A self-designed liver circle for on-demand Pringle’s manoeuver in laparoscopic liver resection

Zhenzhen Gao¹, Zhiwei Li², Bo Zhou¹, Lifeng Chen³, Zhenhua Shen⁴, Yuancong Jiang¹, Xiang Zheng¹, Jie Xiang², Qiyi Zhang¹, Weilin Wang¹, Sheng Yan¹

¹Department of Hepatobiliary and Pancreatic Surgery, The Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China, ²Department of Surgery, Division of Hepatobiliary and Pancreatic Surgery, First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China, ³Department of Medical Engineering, First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China, ⁴Department of Surgery, Division of Hepatobiliary and Pancreatic Surgery, Huzhou Central Hospital, Huzhou, Zhejiang, China

Abstract
Background: Laparoscopic liver resection (LLR) allows minimal incisions and relatively quicker post-operative recovery, while intraoperative massive haemorrhage led to conversion to laparotomy. This study aimed to introduce a new, safe and convenient device to serve as Pringle’s manoeuver according to the demand in LLR.

Methods: A liver circle consisting of a hole and a round stem with an obtuse small head was made by medical silica gel. It was applied in LLR to perform on-demand Pringle’s manoeuver and developed its function in inferior vena cava (IVC) occlusion. The time of performing Pringle’s manoeuver by liver circle, extracorporeal tourniquet and endo intestinal clip under laparoscopic simulator and LLR was compared.

Results: The liver circle was successfully applied to perform Pringle’s manoeuver, IVC exposure and occlusion. It took less time in the occluding step of Pringle’s manoeuver than the extracorporeal tourniquet (4.15 ± 0.35 s vs. 9.90 ± 1.15 s, \( P < 0.05 \)) and the endo intestinal clip (4.15 ± 0.35 s vs. 47.91 ± 3.98 s, \( P < 0.05 \)) under LLR. The total manipulating time for Pringle’s manoeuver with liver circle remained the shortest, and the advantages were more obvious with increased frequencies of intermittent Pringle’s manoeuver.

Conclusion: The new-designed liver circle is more convenient compared to other techniques in performing Pringle’s manoeuver, especially the intermittent Pringle’s manoeuver in LLR. It can be used to perform on-demand hepatic blood inflow occlusion in every LLR by pre-circling the hepatoduodenal ligament to control bleeding during surgery. It can also be applied to expose the surgical field of vision and perform IVC occlusion to reduce intraoperative blood loss.

Keywords: Endo intestinal clip, extracorporeal tourniquet, inferior vena cava, laparoscopic liver resection, Pringle’s manoeuver

Address for correspondence: Dr. Sheng Yan, Department of Hepatobiliary and Pancreatic Surgery, The Second Affiliated Hospital, School of Medicine, Zhejiang University, 88 Jiefang Road, Hangzhou 310003, China.
E-mail: shengyan@zju.edu.cn

Dr. Weilin Wang, Department of Hepatobiliary and Pancreatic Surgery, The Second Affiliated Hospital, School of Medicine, Zhejiang University, 88 Jiefang Road, Hangzhou 310003, China.
E-mail: wam@zju.edu.cn

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INTRODUCTION

Laparoscopic liver resection (LLR) in comparison to open surgery has advantages such as decreased post-operative pain, reduced recovery time and shorter hospital stay, while intraoperative haemorrhage remains to be the main concern.\(^3\)\(^{-2}\) Increased blood loss during liver resection is an independent risk factor for post-operative morbidity and mortality.\(^3\) What’s more, increased blood loss in turn causes a higher rate of blood transfusion. Previous studies have shown that perioperative blood transfusion indicates higher tumour recurrence rate and lower patient survival rate.\(^4\) Soubrane et al.\(^5\) performed a survey in nine French centres and found that 13% of 351 patients, who underwent LLR for liver cancer were converted to open surgery, and the main cause of  this transition was due to intraoperative bleeding. To avoid massive haemorrhage during LLR and conversion of  it to an open approach, techniques to control intraoperative bleeding are more demanding than open liver resections.\(^6\)\(^{-7}\)

Many reports on open liver resections have reported that vascular occlusion can be used to reduce intraoperative blood loss during parenchymal dissection.\(^8\)\(^{-10}\) Although the advantages and disadvantages of  blood flow control during liver resection have been debated for decades, Pringle’s manoeuvre (total vascular inflow occlusion) remains the most acceptable type to block the blood flow and is most widely used in open liver resections.\(^11\)\(^{-14}\) Decailliot et al.\(^15\) reported that the use of  Pringle’s manoeuvre in LLR in a small number of  patients achieved the same effect as open liver surgery, causing similar hemodynamic changes. However, due to limited operation field of vision, and narrow space between hepatoduodenal ligament and inferior vena cava (IVC), it remains a great challenge for the application of Pringle’s manoeuvre during LLR.

