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Optimizing liver division technique for procuring left lateral segment grafts – new anatomical insights.

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Figures **2**

ABBREVIATIONS:

DL:	Division of liver / liver division
LD:	Living donors
DD:	Deceased donors
LLG:	Left liver lobe (left lateral segment) graft
TH:	Trans-Hilar (division)
TU:	Trans-Umbilical (division)
LHA:	Left hepatic artery
BD:	Bile duct / biliary drainage
S2, S3, S4:	Segments II, III, IV
RexR:	Rex Recessus

INTRODUCTION

Left liver lobe (left lateral segment) grafts (LLG) is currently the most commonly used graft to transplant children (2/3 of cases currently in Europe); it is prepared by liver division (DL) in both living (LD) and deceased donors (DD) settings.

Technically speaking, classical DL is through the parenchyma of segment IV - dividing the main left glissonean pedicle left to the main biliary confluence (trans-hilar (TH) approach): historically, this technique was introduced by Bismuth and Pichlmayr in 1988 in DD setting, and applied one year later for the first successful living donor transplantations by Strong (Figure 1) [1]. Although TH-DL use expanded further for ex-situ splitting in Europe and LD in Japan, Broelsch modified the approach in1990 to simplify the procurement in LD, by DL along the umbilical scissure - leaving whole segment IV with right liver (Trans-Umbilical (TU) approach)[1,2]. The latter DL allowed Broelsch team expanding LD program in Hamburg, where it was applied for in-situ splitting in DD, from 1995 onwards. Since then, TU-DL has been used by many teams – worldwide and in both DD and LD - and is the standard technique in Germany, Italy and Saudi Arabia. Although TU-DL has few disadvantages from an anatomical point of view, it has major advantages for in-situ DD splitting - i.e. smaller cut-surface, shorter donor-hospital operative time, and limited prolongation of ischemic time (Figure 1)[1].

In this letter, uncommon (though not rare) anatomical arterial variations are presented as they may be challenging the surgeon at work; they were relevant for DL decision-making in this series. We believed this information is important to share, as arterial complications are a major cause of morbidity after pediatric liver transplantation.

Patients and Method

The study was conducted in accordance with the guidelines of the local ethics committee. Liver anatomy of 39 consecutive LD (2017-2020) was prospectively analyzed by studying pre-operative imaging; the analysis focused in particular on the anatomy of left arterial artery (LHA) and its segmental distribution mode towards segments II, III and IV (S2, S3, S4), and the relation with umbilical scissure and Rex recessus (RexR).

Briefly, TU-DL divides the parenchyma along a line separating S4 and the left lobe (LL: S2 and S3) and divides the umbilical plate sagittally after mobilization of left portal vein from S4 and I. TH-DL divides the liver slightly to the right of the umbilical scissure (Figure 1). These techniques are illustrated in Figure 1; the technical aspects and their respective advantages/limits have been detailed in a previous paper [1]. Peri-operative management has been detailed in previous publication[3].

Both TU and TH technique were used, using a local decision-making algorithm based on donor hepatic anatomy, recipient weight and estimated LLG volume. Although there was local preference for TH-DL in case of alternative, TH-DL was opted for when ratio “S2+3 volume/ recipient weight” was close to 1%, and when necessary to ensure adequate arterial support to S2 and S3 (Figure 2-D,E). TU-DL was chosen when TH-DL would have imposed a double arterial reconstruction while TU-DL allowed single arterial reconstruction.

RESULTS

Donors were 16 men and 23 women (mean age 32.2 years, mean weight 68,4 Kgs). All recipients were children, weighing 4 to 25 Kgs (mean: 8.7 Kg). Main variations of arterial supply for S2, S3 and S4 are detailed in Figure 2. Interestingly, a left segmental artery was running in a very unusual manner (over RexR) in 12 patients (31%)(Figure 2, D-E-F); this course is impossible to identify at surgical exploration and likely the artery is sectioned during TU-DL. Figure 2-D,E shows the most challenging anatomical condition for preparing a LLG: S2, S3, or both arter(ies)y run(s) from right to left above RexR, between parenchyma and RexR (within glissonean plate)(4/39 cases – 10%). In this configuration, TU-DL division is a high risk of arterial traumatism/division and TH-DL must be preferred.

