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Cohort Study

Hepatic and portal vein transection by vascular stapler in open living donor hepatectomy – A retrospective cohort study

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ABSTRACT

Background: In an effort to increase donor safety in living donor liver transplantation, the utilization of vascular staplers for the division of the right portal and hepatic veins in patients undergoing right lobe liver donation for living donor liver transplantation (LDLT) was implemented. In here we report our experience with vascular staplers in patients undergoing LDLT and evaluate the subsequent feasibility and safety for donors.

Material and methods: 17 cases of living donor liver transplant were retrospectively analyzed. The right portal vein was transected directly at the bifurcation of the main portal vein, the right hepatic vein was resected directly at the wall of the inferior vena cava using a vascular stapler device.

Results: We registered a complication rate of 41.2% (7 donors). According to the Clavien-Dindo classification, grade II and grade III complications were each observed in 5.9% and grade IIIb complications in 29.4%, whereas catastrophic bleeding, complications with residual disability or the necessity of re-laparatomy did not occur. Upon 6 weeks, all donors were able to return to their previous occupation in fully recovered condition.

Conclusions: The utilization of vascular staplers in donors during open LDLT presents an encouraging alternative to manual over-sewing of vascular stumps. Apart from its timesaving aspect, the technique reduces the potential risk of life-threatening clamp slippage with subsequent uncontrolled blood loss.

1. Introduction

Liver transplantation remains the most efficient and the only curative therapeutic option for patients with end-stage liver disease. Nonetheless, long waiting times and growing records of deaths in patients awaiting organs whilst listed have become severely disheartening. As a high-risk solution to the problem, living donor liver transplantation (LDLT) provides an alternative to mitigate the marked shortage of liver grafts worldwide [1]. Most prominent obstacle in LDLT, particularly in adult-to-adult LDLT involving the right liver lobe, is the risk to healthy donors undergoing a large-scale operation void of health benefits to them. Prominently publicized reports of donor deaths and morbidity have contributed to the scarce implementation of LDLT in practice, making up only about 4% of all adult liver transplants [2–4]. Therefore, the assignment of particular value to avoid any harm to the donor in the course of transplantation is of utmost importance.

Intraoperative complications due to technical mishandling, such as portal vein (PV) and hepatic vein (HV) injuries and bleeding due to vein clamp slippage are particularly distressing and have been reported in the past [5,6]. Avoiding any bleeding from these vessels is hence of great importance. In an effort to increase donor safety, we started to implement the utilization of vascular staplers for the division of the right PV and the right HV in patients undergoing right lobe liver donation for LDLT in our clinic from May 2017 to March 2020. This technique has earlier been successfully implemented with the use of different methods like metal clips, Hem-O-Lock and vascular stapler in laparoscopic hepatectomy and already proven to be feasible in the donor [7,8]. We thereby aimed to evaluate the subsequent feasibility and safety for donors undergoing open LDLT. This retrospective study was planned and discussed among team members of our transplantation program and approved by the hospital's ethics committee. This research was retrospectively registered in the German Clinical Trials Register (UIN:

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2. Patients and methods

2.1. Recipients

This retrospective cohort study included all 17 recipients (14 males and 3 females) aged 14–70 years (median age 51 years) who underwent LDLT using right lobe liver grafts between May 2017 and March 2020. Their underlying diseases entailed non-alcoholic steatohepatitis-related cirrhosis in seven cases, Hepatitis B and Hepatitis C associated cirrhosis in six cases, Morbus Wilson in two cases and primary hepatocellular carcinoma and Budd-Chiari syndrome in one case each. No exclusion criteria were applied.

2.2. Donors

Right lobe liver grafts were recovered from 17 donors (13 males and 4 females) aged 22–58 years (median age 31 years). Of these 17 donors undergoing right hepatic lobectomy, all had a relationship within the 3rd degree of consanguinity with the recipient. Donor and recipient work up was only initiated upon extensive internal evaluation by the ethics committee, after thorough psychiatric examination and upon approval of indication by the Transplant Board.