Pringle’s manoeuvre can be achieved through intra- or extra-corporeal techniques during LLR. Extracorporeal Pringle’s manoeuvre can easily manipulate the blood inflow occlusion extracorporeally using biliary scope\(^16\) or Endo Retract Maxi,\(^17\) making it simple and convenient to achieve repeated blood inflow occlusion during LLR. However, this technique requires an extra-trocar and occupies a large operating space, which might interfere with the operation. Intracorporeal techniques such as six-loop Pringle’s manoeuvre\(^18\) and endo intestinal clip\(^19\) did not require an additional incision and are easy to perform in different positions, but are complex to reproduce under LLR. According to a previous study, liver parenchyma is more tolerant to intermittent Pringle’s manoeuvre than to continuous Pringle’s manoeuvre.\(^19\) Devices that can easily repeat blood flow interruption during LLR without artificially increasing the damage are more demanded.

To combine the advantages and overcome the disadvantages of  the existing techniques, we suggest using liver circle to achieve safe and convenient Pringle’s manoeuvre, especially intermittent Pringle’s manoeuvre, in LLR. The application of  liver circle is not limited and can also be used for partial hepatic inflow occlusion, tissue exposure and IVC occlusion.

PATIENTS AND METHODS

Design of  liver circle

The idea of  the liver circle was inspired by the gastric band and the cable tie used in daily life. The liver circle is made up of  medical silica gel and consists of  a circular hole and a stem. Due to its design of  a round stem, it can be easily inserted into the lesser sac and go through the foramen of  Winslow. The end of  the stem has a relatively smaller diameter than the hole, while the other parts of  the stem have a bit larger diameter. As the device was made up of  medical silica gel, the other parts of  the stem could also pass through the hole by stretching the head to decrease the diameter. The vascular occlusion was then achieved through strong friction produced by unmatched diameters [Figure 1]. The occlusion could be released by slightly pulling the stem out of  the hole to some extent.

To design a reasonable length of  the round stem, we measured the circumference of  the hepatoduodenal ligament in six patients undergoing open hepatectomies, and the mean hepatic portal circumference was 7.45 cm ± 1.28 cm. Considering the operability of  the device, the length of  the stem should exceed the circumference of  hepatoduodenal ligament and should not be too long to interfere with the intraoperative visual field. Combined with our experience, the final design of  the stem length was kept as 14.7 cm, and the effective length available for occlusion was 10.5 cm. We added a scale ruler for every 5 mm in the effective occluding segment, which can further increase the resistance to maintain the blockage and provide thickness for the portal triad after complete blockage, laying a foundation for subsequent partial inflow occlusion study.

Application of  liver circle in laparoscopic liver resection

The self-designed liver circle was designed to serve the purpose of Pringle’s manoeuvre. The device was placed into the abdomen after the lesser sac was opened. The small head of  the stem was inserted into the lesser sac and then through...
the foramen of Winslow. The head was easily passed through the hole of the device due to a smaller diameter. As the device was made up of silica gel, the other parts of the stem could also pass through the hole by stretching the head to decrease the diameter and was pulled to an appropriate space. Then, the circle could maintain its shape through strong friction produced by the unmatched diameters. A Hem-O-Lok clip was placed at the tail of the stem to avoid reinstalling the ring after releasing the occlusion, making it more effective in performing intermittent Pringle’s manoeuver [Figure 2]. The occlusion could be achieved by tightening the circle and could be released by slightly pulling the stem out of the hole to some extent. The Hem-O-Lok clip at the tail made the circle to revert to the pre-blocking state after releasing [Figure 3]. Using the Hem-O-Lok clip, the occlusion could be easily repeated to perform intermittent Pringle’s manoeuver. The occlusion of hepatic inflow was verified by Doppler sonography [Figure 4].

To use liver circle for other functions, we tried to apply it for IVC occlusion during LLR. First, the liver circle was placed through the hepatoduodenal ligament to act as Pringle’s manoeuver. Then, a straight needle with a suture that has a knot at the end was placed into the abdomen and passed out of the patient’s left abdominal wall. Hem-O-Lok clips were used to fix the suture together with the stem of the liver circle. By pulling the suture extracorporeally, the hepatoduodenal ligament was dragged and the IVC was exposed. Then, the liver circle was used to surround the IVC easily and perform IVC occlusion [Figure 5].