Basis on preoperative imaging, 12 TU-DL and 27 TH-DL were planned and performed. In 2 cases > 20 Kgs, TH-DL was preferred to prepare a larger LLG. Out of other 37 LLG, 13 were TU-DL because there was an independent artery feeding S4: TU-DL allowed both a single arterial reconstruction at transplanting LLG and leaving vascularized S4 in donor. TH-DL was used for all other cases. Four of these 27 LLG (2 TU and 2 TH) were further reduced for transplanting small infants when the ratio “S2+3 volume/recipient weight” was > 4.5.

All donor and recipient surgeries went uneventful. There were no arterial complications in this series and all grafts are currently well and functioning, at follow-up ranging from 1 to 37 months (mean: 19 months).

DISCUSSION

Ex-situ splitting did allow studying graft anatomy in detail (arteriography and cholangiography on back-table) and provide full information to the surgeon before division; more, it was performed using TH-DL in most cases. It is however rare practice nowadays as it comes at the price of prolonging cold ischemic time and difficult sharing/allocating of the second graft.

Historically, TU-DL was developed by Broelsch team to minimize the operative trauma in living donors and related risks, as it reduces the parenchymal transection and the risk of trauma to the main biliary confluence by shifting Glisson plate division to left (Figure 1) [1,2] . The latter advantage was pivotal in developing in-situ splitting in DD, while many teams around the world were reducing/abandoning ex-situ splitting because of the associated logistical problems and unsatisfactory outcomes [4]. Because in TU-DL, parenchymal cut surface is smaller and glissonean plate division is far from the main confluence, TU-DL is quicker and safer to use for in-situ division in DD: practically speaking, in-situ splitting of DD livers is usually performed in donor hospital, during the night, and in absence of specific imaging of the vasculature and anatomy of the liver. The procurement team, often young surgeons not highly expert in complex liver surgery, must rely only on macroscopic examination of the extrahepatic hepatic vascular supply on the one side, and on knowledge of liver anatomy variations on the other side, to divide the liver in a safe manner for both sides.

However, the shift towards the left for dividing the Glissonean plate within the umbilical scissure (TU-DL) is associated with a relatively high technical morbidity: a recent Italian survey of TU-DL performed in 2015- 2016, showed 79% only 1-year graft survival for LLG split. This suggests that TU-graft outcome is plateauing, as results are equal for more than a decade [5]. TU-DL technique has likely reached its full technical potential, with its limit being the technique itself - and technical refinements necessary. In this series, if TU-DL had been used blindly for all livers, S2-3 arterial supply would have been damaged in 4 cases (10%).

In the LD setting, systematic pre-operative imaging of hepatic anatomy is a major advantage, allowing the surgeon to plan the operation in detail; it is key for avoiding trauma to the residual liver in the donor, but also instrumental for providing excellent early graft function, low complication rates and optimal transplant outcome. LD is the best setting for optimizing surgical strategies, as it is essential for guarantying both donor safety and optimal graft outcome, and this can be achieved by combining TU and TH approaches - as shown in this series.

For transplant surgeons procuring in-situ LLG from DD donors, there may be lessons to learn from these observations of very unusual arterial anatomical variations, and from this flexible strategy. When DD livers are divided in-situ, surgeons rely only on the macroscopic observation of the extrahepatic vasculature, and base decision-making on deep knowledge of all anatomical variations ("In the land of the blind, one eyed is king"). In these conditions, experience and a high index of suspicion are only keys for detecting the unusual variants: these must be suspected in case of

- absence of artery entering the glissonean plate on the left side of RexR (either from the main artery or from a left accessory artery) is an obvious and easily recognizable sign of problem for procuring the left lobe: in these cases, S2+3 artery passes over RexR, from right to left (Figure 2, E), and TH division is mandatory (attempting TU-DL would be likely a risk of arterial trauma).

