Liver Research 8 (2024) 207–217

Contents lists available at ScienceDirect

Liver Research

journal homepage: http://www.keaipublishing.com/en/journals/liver-research

Practice Guideline

Chinese clinical practice guidelines for pediatric split liver transplantation☆

Binsheng Fu [a], Xiao Feng [a], Jianrong Liu [b], Jie Ren [c], Jin Wang [d], Shuhong Yi [a,*], Yang Yang [a,*]; Chinese Society of Organ Transplantation of Chinese Medical Association; Surgery Group of Chinese Society of Surgery of Chinese Medical Association; Transplantation Group of Chinese Society of Surgery of Chinese Medical Association; South China Alliance of Split Liver Transplantation

[a] Department of Hepatic Surgery, The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China
[b] Surgical Intensive Care Unit, The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China
[c] Department of Medical Ultrasonic, The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China
[d] Department of Radiology, The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China

ARTICLE INFO

Article history:
Received 3 August 2024
Accepted 7 November 2024

Keywords:
Split liver transplantation (SLT)
Pediatric liver transplantation
Liver transplantation
Donor
Recipient
Guideline

ABSTRACT

Liver transplantation is an effective treatment for end-stage liver disease in children, and its clinical efficacy has been validated. Split liver transplantation (SLT) can effectively expand the donor liver pool for children. SLT for children has unique clinical characteristics and principles. Establishing technical operation specifications for pediatric SLT plays a significant role in improving clinical efficacy. In this paper, clinical practice guidelines on pediatric SLT were established in the aspect of donor and donor liver evaluation, donor-recipient matching, and ductal segmentation and reconstruction of donor liver, aiming to standardize the technical process, optimize surgical operational details, minimize the risk of complications of SLT for children, further promoting the rapid development of pediatric SLT in China.

1. Introduction

Continuous exploration, development, and advancements in pediatric liver transplantation have led to its widespread adoption in numerous centers worldwide; moreover, this treatment strategy has continuously improved postoperative long-term survival rates. Donor sources for pediatric liver transplantation include whole/size-reduced donor livers, living donor livers, and split donor livers. Earlier, whole/size-reduced donor livers were the primary donor source, but the matching success rates were extremely low. With the evolution of pediatric liver transplantation, its indications have expanded and the demand for donor livers has grown rapidly. Consequently, living donor liver transplantation (LDLT) and split liver transplantation (SLT) have emerged and gained popularity as the primary procedures for liver transplantation in children.

In LDLT, the donor-recipient pair is relatively fixed, whereas SLT offers greater flexibility in donor-recipient matching. In terms of assessment methods, LDLT donors have sufficient time and access to comprehensive evaluation tools, whereas SLT donors have a short evaluation window, and assessment methods are constrained by donor factors. In cases where LDLT cannot be successfully performed, SLT plays a crucial role. Employing effective measures for targeted donor-recipient assessment and standardized technical procedures in pediatric SLT is important.

At present, SLT accounts for approximately 35% of pediatric transplants in some parts of Europe. Although the proportion of SLT in China has increased rapidly in recent years, there is still considerable room for improvement. Therefore, establishing a comprehensive technical system and relatively standardized procedures for pediatric SLT in China is urgently needed. To this end, leading experts in the field from the Chinese Society of Organ Transplantation of Chinese Medical Association, Surgery Group of Chinese Society of Surgery of Chinese Medical Association, Transplantation Group of Chinese Society of Surgery of Chinese Medical

☆ Full list of author information is available at the end of the article.
* Corresponding authors.
E-mail addresses: yishuhong@163.com (Shuhong Yi), yysysu@163.com (Yang Yang).

https://doi.org/10.1016/j.livres.2024.11.002

Association and South China Alliance of Split Liver Transplantation collaborated to develop the Chinese Clinical Practice Guidelines for Pediatric SLT, encompassing technical details and protocols for donor-recipient assessment, donor-recipient matching, vascular and biliary dissection and reconstruction, and blood flow monitoring.

2. Methodology

This guideline has been registered in both English and Chinese on the Practice Guideline Registration for Transparency (http://www.guidelines-registry.org; Registration No. PREPARE-2024CN091).

