 1 Patient characteristics

	Pringle (*n* = 67)	Non-Pringle (*n* = 67)	*P* value
Age	50.1 ± 10.8	52.3 ± 11.5	0.251
Gender (male/female)	23/44	26/41	0.591
ASA scores (I, II vs. III, IV)	47/20	51/16	0.436
BMI (kg/m^2)	24.0 ± 4.4	24.1 ± 4.2	0.886
Admission (emergent/elective)	10/57	8/59	0.612
Accompanied diseases (yes/no)	3/64	4/63	1.000
Hypertension	2	3	
Diabetes	1	0	
Chronic respiratory disease	0	1	
Reasons for difficult LC[a]			0.741
Acute cholecystitis (L/M/S)	42 (0/2/40)	45 (0/3/42)	
Adhesions at Calot's triangle (L/M/S)	14 (0/1/13)	15 (0/0/15)	
Portal hypertension	5	4	
Portal cavernous transformation	6	3	

ASA American society of anesthesiology, *L* slight, *M* moderate, *S* severe, *BMI* body mass index

[a]When one case had more than one of the issues, only the most significant difficulty was selected

Surgical outcomes

Surgical outcomes of the two groups are shown in Table 2. The mean occlusion time in the Pringle group was 6.7 min (range, 3–18 min). The mean operative time in the Pringle group tended to be shorter than non-Pringle group (75.9 ± 24.2 min vs. 82.9 ± 26.0 min); however, the difference was not statistically significant (*P* = 0.110). The amount of intraoperative blood loss in Pringle group was significantly less than that in non-Pringle group (37.5 ± 24.1 mL vs. 94.5 ± 67.8 mL; *P* = 0.002).

The conversion rate in the Pringle group was notably lower than that in the non-Pringle group (1/67 vs. 8/67; *P* = 0.038). The reason for conversion in the Pringle group was difficulty in dissecting Calot's triangle where there was severe adhesion with the gastric and duodenum, whereas the reasons for conversion in the non-Pringle group were difficulty in hemostasis (*n* = 3) and difficulty in dissecting the Calot's triangle where continuous and mild bleeding seriously obscured visualization (*n* = 4), and CBD damage (*n* = 1). All LCs were completed without CBD injury in the Pringle group, but there was one incident in the non-Pringle group; this difference was not significant (*P* = 1.000). In that patient, the CBD was burned during electrocoagulation for hemostasis in the Calot's triangle. This issue was resolved with T-tube placement.

The Pringle group had significantly shorter postoperative hospital stay (2.5 ± 1.4 days vs. 3.5 ± 2.5 days; *P* = 0.005) and lower total cost ($1343 ± $751 USD vs. $1674 ± $609 USD; *P* = 0.024) than the non-Pringle group. There was no readmission within 30 days in the Pringle group, but in the non-Pringle group, one patient was readmitted because of bile leakage, which was eventually resolved by endoscopic nasobiliary drainage. The incidence of postoperative complications was similar between the two groups (2 vs. 5; *P* = 0.437). Postoperative complications in the Pringle group were incision site infection (*n* = 1) and difficulty in urination (*n* = 1); those in the non-Pringle group were incision site infection (*n* = 2), bile leakage (*n* = 1), pneumonia (*n* = 1), and arrhythmia (*n* = 1). All complications were resolved by conservative treatment without reoperation.

No difference was found between the Pringle and non-Pringle groups in serum alanine aminotransferase (ALT) levels on postoperative day (POD) 1 (37.4 ± 19.5 vs. 35.2 ± 14.7 IU/L, *P* = 0.290), POD 3 (27.6 ± 12.5 vs. 26.1 ± 13.8 IU/L, *P* = 0.258), and POD 5 (22.5 ± 7.7 vs. 20.4 ± 13.3 IU/L, *P* = 0.271). There was no mortality in this series.

Discussion

This study showed that hepatic pedicle occlusion with the Pringle maneuver was an effective method to control bleeding, ensure a clear surgical field in the Calot's triangle, and significantly lower the rate of conversion during difficult LC. In addition, duration of hospital stay and total cost were distinctly decreased. The method can be considered safe because there was no obvious damage to liver function. To the best of our knowledge, this is the first study reporting application of hepatic pedicle occlusion with Pringle maneuver in difficult LC.

LC has replaced open cholecystectomy as the gold standard procedure for benign gallbladder disease [1]. However, the rates of conversion can reach as high as 2–15% in difficult LC [13–15]. Recently, laparoscopic subtotal cholecystectomy (LSC) has been advocated for some difficult cases with severe cholecystitis or portal hypertension. LSC has been reported to reduce the rate of conversion and CBD injury by avoiding hazardous dissection at Calot's triangle [16, 17]. However, LSC has many disadvantages such as high rates of postoperative bile leak, prolonged drainage, frequent need for percutaneous drainage, retained stones, subhepatic abscess, and delayed cyst formation, all of which yield unsatisfactory results [18, 19]. Therefore, we explored a novel approach to minimize bleeding and maintain adequate visibility during LC to reduce the risk of adverse outcomes for patients. An ideal approach should be easy to perform, effective, less costly, fast to complete, and safe.