Written informed consent was obtained from all patients to perform the procedure. Transplant protocols and all procedures that followed were in accordance with the ethical standards of the responsible institutional and national committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Every donor who offered to undergo the procedure underwent an elaborate evaluation comprising of physical examination, blood group verification, lab testing, liver and renal biochemistry, complete blood count and coagulation analysis, hepatotropic virologic assays and HIV, CMV and EBV screening. Besides, pulmonary function tests and electrocardiography were routinely performed. Hepatic ultrasonic examinations, triple-phase CT scans including volumetry and MRCP were used to evaluate anatomical variations of the hepatic vascular/biliary system and for size calculations of the right and left liver lobes. Every donor underwent percutaneous liver biopsy as part of the evaluation in order to exclude fatty infiltration exceeding 10%. Prior to transplant we determined the optimal liver lobe to retrieve, with the overriding concern of safety for the donor.

2.3. Clinical methods

For confirmation of biliary anatomy during right lobe hepatectomy, intraoperative cholecystectomy and cholangiography were routinely done. For the evaluation of the hepatic vein drainage of the graft, we performed intraoperative ultrasound. The middle HV was preserved in all donors in order to prevent outflow obstruction to the residual segment. Tributaries of segments 5 and 8 drained in the middle HV and exceeded a diameter of 5 mm were reconstructed. Inferior right HVs exceeding a 5 mm diameter were preserved for subsequent anastomosis to the recipient's inferior vena cava (IVC). Liver resection was conducted using an ultrasonic dissector, scissor dissection and conventional coagulation as previously described [9].

We started to implement the use of vascular staplers for the division of the right PV and the right HV in a standardized manner. The right PV was transected directly at the bifurcation of the main PV, the right HV was resected directly at the wall of the IVC using a vascular stapler (Echelon Flex Powered Vascular Stapler and EndoGIA 45–2.5) (Figs. 1 and 2). Attention was given during vein division to the direction and angle of both PV branches to avoid any twisting or narrowing of the remaining left PV. Upon first warm ischemia time and removal of the stapler line, we initiated cold perfusion using Histidine-Trytophan-Ketoglutarate solution (HTK). The HV and PV of all grafts had sufficient lengths for performing vein anastomoses without tension (Fig. 3).

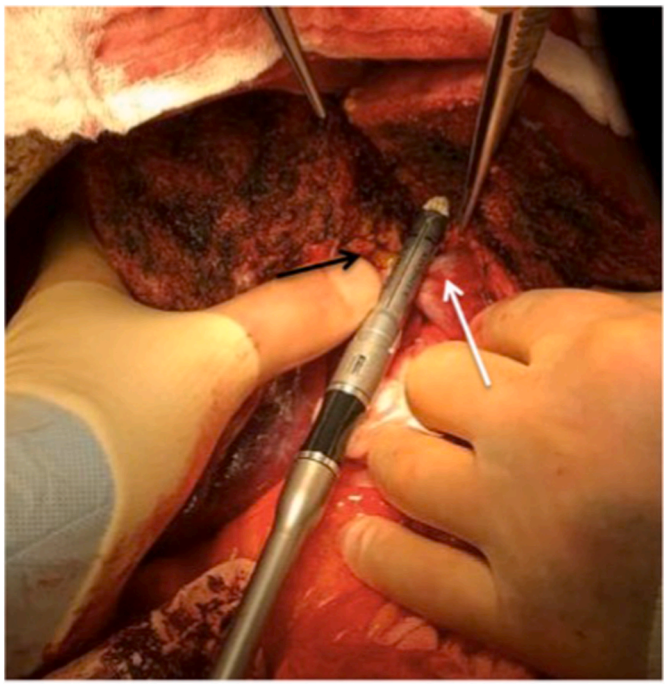

Fig. 1. Endovascular stapler utilized for dissection of the right portal vein (white and black arrows pointing at the left/main and right portal vein, respectively).