To facilitate guideline development, two separate working groups were established: the Guideline Development Group and the Guideline Review Group, which were spearheaded by the Third Affiliated Hospital of Sun Yat-sen University. Based on the identified clinical questions, evidence retrieval and literature screening were conducted. The Guideline Development Group comprehensively searched domestic and international databases (including but not limited to PubMed, Medline, Embase, Wanfang Databases, and China National Knowledge Infrastructure). The writing group screened the literature based on key questions and graded the evidence according to the Oxford Centre for Evidence-Based Medicine level of evidence (Table 1) and recommendation strength grading standard (Table 2).[1] Subsequently, consensus was reached on the recommendations, the guideline was drafted, and two rounds of expert meetings were held with the Guideline Review Group to gather feedback on the guideline. Based on the feedback received, the guideline was further refined.

3. Donor assessment and donor liver assessment for SLT in children

3.1. Donor assessment

The evaluation criteria for SLT are more stringent than those for whole-liver donation. Due to the various causes and degrees of damage that deceased donor livers may sustain prior to donation, their functional donor liver volume is lesser than their actual volume. Consequently, the quality requirements for split donor livers are higher, and donor selection criteria vary across transplantation centers. The general requirements for SLT donors are summarized in Table 3.

Table 1
Oxford Centre for Evidence-Based Medicine: levels of evidence.

Level of evidence	Definition
1a	Systematic review of randomized controlled trials (homogeneity)
1b	Individual randomized controlled trials (narrow confidence interval)
1c	When all patients died before the measure was introduced, but some patients now survive on it
2a	Systematic review of cohort studies (homogeneity)
2b	Individual cohort studies (including low-quality randomized controlled trials; *e.g.*, follow-up rate <80%)
2c	A study of the outcome; an ecological study
3a	Systematic review of case-control studies (homogeneity)
3b	Individual case-control study
4	Case series (and poor-quality cohort studies and case-control studies)
5	Lack of clear and strictly evaluated expert advice, or derived from physiology, laboratory research, or "first principles"

Table 2
Recommendation strength and its definition.

Level of recommendation	Definition
A	Evidence of consistent level 1
B	Consistent level 2 or 3 evidence, or extrapolation based on level 1 evidence. ("Extrapolation" means that data are applied to situations with potentially clinically important differences rather than the original research)
C	Level 4 evidence, or extrapolation based on level 2 or 3 evidence
D	Level 5 evidence, either inconsistent or inadequate research (any level)

Recommendation 1: Donors should generally meet the above general requirements; however, the conditions can be relaxed appropriately based on the donor and recipient status, splitting method, and donor liver quality to expand the pool of donor livers (Evidence level 5, Recommendation strength D).

3.2. Donor liver assessment tool

In addition to routine laboratory tests, donor liver evaluation includes radiologic and pathological assessments. These assessments include color Doppler ultrasound and contrast-enhanced ultrasound. If conditions permit, abdominal computed tomography (CT) should be performed to accurately assess the volume of donor liver, anatomy, and function.[2] Preprocurement percutaneous biopsy and intraoperative frozen section biopsy can better reflect donor liver quality.

Color Doppler ultrasound is the most convenient and effective tool for evaluating donor liver vessels. Ultrasound can assess the size of donor liver, fatty degeneration, and vascular variations. In addition, shear wave elastography and contrast-enhanced ultrasound can evaluate donor liver stiffness and microcirculation perfusion. Intraoperative ultrasound can be used for real-time vessel assessment during *in situ* SLT, whereas contrast-enhanced ultrasound can be used for anatomical vessel assessment during *ex situ* SLT.

Recommendation 2: If conditions permit, contrast-enhanced abdominal CT, along with liver ultrasound elastography and contrast-enhanced ultrasound, should be used for initial examination of split donor livers. Pathological examination should be performed before/during donor liver procurement (Evidence level 2b, Recommendation strength B).

Table 3
General requirements for pediatric SLT donors.

Indicator	Reference
Age (years)	<50
BMI (kg/m^2)	<26
Length of ICU stay (d)	<5
Vasopressors	Hemodynamically stable or on low-dose vasopressors
Hepatic steatosis (%)	<10
AST/ALT (×ULN)	<3
Total bilirubin (×ULN)	<2
GGT (U/L)	<50
Serum sodium (mmol/L)	<160
Expected cold ischemia duration (h)	<10

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; GGT, gamma-glutamyl transferase; ICU, intensive care unit; SLT, split liver transplantation; ULN, upper limit of normal.