Occlusion of blood inflow by the Pringle maneuver was initially applied during conventional open liver surgery, but it has now been extensively used and can easily be performed laparoscopically [9, 10]. In our experience, the pericholecystic tissues were always edematous and fragile in the presence of severe inflammation or adhesions. As a result, continuous and mild bleeding was very common and intractable during dissection of Calot's triangle. Further, because too much use of electrocoagulation without a clear view was generally avoided for fear of CBD damage, bleeding could not be easily stopped. Although in most cases, the bleeding volume was too little to threaten the safety of the patient, the surgical field was completely obscured by the blood. Thus, sometimes laparotomy was an unavoidable choice for fear of bile duct damage. Normally, most vessels in the Calot's triangle branch out from the hepatic pedicle; therefore, hemorrhage can be controlled by occlusion of the pedicle. Compared to the vessel damage, continuous and mild bleeding from inflammatory surrounding tissues caused by dissection of Calot's triangle are more common and seriously bothering the surgeon. This kind of bleeding can also be distinctly alleviated after pedicle occlusion. In our practice, most cases of hemorrhage were indeed terminated soon after the cotton tape surrounding the pedicle was tightened. A clear surgical field helped in the recognition of structures and guaranteed a smooth operation. In addition, fracture of the liver parenchyma is common during dissection of the gallbladder bed, particularly in the presence of cholecystitis. In this case, bleeding of the liver parenchyma can also be stopped by pedicle occlusion to allow precise coagulation or suturing of the fracture. Thus, the Pringle maneuver could help to provide a clear surgical field and identify structures of Calot's triangle.

Table 2 Comparison of outcomes between the two groups

	Pringle (*n* = 67)	Non-Pringle (*n* = 67)	*P* value
Surgical time (min)	75.9 ± 24.2	82.9 ± 26.0	0.110
Estimated blood loss (mL)	37.5 ± 24.1	94.5 ± 67.8	**0.002**
Conversion to laparotomy (*n*)	1	8	**0.038**
Injury of bile duct (*n*)	0	1	1.000
Postoperative hospitalization (days)	2.5 ± 1.4	3.5 ± 2.5	**0.005**
Total cost (USD)	1343 ± 751	1674 ± 609	**0.024**
Readmission within 30 days (*n*)	0	1	1.000
Postoperative complication (*n*)	2	5	0.437[a]
Hemorrhage	0	0	
Incision infection	1	2	
Bile leakage	0	1	
Others	1	2	
ALT of postoperative day 1 (IU/L)	37.4 ± 19.5	35.2 ± 14.7	0.290
Day 3	27.6 ± 12.5	26.1 ± 13.8	0.258
Day 5	22.5 ± 7.7	20.4 ± 13.3	0.271
Occlusion time (min)	6.7 ± 3.2	–	

Results marked in boldface indicate statistical significance

ALT alanine aminotransferase

[a]Comparison of total complication

For the first 19 patients, we performed the Pringle maneuver only after bleeding occurred and the conventional procedure failed to achieve hemostasis. In this circumstance, the view of the Calot's triangle may have already been obscured by the blood. Moreover, after two cases of brisk bleeding that were resolved by hasty performance of the Pringle maneuver, we began to encircle the porta hepatis experimentally at the beginning of surgery. Therefore, in patients who have severe portal hypertension or portal cavernous transformation, we recommend placing the Pringle maneuver empirically at the start of surgery because in such situations, intractable bleeding is extremely probable, carrying higher risk to the patients and also obscuring the surgical field.

In our cohort, tape placement took approximately 3–5 min per patient in the extracorporeal Pringle maneuver and 4–10 min per patient in the intracorporeal maneuver. This implied that the Pringle maneuver could be performed quickly and that it was easy to master. Initially, the intracorporeal Pringle maneuver was used, but we found it difficult to correctly position the hemlock and complete the occlusion. Furthermore, swelling of the pedicle from constant occlusion may make it difficult to remove the hemlock with ultracision. Later, we shifted to the extracorporeal approach because it was easier and faster to complete, although an additional small incision was required [12].

Our results showed that postoperative ALT levels in the Pringle group were slightly higher than those in the non-Pringle group, but this was not statistically significant. The liver can tolerate a certain period of ischemia, for approximately 90 min at most [20]. The relatively short occlusion time with the Pringle maneuver may contribute to lessen this period of ischemia. In our series, the average ischemia time was 6.7 min. When the ischemic period reaches 10 min, 5 min of reperfusion before the following occlusion has been reported to be helpful [21]. For patients with accompanying liver cirrhosis, hepatoprotective drug such as polyene phosphatidyl choline was routinely used. Owing to these factors, there was no liver dysfunction in the present study.

The main limitation of this study was that it was not a randomized controlled trial. However, we used an appropriate historical control group matched by age, gender, and reasons for difficult LC. In addition, this procedure may not be applicable in the presence of gangrene, Mirizzi syndrome, or extremely severe inflammation that makes the structures in Calot's triangle completely unrecognizable. In such cases, LSC or conversion to open surgery would be an inevitable choice. Sometimes the adhesions around the hepatic pedicle and the duodenum may make it difficult to perform Pringle. If the adhesions were too severe and the foramen of Winslow cannot be separated out, which means there was not space for the occlusion tape to be inserted through, it is hardly possible to perform Pringle maneuver.

In conclusion, hepatic pedicle occlusion provided a clear surgical field and enabled the recognition of structures during LC. The Pringle maneuver might offer a feasible and safe approach to prevent bile duct injury and lower the conversion rate of difficult LC.

Acknowledgements This work was supported by grants from the National Natural Science Foundation of China (No. 81602910) and the Fundamental Research Fund for the Central Universities (No. 2017SCU11045).

Authors' contribution YGW, BL, and RCZ contributed to the design of this study; RCZ, KFC, and CYJ contributed to the data collection; FL, KFC, JHC, and RCZ contributed to the data analysis; FL and RCZ contributed to writing the text; BL and YGW contributed to the revision of this article.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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