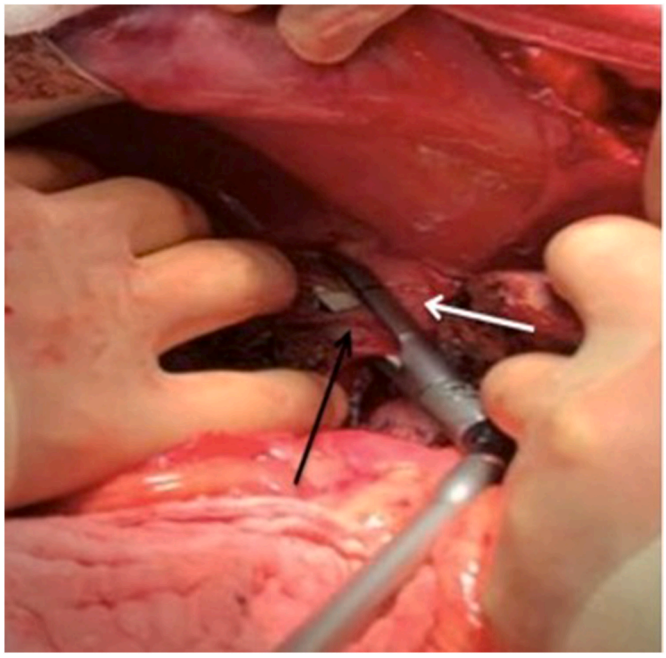

Fig. 2. Endovascular Stapler utilized for dissection of the right hepatic vein (white and black arrows pointing at the inferior vena cava and right hepatic vein, respectively).

In all recipients, direct anastomosis of the graft's right hepatic vein and the IVC was performed. Additionally, in one case we performed the reconstruction of the right inferior hepatic vein and in two cases we performed additional reconstruction of the branches of the middle hepatic vein by interposing a venous graft to grant adequate venous outflow (Fig. 3).

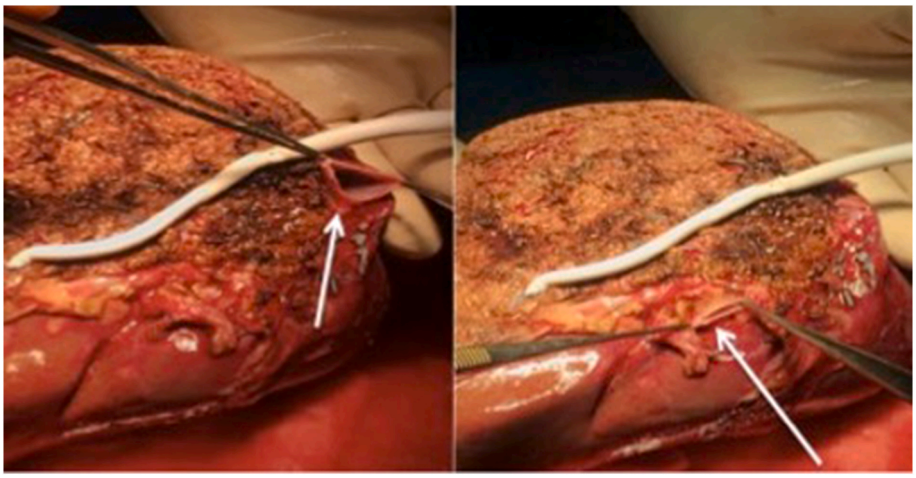

Fig. 3. a. Graft hepatic vein and 3b. graft right portal vein after cold perfusion.