3.3. Donor liver quality assessment

Donor liver quality assessment primarily focuses on the degree of liver fibrosis and steatosis.

3.3.1. Assessment of liver fibrosis

Donor livers with any degree of fibrosis are not recommended.[3] For suspected cases, liver tissue samples should be obtained for pathological examination. The degree of liver fibrosis can also be assessed noninvasively using ultrasound.[4] Ultrasound elastography can provide liver stiffness values, indirectly reflecting the degree of donor liver fibrosis.

Recommendation 3: Donor livers should meet pathological grading S0 and ultrasound elastography stiffness <7 kPa (Evidence level 2b, Recommendation strength B).

3.3.2. Assessment of the degree of steatosis

Hepatic steatosis is common in donors with advanced age, obesity, dyslipidemia, metabolic disease, or a history of diabetes. Steatotic donor livers are more susceptible to ischemia–reperfusion injury.[5] Macrovesicular steatosis is a risk factor for primary nonfunction (PNF) or transplantation failure.[6] Microvesicular steatosis is associated with less ischemia–reperfusion injury, and its post-transplant survival rate is not statistically different from that of nonsteatotic donor livers.[7] The degree of steatosis is generally assessed through ultrasound, CT, organ procurement, visual inspection, and pathological examination.[8] Pathological examination can help determine the accurate proportion of steatosis and distinguish between microvesicular and macrovesicular steatosis, serving as the gold standard for determining the type and degree of donor liver steatosis.[9]

Recommendation 4: Comprehensive assessment of donor characteristics, donor liver cold ischemia time, *in situ*/*ex situ* splitting methods, and other factors should be used to determine whether to split a steatotic donor liver (Evidence level 3a, Recommendation strength B).

3.3.3. Donor liver infection assessment

Deceased donor livers, especially those that have spent an extended period in the ICU, are prone to infections, particularly those caused by drug-resistant bacteria. These infections can lead to donor-related infections in the recipient, increasing surgical risks, prolonging the recipient's hospital stay, and escalating treatment costs. When selecting a donor liver, it is crucial to pay special attention to the donor's infection status during their ICU stay, particularly evaluating for drug-resistant infections. Detailed microbiological testing should be conducted to assess the potential infection risks of the donor liver.[10–12]

Recommendation 5: For donor livers with a high risk of infection, their suitability for transplantation should be carefully considered. If necessary, prophylactic anti-infective treatment may be administered (Evidence level 2b, Recommendation strength B).

3.4. Anatomical assessment of donor liver

During SLT, the anatomy of the hepatic artery, portal vein, hepatic vein, and bile ducts should be carefully evaluated. A vascular division and reconstruction plan should be developed based on the different splitting methods and donor-recipient characteristics to prevent increased transplant reconstruction difficulty or functional damage due to abnormal anatomical structures.[13]

3.4.1. Hepatic artery

Anatomical variations in the hepatic artery are relatively common (24%–45%) and notably higher in the left hepatic artery.[14–19] Before splitting the hepatic artery, the specific structure of the donor's hepatic artery must be thoroughly examined, and a reasonable plan must be formulated based on the recipient's specific situation.[13,20–24]

Recommendation 6: A combination of imaging techniques should be used in conjunction with the actual intraoperative findings to accurately assess the structure of the hepatic artery to ensure successful arterial reconstruction (Evidence level 2b, Recommendation strength B).

3.4.2. Portal vein

Compared with the hepatic artery, the portal vein has less anatomical variation. However, some rare variations may prevent the liver from being split effectively.[24–31] Intraoperative ultrasound can be used to roughly determine the course of the portal vein. If abnormalities are detected during liver division, the procedure should be stopped immediately to avoid cutting off large portal vein branches without a clear understanding of anatomical variations.[13,29,32–35]

Recommendations 7: Type I and II portal veins are generally suitable for SLT, whereas type III portal vein can be cautiously reconstructed without affecting classic splitting; type IV and V portal veins are generally not recommended for SLT (Fig. 1) (Evidence level 2b, Recommendation strength B).[36]