- more insidious and difficult to recognize is a similar situation with only one artery (S2 or S3) routing over RexR (Figure 2, D); suspicion should arise from observing a much larger artery branch routing to to S4 compared to (smaller) branch to left lobe.

- absence of identifiable artery routing towards S4 extraepatically, while a large artery is found supplying the left lobe (Figure 2, F); this leads to S4 devascularization in any division type, and TH should be preferred to TU as the latter leaves a larger ischemic parenchymal residual mass with the right liver.

CONCLUSION

In this series, opting for TH or TU technique helped dealing with some uncommon arterial branching in 11 cases (33% of the series), avoiding vascular damage at procurement and preparing optimal grafts, as suggested by the 100% graft survival, absence of arterial complications and low biliary complication rate.

Overall, this suggests that both techniques have their place in the surgical armamentarium of the modern transplant surgeon. Mastering both approaches is important, as it helps procuring optimal grafts, and better matching graft weight recipient needs in larger children. As it applies to in-situ splitting of DD livers, this is also a call for performing pre-procurement angio-CT studies in DD proposed for liver splitting – in the same manner that coronarographies are used before heart procurement.

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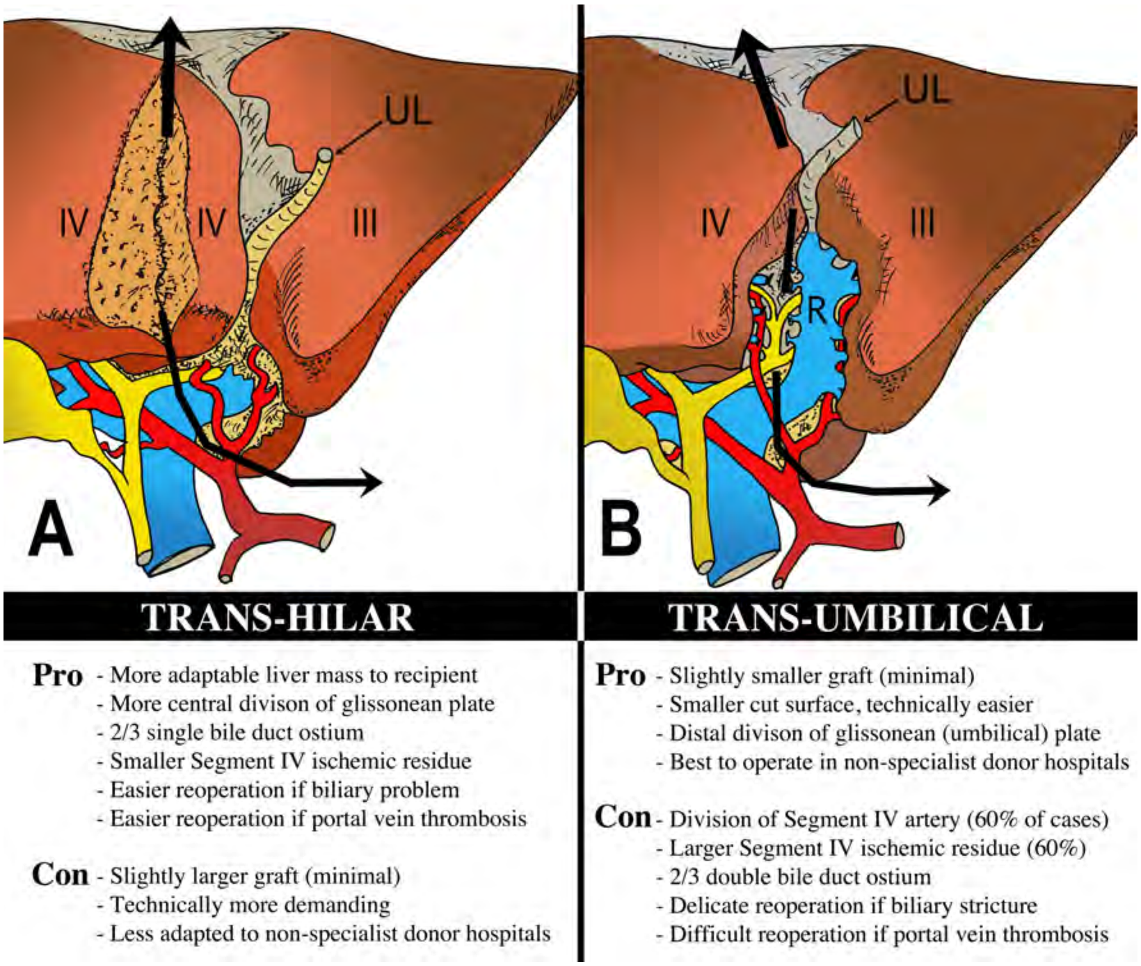
FIGURE LEGENDS