End-to-end anastomosis was performed between the right hepatic artery of the graft and the recipient's main hepatic artery to ensure arterial perfusion. Bile ducts were reconstructed by duct-to duct anastomosis. None of the recipients developed small-for-size syndrome and all grafts were adequately perfused and without sings of venous outflow disturbance (Fig. 4).

Upon LDLT, all donors were supervised in a designated intensive care unit (ICU) for generally 48 h. We deviated from this timeframe upon multidisciplinary evaluation to allow for early and late ICU discharge when deemed safer for the donor.

The study was reported in line with the STROCSS criteria [10].

3. Results

A summary of operative characteristics is given in Table 1. In this observational study, the mean operative time was 268 min (range: 210–300 min). Right lobe graft weight ranged from 720 g to 1242 g (mean 962 g). The mean remaining liver weight was 630 g (range: 440–1100 g). Mean initial warm ischemia time after using the vascular stapler and prior to initiation of cold perfusion was 3 min long (range: 2–4 min), followed by a mean cold ischemia time of 85 min (range: 50–118 min) and mean anastomosis time of 29 min (range: 20–41 min) during the anastomoses of HV and PV. None of the patients required blood transfusions.

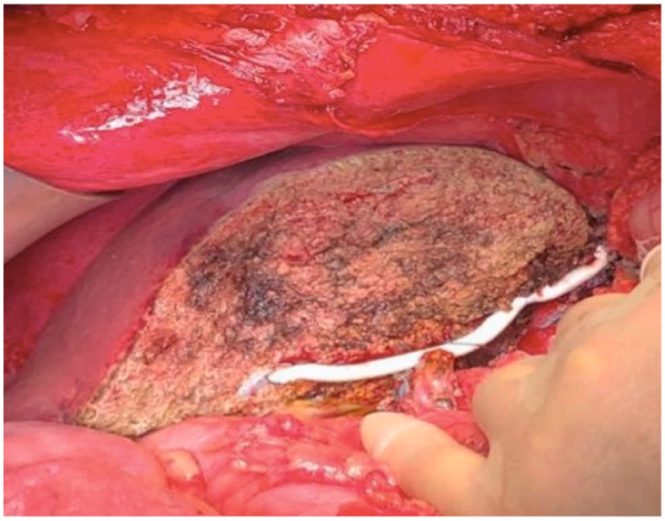

Fig. 4. Right lobe graft after reperfusion.

Table 1
Donor demographic and perioperative characteristics.

Characteristic	Mean (±SD)
Age (years)	34.8 (±10.8)
Weight (kg)	79 (±13.6)
Operation time (min)	384 (±48)
Graft weight (g)	961.5 (±141.5)
Remaining liver weight (g)	679.7 (±169.6)
Mean duration of hospital stay (days)	8.6 (±3.3)
Mean duration of ICU stay (hours)	48 (±12)
Gender, *n* (%)	
Male	13 (76.5)
Female	4 (23.5)
Postoperative complication <30 days, *n* (%)	5 (29.4)
Re-laparatomy, *n* (%)	1 (5.9)

Postoperatively, liver biochemistry testing revealed liver function impairment, reflected by elevated liver enzymes, hypoalbuminemia and hyperbilirubinemia. However, all parameters rapidly improved within three days postoperatively. Prior to discharge, ranging from day 5 to day 16 postoperatively (median day 7), all lab parameters had returned to normal range or had been decreasing significantly.

Within the total of 17 donors, we registered a complication rate of 41.2% (7 donors).

According to the Clavien-Dindo classification [11], grade II and grade III complications were each observed in 5.9% and grade IIIb complications in 29.4%, whereas complications with residual disability did not occur. A summary of the postoperative complications is given in Table 2.

One donor (5.9%) experienced postoperative common bile duct stricture requiring endoscopic dilation with stenting. The patient suffering from ampullary stenosis was treated by endoscopic sphincterotomy. Postoperative bleeding from a right diaphragmatic artery occurred in one case and was managed surgically. The donor experiencing pleural effusion was successfully treated by diuretic medication, whereas the patient with mild postoperative hypertension was treated

Table 2
Postoperative donor complications according to the Clavien-Classification.