3.4.3. Hepatic vein

Variations in the left hepatic vein are relatively common.[24,37,38] For certain types, such as type III hepatic vein, the decision of whether to retain the left hepatic vein can be made based on the drainage range of its superior branch. Type IV hepatic vein may

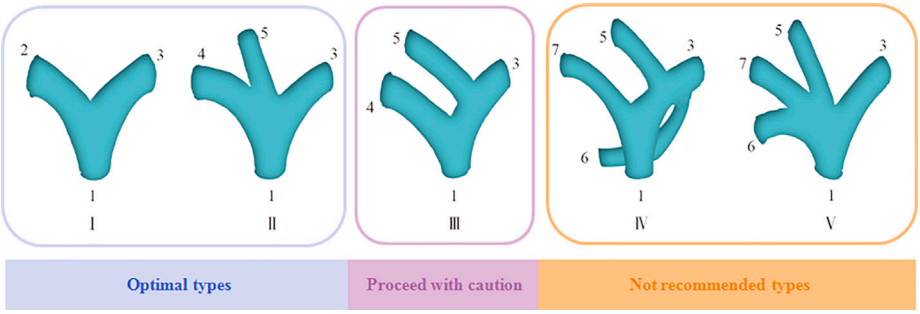

Fig. 1. Common portal vein types for donor liver splitting (type I–V). The numbers represent the various liver segments, as follows: 1, main portal vein; 2, right branch of the portal vein; 3, left branch of the portal vein; 4, right posterior branch of the portal vein; 5, right anterior branch of the portal vein; 6, right posterosuperior branch of the portal vein; 7, right posteroinferior branch of the portal vein.

require plastic repair of the outflow tract (*e.g.*, patching and bridging) (Supplemental Fig. 1).[39–43]

Recommendations 8: During liver segmentation, the characteristics of the left hepatic vein and its confluence with the middle hepatic vein should be fully understood, and attention should be paid to other possible anatomical variations while protecting the vein during separation. Moreover, attention should be paid to the course of the common branches of the middle hepatic vein, segments V and VIII, and reconstruction of relatively large segments (V and VIII) of hepatic veins during left and right hemiliver splitting (Evidence level 1a, Recommendation strength A).

3.4.4. Biliary ducts

Due to various anatomical variations in the bile ducts, their anatomy should be understood before dividing the liver parenchyma.[44,45] Cholangiography should be performed first during *in situ*/*ex situ* splitting to clarify the anatomy of the bile duct as early as possible.[46,47]

Recommendations 9: Anatomical abnormalities of the bile ducts are not an absolute contraindication for SLT. The anatomy of the bile duct should be fully evaluated to determine the optimal separation and reconstruction methods, thereby avoiding complex bile duct anastomoses and bile leaks caused by small bile ducts (Evidence level 2a, Recommendation strength B).

4. Recipient selection and donor-recipient matching principles for pediatric SLT

4.1. Recipient selection

Similar to LDLT, all pediatric recipients undergoing SLT should receive a comprehensive preoperative assessment by a multidisciplinary team. The assessment includes growth and development indicators, nutritional status, virological markers, imaging, and other relevant tests.[48–57] SLT does not pose any risk to living donors and offers greater flexibility in selecting the splitting approach based on the required donor liver volume. This allows SLT to be considered for more critically ill children preoperatively.

Recommendation 10: SLT should be prioritized for critically ill children and in cases where ethical approval for LDLT is uncertain (Evidence level 5, Recommendation strength D).

4.2. Donor-recipient matching principles

Donor-recipient matching in pediatric SLT has some flexibility and can be based on factors such as donor liver size, volume, recipient weight, abdominal cavity space, and the relative size of vascular and biliary orifices.[58–62] In general, graft-versus-recipient weight ratio (GRWR) is used as the basic standard for donor-recipient matching.[63–65]

Recommendation 11: Donor-recipient matching principles are as follows:

(i) The ideal range for GRWR in pediatric recipients is 1.5%–2.5%. To avoid large-for-size syndrome, it is recommended that the GRWR not exceed 4%. However, the selection of appropriate liver segments/hemiliver based on the recipient's portal vein diameter and flow may necessitate adjustments to the GRWR range (Evidence level 2a, Recommendation strength B).

(ii) Ensure sufficient abdominal cavity space in the recipient to accommodate the split donor liver's thickness, avoiding the development of large-for-size syndrome (LFSS) or the inability to close the abdomen (Evidence level 2b, Recommendation strength B).