FIGURE 1

Artist view of techniques for division of the liver A: Trans-hilar (TH) and B: Trans-umbilical (TU) technique. The lines show the splitting line through the parenchyma and the level of division of bilio-vascular elements. (Roman numbers: segments according Couinaud, R: rex recessus, UL: Umbilical ligament). Pro and Cons.

FIGURE 2

Arterial supply for segments II, III and IV. Well-known ("conventional") anatomical types (A and B) were found in 12 cases each. In these cases, arteries for left lobe and for segment IV are easily identified at surgical exploration and can share (A) or not (B) their origin. A very rare and unusual arterial supply -being a separate artery for each left segment (II, III and IV)- was found in one donor (C). Types D, E and F are exceptional variations where at least one artery of one left segment cross over the Rex recessus (RexR) dorsally (between the vein and the parenchyma, within the glissonean umbilical plate). In type D and E, one (D: 1 case) or both (E: 1 case) arteries for left lobe segment(s) run from right to left over RexR. In type F (8 cases), the artery of segment IV runs from left to right over RexR. Continuous and dotted lines show how vascular supply would be dealed with at TU or TH divisions, respectively; the images confirm that anatomical types E and D are very challenging for TU division, with a likely risk of trauma to the arterial supply of the left split graft.



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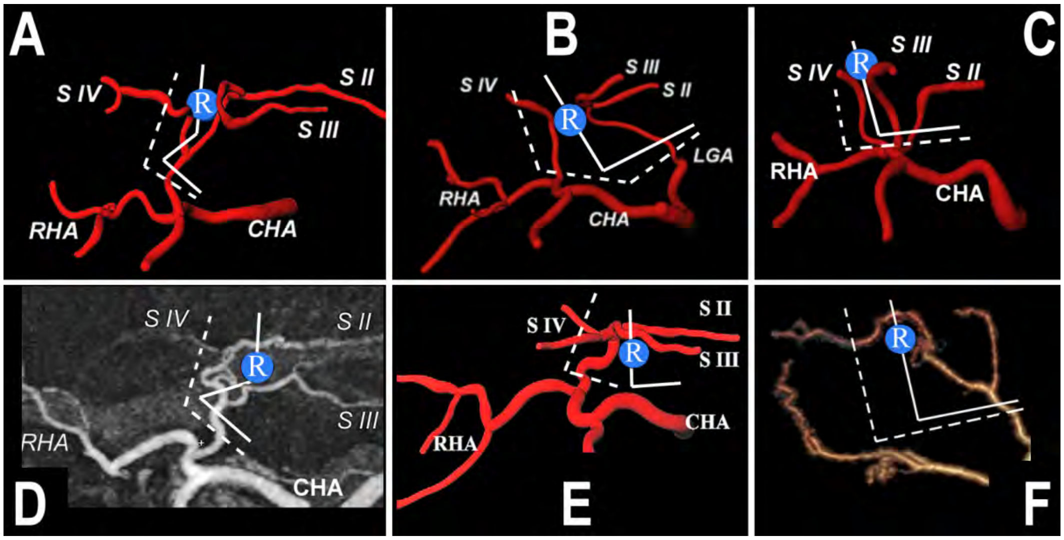

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