Complication	*n* (%)	Classification
Postoperative hypertension	1 (5.9)	II
Pleural effusion	1 (5.9)	III
Incisional hernia	2 (11.8)	IIIb
Ampullary stenosis	1 (5.9)	IIIb
Common bile duct stricture	1 (5.9)	IIIb
Postoperative bleeding	1 (5.9)	IIIb

conservatively. Both abdominal incisional hernias occurring after 4 and 6 months postoperatively, respectively, were treated surgically.

Within the mean follow-up of 20 months (range 6–40), we did not register any donor mortality. Upon 6 weeks, all donors were able to return to their previous occupation in fully recovered condition. Neither long-term liver impairment, nor other continuing complications were experienced during follow-up.

4. Discussion

LDLT has paved the way to improved organ availability and has allowed for ameliorated set-up preparation and a reduction of primary organ dysfunction [12]. Nonetheless, LDLT remains an ongoing source of ethical concerns in many transplant centers, as it exposes the donor to a major and potentially fatal procedure without deriving any benefit. Of utmost importance to be considered is thus the donor survival and safety.

To date, no centrally managed register for donor complications exists, rendering the actual donor complication rates unspecified [13]. Studies reporting donor complications quote rates of up to 60% [14]. However, inconsistent and non-standardized reporting of complications, especially of major complications or fatalities, results in significant variability and discrepancy of given rates.

Intraoperative donor mortality and devastating blood loss have been reported in LDLT due to vein clamp slippage and injury of PV and HV [5,6]. Given their valve-less character and their direct outflow into the IVC, rhexis of the HV and PV can lead to catastrophic bleeding and to pulmonary embolism [15]. The deterrence of bleeding from these vessels is hence essential.

In an effort to render the procedure safer for the donor and to minimize considerable risk of clamp slippage and left PV-stenosis followed by thrombosis that may contribute to adverse complications, we started to use the vascular stapler for the transection of the PV and HV. After having experienced distressing situations in previous LDLT cases in which clamp slippage or incorrect positioning have resulted in significant blood loss, we aimed to address and optimize this particular step by replacing the clamping of the main venous vessels in LDLT with subsequent dissection by vascular stapling. Earlier, this technique has been used successfully in laparoscopic hepatectomy and shown to be feasible and safe for the donor [7,8].

Our results show that the vascular stapler allowed for a faster vein transection, less tissue manipulation and an optimized positioning of the suture line by adapting to the natural angle of the vessels. In comparison to manually running sutures, the uniform stapler suture line provided less tension on the venous tissue. Besides, surgeons in training were able to adapt the technique quickly in practice.

In our experience, the use of vascular staplers is particularly helpful when the technical performance of a manual suture can be challenging, for instance in left-lobe hypertrophy or large graft volumes e.g., in obese donors. Also, whenever liver grafts were retrieved from elderly donors or presented with signs of hypoxia or steatosis, vascular staplers were utilized to keep warm ischemia time as short as possible. We found that the use of the vascular stapler allowed for improved liver mobilization and precise staging and therefore reduced the manual manipulation around the graft. Hence, we also recommend the stapling of the veins in those patients presenting with complex anatomy and vulnerable vein walls.

Other potential advantages linked to vascular staplers that have been described in the literature include the reduction of: foreign material extending into the lumen, micro-bleeding, perforation of the vessel wall, and subsequently thrombogenic effects [16].

The reduction of surgical trauma and consequent blood loss may have additionally contributed to reduce the occurrence of local infections of which we have experienced none in our donors.

Initial concerns regarding a resulting short length of the PV have proven to be unsubstantial, since in all our cases recipient PV length exceeded the required length and even had to be shortened in order to meet our surgical standards for anastomosis in the recipient.