**Comparison of the convenience of different methods for Pringle’s manoeuver**

*Under laparoscopic simulator*

We simulated the hepatoduodenal ligament with a red rubber tube that was fixed at both the ends under a laparoscopic simulator. Liver circle, extracorporeal tourniquet and endo intestinal clip, respectively, were used to block the rubber tube, performing as Pringle’s manoeuver. The time required to place, occlude and release the Pringle’s manoeuver was compared between the liver circle and other techniques.

*Under clinical laparoscopic liver resection*

Liver circle, extracorporeal tourniquet and endo intestinal clips were used to occlude the hepatic blood inflow during LLR. Intermittent Pringle’s manoeuver was performed and the strategy was 15–20 min’ occlusion followed by 5 min’ releasing alternately. The time to place, occlude and release of the device were recorded for each cycle of intermittent Pringle’s manoeuver. The time spent in each step of Pringle’s manoeuver and the cumulative time was compared separately among different devices used.

**Statistical methods**

Continuous variables were presented as means ± standard deviation. Student’s t-test, Chi-squared test, Fisher’s exact test and Kruskal–Wallis H-test were performed accordingly. Statistical analyses were performed using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). *P* < 0.05 was considered to be statistically significant.

**Ethical approval**

Patients in the liver circle group were informed of the possible risks. Written informed consent was obtained from all participants. Ethical approval was obtained from the Ethics Committee of the First Affiliated Hospital, School of Medicine, Zhejiang University, China, in accordance with the ethical guidelines of the 1975 Declaration of Helsinki.

**RESULTS**

**Comparison of the convenience of different methods for Pringle’s manoeuver under laparoscopic simulator**

Under laparoscopic simulator, three ways of Pringle’s manoeuver were performed 20 times for each by a skilled surgeon using liver circle, extracorporeal tourniquet and endo intestinal clip. These methods were compared in terms of time required to place, occlude and release the device.
Gao, et al.: Pringle’s manoeuver with liver circle

The time was recorded by two individuals and then averaged. The processes for performing liver circle and extracorporeal tourniquet were similar, which consisted of three steps (placing the manoeuver, occluding the inflow and releasing the occlusion). Comparison of the time spent in each step showed that the liver circle was faster in the placing step than the tourniquet (43.20 ± 10.98 s vs. 63.21 ± 16.82 s, $P < 0.05$), and similarly in the occluding step [Table 1]. No significant difference was found in the speed of releasing step ($P > 0.05$). The process of applying endo intestinal clip to achieve Pringle’s manoeuver could be divided into clamping the hepatoduodenal ligament and releasing the blood inflow, which corresponded to the occlusion and releasing steps of the liver circle. As shown in Table 1, less time was spent to occlude the rubber tube under the laparoscopic simulator than the endo intestinal clip (6.12 ± 1.32 s vs. 9.27 ± 3.69 s, $P < 0.05$). There was no significant difference for the time to release the rubber tube between the liver circle group and the endo intestinal clip group.

**Comparison of the convenience of different methods for Pringle’s manoeuver during laparoscopic liver resection**

Liver circle, extracorporeal tourniquet and endo intestinal clips were separately applied in 18 patients who were undergoing LLR (six patients in each group). The intermittent Pringle’s manoeuver was performed in patients, and these patients received one to four times of hepatic inflow occlusion. The time for each step of Pringle’s manoeuver was studied. The process of intermittent Pringle’s manoeuver could be divided into placing the manoeuver, occluding the inflow, releasing the occlusion, occluding the inflow, releasing the occlusion and then repeating (the placement process of the clip was included in the occluding step). The times of placing the device were fixed at 6, while the times of occluding and releasing steps were determined by the cycles of intermittent Pringle’s manoeuver.

As shown in Figure 6a, the time of placing and occluding the steps spent by the liver circle was less than the tourniquet (41.07 ± 2.96 s vs. 60.51 ± 4.06 s, $P < 0.05$;
4.15 ± 0.35 s vs. 9.98 ± 1.09 s, P < 0.05). There was no significant difference in the time of releasing step between the two groups. The time of occluding and releasing steps in the liver circle group was also significantly less than the clip group (4.15 ± 0.35 s vs. 47.91 ± 3.98 s, P < 0.05; 3.41 ± 0.50 s vs. 23.45 ± 3.53 s, P < 0.05). To reduce the impact of installation process, we further compared the cumulative time among different devices.