(iii) Ensure adequate space for portocaval and biliary reconstruction (considering the relative positions of the first and second portal veins) to avoid difficulties with anastomosis and insufficient perfusion (Evidence level 5, Recommendation strength D).

5. Vessel division and allocation in split donor livers for pediatric transplantation

The division and allocation of vessels and bile ducts in SLT require careful consideration to maintain the relative integrity of blood supply and biliary drainage in both split liver segments, while minimizing the risk of postoperative technical complications arising from complex reconstruction.

5.1. Hepatic artery

Due to the frequent variations in the hepatic artery, the splitting method for the hepatic artery in SLT depends primarily on the arterial type. Second, the main artery should be allocated to the side with a smaller arterial diameter and greater reconstruction difficulty based on the diameter of the arteries.[13,66–70]

Recommendation 12: The division should be based on the size of the donor-recipient arterial diameter, while minimizing the number of branches to the greatest extent possible to reduce the difficulty of reconstruction (Evidence level 3a, Recommendation strength B).

5.2. Portal vein

After excluding donor livers with portal vein variations that are unsuitable for splitting during preoperative assessment, the portal vein is easier to divide and allocate than the hepatic artery.[13,68,70–72]

Recommendation 13: The division should be based on the donor-recipient portal vein diameter, length, and branches to maximize the protection of inflow and minimize the difficulty of reconstruction (Evidence level 3a, Recommendation strength B).

5.3. Hepatic vein

The division of the hepatic vein and retrohepatic inferior vena cava is crucial for the success of SLT.[13,68,70,73,74] In complete left and right hemiliver splitting, the division of the middle hepatic vein is critical, and the anatomical characteristics of the middle hepatic vein should be carefully understood.[13,70,73–75]

Recommendation 14: In the classic splitting method, the right trilobate donor liver retains the middle hepatic vein, right hepatic vein, and main inferior vena cava. If left and right hemiliver splitting is performed, the choice should be made based on the drainage area of the middle hepatic vein and functional liver volume after splitting. The middle hepatic vein can be retained on either side or split in the middle (Evidence level 3a, Recommendation strength B).

5.4. Bile ducts

The location of bile duct transection is determined using the splitting method. Attention should be paid to preserving the blood supply to the bile ducts. The retention of the main bile duct should be as consistent as possible with the retention of the main artery to avoid liver-to-liver bile duct arterial blood supply damage and subsequent bile duct complications.[54,76,77]

Recommendation 15: In the classic splitting method, the left hepatic duct is transected at its junction with the common hepatic

duct, and the common hepatic duct is retained in the right trilobate donor liver. For left and right hemiliver splitting, the bile ducts are allocated based on the diameter, length, and ease of anastomosis of the donor and recipient bile ducts (Evidence level 3b, Recommendation strength B).

5.5. Repair and shaping of vascular defects

Repair and shaping of vascular defects are essential in SLT to ensure the integrity of the vascular division of the split donor liver and facilitate subsequent anastomosis of the recipient's vessels. The ends of the divided main branches of the artery, portal vein, and bile duct in split donor livers do not require patch repair.[54,76,78,79] For defects resulting from the division of the inferior vena cava and left hepatic vein, allograft liver vascular patches are required for repair and reconstruction of the vasculature.[80–82] In particular, when the middle hepatic vein is split in the middle, the middle hepatic vein needs to be repaired with an allograft liver vascular patch.[75,83,84]

Recommendation 16: For the ends of the main artery, nonabsorbable vascular sutures are recommended for interrupted suture repair along the vertical axis; for the ends of the main bile duct, absorbable sutures are recommended for continuous suture repair; for the ends of the main portal vein, nonabsorbable vascular sutures are recommended for continuous suture repair along the vertical axis (Evidence level 3b, Recommendation strength B).

Recommendation 17: The purpose of repair and shaping is to create favorable conditions for the recipient's surgery. It should be completed as much as possible during the donor liver repair process to avoid increasing the complexity and difficulty of the recipient's surgery (Evidence level 3b, Recommendation strength B).