Indeed, the use of the vascular stapler in the surgical setting remains costly. Taking health economics into account, we are aware that its utilization adds an additional cost driver in LDLT, particularly with regard to transplant programs in countries undergoing cost containment [17]. However in our view, the benefits derived from using the same vascular stapler device for PV and HV justify the higher costs and moreover, cost-saving strategies at the expense of the donor should be discouraged in a highly delicate procedure such as LDLT.

Several studies have showed unstandardized methods for the division of HV and PV in laparoscopic donor hepatectomies. Portal vein stumps were controlled with metal clips, sutures, Hem-O-Lock clips, unilateral linear stapler or vascular stapler. Besides, the HV was divided by unilateral linear stapler or vascular stapler (Echelon 7; Ethicon Endosurgery, OH, USA) [18–21].

In contrast, our study was designed to enhance the safety of the donors with the use of a standardized and widely available approach of the same stapler device [22,23].

Some limitations need to be pointed out with regard to our results. In this analysis, we did not include a control group, which renders the analysis less valid. Also, our results are based on a very specific and small single-center patient cohort and retrospective data, hence they may only be partially transferrable. Therefore, we encourage the adaptation of national donor registries in order to enable follow-up on complications based on extensive databases which may assist in the detection of risk factor associations.

In summary, given that clamping time in LDLT with various vascular reconstructions is critical and that every potential risk reduction for the donor should be implemented, we believe that the use of vascular staplers in open live donor hepatectomies seems to be a promising alternative to manually sewn HV and PV. This study does not entail any comparison between open and laparoscopic living donor hepatectomies, however it aimed at emphasizing possible surgical options that may further improve overall safety in open living donor hepatectomies.

Based on our results, future large-scale research is warranted and should evaluate the long-term safety of the use of vascular staplers in LDLT. Randomized controlled trials comparing stapled veins with hand-sewn veins should be conducted to compare vessel patency and conversion rates and to give an evidence-based assessment on the validity of the technique. Also, given the significantly reduced manipulation and mechanical stress of the vein walls during the stapling of the veins, we hypothesize that the vascular stapler causes less inflammatory responses in comparison with hand-sewn sutures and could potentially reduce the risk of neointimal hyperplasia. Therefore, histopathological analyses should be conducted in the future to validate this technique. One of the major advantages of the utilization of vascular staplers is the timesaving aspect, and particularly the reduction of warm ischemia time. Consequently, future research may also investigate the effects on postoperative organ dysfunction rates e.g. graft dysfunction, biliary dysfuntion and renal complications.

5. Conclusion

The utilization of vascular staplers in donors during open live donor hepatectomy presents an encouraging alternative to hand over-sewing of vascular stumps. Apart from its timesaving aspect, the technique reduces the potential risk of clamp slippage with subsequent blood loss. A larger-scale study is needed in order to confirm the safety and superiority of this approach in comparison with manually hand-sewn vessel sutures.

Ethical approval

Ethical approval has been given by the ethics committee of Jordan Hospital Amman.

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None.

Author contribution

Doha Obed: Acquisition of data, interpretation of data, manuscript preparation, Anwar Jarrad: Acquisition of data, interpretation of data, critical revision of manuscript, Abdalla Bashir: Acquisition of data, analysis of data, study design, Mohammad Ibrahim Othman: Study design, critical revision of manuscript, acquisition of data, Mahmoud Siyam: Study design, critical revision of manuscript, acquisition of data, Aiman Obed: Conception of study, study design, acquisition of data, critical revision, All authors have given their final approval of the submitted version.

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Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.drks.de/drks_web/navigate.do?navigationId=trial.HTML&TRIAL_ID=DRKS00028573.

Guarantor

Doha Obed, MD.

Provenance and peer review

Not commissioned, externally peer reviewed.

Statement of informed consent

Informed consent was obtained from all patients for being included in the study.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103823.

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