For patients, who underwent one or more times of intermittent Pringle’s maneuver, the first cycle was included in the study of one-cycle cumulative time (placing, occluding and releasing). For patients, who underwent two or more times of intermittent blood inflow interruptions, the first two interruptions were included in the study of two-cycle cumulative time (placing, occluding, releasing, occluding and releasing). In patients, who received three or more interruptions, the first three were included in the study of three-cycle cumulative time. As shown in Figure 6b, the liver circle demonstrated less cost for one-cycle cumulative time of Pringle’s maneuver than extracorporeal tourniquet (48.65 ± 3.02 s vs. 74.27 ± 4.12 s, P < 0.05) and endo intestinal clip (48.65 ± 3.02 s vs. 69.68 ± 6.54 s, P < 0.05) under LLR. Furthermore, the effect was more pronounced with the increased number of cycles.

DISCUSSION

Our occlusion device, also known as “liver circle,” was made up of medical silica gel and remained harmless in human beings. The liver circle can be easily applied in LLR and achieve rapid hepatic vascular occlusion and release. In comparing the time for performing Pringle’s maneuver, we found that it was much more convenient than extracorporeal tourniquet and could save time in placing the device. The results were consistent under laparoscopic simulator and LLR. The superiority of liver circle in reducing the occluding time over extracorporeal tourniquet and endo intestinal clip was more obvious during LLR than under laparoscopic simulator. This was because the lubrication of the liquid and lipids in the abdomen made the liver circle easier to be tensioned and released, while the tissue around the hilum increased the complexity of extracorporeal tourniquet and endo intestinal clip during installing and occluding steps. In addition to convenience, the liver circle does not require an additional incision and does not interfere with the operation through its design due to small size. Taking the installation time of liver circle into consideration, the more times the intermittent Pringle’s maneuver was performed, the more times the liver circle will save when compared to extracorporeal tourniquet and endo intestinal clip. In the clinical application of the endo intestinal clip, we found that some blood still passed through the tip of the clip when the portal triad was fat-rich, which was confirmed by an ultrasound. This may be due to the uneven force generated by the endo intestinal clip and the relatively weaker pressure at the tip. When compared with the six-loop invented by Chao et al.\cite{18} and Huang’s loop,\cite{20} the liver circle was easy to perform and more suitable for intermittent Pringle’s maneuver. As the Hem-O-Lok clip at the end of the stem could avoid the stem escaping out of the hole of the liver circle, repeated installation of the device was not required when performing intermittent Pringle’s maneuver.
Chen et al.\(^{[21]}\) combined Pringle’s manoeuver with the occlusion of infrahepatic IVC and conducted a randomised clinical trial in 118 patients who had giant tumours (>5 cm) located in the central part of the liver but are not directly invading the hilar region. The results showed that the addition of occlusion of infrahepatic IVC reduced intraoperative bleeding and transfusion rates compared with simple Pringle’s manoeuver, showing no significant differences in post-operative liver enzymes, bilirubin changes and complication rates.\(^{[21]}\) This method is particularly suitable for patients with tumour thrombosis in the IVC,\(^{[22]}\) as well as patients with tumour infiltration of IVC that require partial excision of the IVC.\(^{[23]}\) However, under LLR, there are huge difficulties in the exposure, dissection and occlusion of the IVC. The liver circle could not only be applied as Pringle’s manoeuver but also serve to expose the IVC and perform the IVC occlusion. The liver circle around the portal triad could be grasped for multidirectional traction: pulled towards the left to expose the right caudal lobe and IVC; pulled towards the right to expose the left caudal lobe; pulled towards the lower left to lower the hepatic hilum and maintain hepatic portal tension to help separate the hepatic pedicle.

**CONCLUSION**

Our study designed a safe, effective and simple device to easily perform Pringle’s manoeuver, especially the intermittent Pringle’s manoeuver under LLR. Although not all liver surgeries are suitable for Pringle’s manoeuver, pre-circling of this liver circle during LLR can help us to cope with accidental massive bleeding by rapid occlusion of the blood inflow. This presented a new clinical foundation in the study of intermittent Pringle’s manoeuver under LLR, and more studies should be conducted in this area in future. The liver circle can also be applied for hepatic pedicle traction and IVC occlusion. Further studies regarding its effectiveness in laparoscopic resection of hepatic caudate lobe by pulling the portal triad and in the reduction of intraoperative bleeding by combining IVC occlusion with Pringle’s manoeuver under LLR are demanded.

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**Conflicts for interest**

There are no conflicts for interest.

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