6. Hepatic vessel reconstruction and anastomosis in pediatric split liver transplant recipients

6.1. Hepatic artery

The smaller diameter of the arteries in split donor livers makes meticulous anastomosis crucial for reducing arterial complications.[23] For older children, direct-vision anastomosis under a head-mounted magnifier is recommended, whereas for younger children, microsurgical anastomosis can effectively lower the incidence of hepatic artery complications.[85,86]

Recommendation 18: Preserve as many recipient hepatic artery branches as possible. When there are multiple donor arteries, strive to perform separate anastomosis and reconstruction for each. Nonabsorbable sutures are preferred for full interrupted anastomosis (Evidence level 2b, Recommendation strength B).

6.2. Portal vein

The principle of portal vein shaping and reconstruction is to avoid stenosis and torsion. Length and angle control as well performing anastomosis in a tension-free manner are key to accomplishing this.[79,87]

Recommendation 19: Portal vein reconstruction should avoid stenosis and ensure smooth blood flow. Reconstruction options include trimming the anastomosis into a cuff and replacing the recipient segment of the portal vein. Absorbable sutures are recommended for continuous end-to-end anastomosis (Evidence level 2c, Recommendation strength B).

6.3. Hepatic vein and inferior vena cava

Optimal venous return in the donor liver ensures effective functional liver volume of the donor liver. Reconstruction of the hepatic vein and retrohepatic inferior vena cava is one of the keys to successful SLT.[88] The goal of hepatic vein shaping and reconstruction is to establish a wide outflow tract to ensure unimpeded return flow.[89,90]

Recommendation 20:

(i) In the classic splitting method, attention should be paid to the venous management of the left hepatic lobe. To ensure smooth return flow, a triangular anastomosis can be employed. For multiple venous openings, integrate them into a common opening as appropriate, anastomose them separately to the recipient inferior vena cava, or use allograft liver vasculature for encirclement (Evidence level 2b, Recommendation strength B);

(ii) For complete right and left hemiliver splitting, the management of the middle hepatic vein is critical. The decision should be based on the drainage area and liver volume. For the side without a retained middle hepatic vein, the decision to bridge the hepatic vein stump depends on its diameter. If the middle hepatic vein is split in the middle, donor iliac vasculature can be used to reconstruct the middle hepatic vein on both sides (Evidence level 2b, Recommendation strength B);

(iii) To prevent torsion and stenosis of the outflow tract caused by liver enlargement during childhood growth and development, the use of absorbable sutures for anastomosis is recommended (Evidence level 2b, Recommendation strength B).

6.4. Bile ducts

The bile duct caliber of pediatric recipients is often small, and the proportion of biliary atresia patients is relatively high. Therefore, bilioenteric anastomosis should be used where possible.[91]

Recommendation 21: Donor-recipient Roux-en-Y bilioenteric anastomosis is preferred. For bile ducts with similar diameters and no tension, end-to-end anastomosis can be performed. For multiple bile duct openings, if the intervals are small, they can be integrated into a common opening for bilioenteric anastomosis. Otherwise, they should be anastomosed separately. Interrupted anastomosis using absorbable sutures is recommended (Evidence level 3b, Recommendation strength B).

7. Blood flow monitoring

Close monitoring of donor liver blood flow is crucial.[92–96] Appropriate hemodynamic status is essential for optimal donor liver function and can reduce the incidence of related complications.[97–100] Ultrasound and flowmetry can be used to monitor donor liver blood flow.[101–103]

Recommendation 22: Recommended portal vein flow is 80–120 mL/100 g, not exceeding 250 mL/100 g, with a hepatic artery resistance index of 0.4–0.8 (Evidence level 2b, Recommendation strength B).

Recommendation 23: Intraoperative ultrasound should be used to assess blood flow and position the donor liver in the ideal location. Anticoagulation therapy can be initiated intraoperatively, if necessary. Monitor the blood flow of the transplanted liver both before and after abdominal closure, observing any changes in blood flow. If changes are detected, it is recommended to readjust the

Table 4
All recommendations in this guideline.

No.	Recommendation	Evidence level	Recommendation strength
1	Donors should generally meet general requirements; however, the conditions can be relaxed appropriately based on the donor and recipient status, splitting method, and donor liver quality to expand the pool of donor livers.	5	D
2	If conditions permit, contrast-enhanced abdominal CT, along with liver ultrasound elastography and contrast-enhanced ultrasound, should be used for initial examination of split donor livers. Pathological examination should be performed before/during donor liver procurement.	2b	B
3	Donor livers should meet pathological grading S0 and ultrasound elastography stiffness of <7 kPa.	2b	B
4	Comprehensive assessment of donor characteristics, donor liver cold ischemia time, *in situ*/*ex situ* splitting methods, and other factors should be used to determine whether to split a steatotic donor liver.	3a	B
5	For donor livers with a high risk of infection, their suitability for transplantation should be carefully considered. If necessary, prophylactic anti-infective treatment may be administered.	2b	B
6	A combination of imaging techniques should be used in conjunction with the actual intraoperative findings to accurately assess the structure of the hepatic artery to ensure successful arterial reconstruction.	2b	B
7	Type I and II portal veins are generally suitable for SLT, whereas type III portal vein can be cautiously reconstructed without affecting classic splitting; type IV and V portal veins are generally not recommended for SLT.	2b	B
8	During liver segmentation, the characteristics of the left hepatic vein and its confluence with the middle hepatic vein should be fully understood, and attention should be paid to other possible anatomical variations while protecting the vein during separation. Moreover, attention should be paid to the course of the common branches of the middle hepatic vein, segments V and VIII, and reconstruction of relatively large segments (V and VIII) of hepatic veins during left and right hemiliver splitting.	1a	A
9	Anatomical abnormalities of the bile ducts are not an absolute contraindication for SLT. The bile duct anatomy should be fully evaluated to determine the optimal separation and reconstruction methods, thereby avoiding complex bile duct anastomoses and bile leaks caused by small bile ducts.	2a	B
10	SLT should be prioritized for critically ill children and in cases where ethical approval for LDLT is uncertain.	5	D
11	Donor-recipient matching principles are as follows:		
	(i) The ideal range for GRWR in pediatric recipients is 1.5%–2.5%. To avoid large-for-size syndrome, it is recommended that the GRWR not exceed 4%. However, the selection of appropriate liver segments/hemiliver based on the recipient's portal vein diameter and flow may necessitate adjustments to the GRWR range.	2a	B
	(ii) Ensure sufficient abdominal cavity space in the recipient to accommodate the split donor liver's thickness, avoiding the development of LFSS or the inability to close the abdomen.	2b	B
	(iii) Ensure adequate space for portocaval and biliary reconstruction (considering the relative positions of the first and second portal veins) to avoid difficulties with anastomosis and insufficient perfusion.	5	D
12	The division should be based on the size of the donor-recipient arterial diameter, while minimizing the number of branches to the greatest extent possible to reduce the difficulty of reconstruction.	3a	B
13	The division should be based on the donor-recipient portal vein diameter, length, and branches to maximize the protection of inflow and minimize the difficulty of reconstruction.	3a	B
14	In the classic splitting method, the right trilobate donor liver retains the middle hepatic vein, right hepatic vein, and main inferior vena cava. If left and right hemiliver splitting is performed, the choice should be made based on the drainage area of the middle hepatic vein and functional liver volume after splitting. The middle hepatic vein can be retained on either side or split in the middle.	3a	B
15	In the classic splitting method, the left hepatic duct is transected at its junction with the common hepatic duct, and the common hepatic duct is retained in the right trilobate donor liver. For left and right hemiliver splitting, the bile ducts are allocated based on the diameter, length, and ease of anastomosis of the donor and recipient bile ducts.	3b	B
16	For the ends of the main artery, nonabsorbable vascular sutures are recommended for interrupted suture repair along the vertical axis; for the ends of the main bile duct, absorbable sutures are recommended for continuous suture repair; for the ends of the main portal vein, nonabsorbable vascular sutures are recommended for continuous suture repair along the vertical axis.	3b	B
17	The purpose of repair and shaping is to create favorable conditions for the recipient's surgery. It should be completed as much as possible during the donor liver repair process to avoid increasing the complexity and difficulty of the recipient's surgery.	3b	B
18	Preserve as many recipient hepatic artery branches as possible. When there are multiple donor arteries, strive to perform separate anastomosis and reconstruction for each. Nonabsorbable sutures are preferred for full interrupted anastomosis.	2b	B
19	Portal vein reconstruction should avoid stenosis and ensure smooth blood flow. Reconstruction options include trimming the anastomosis into a cuff and replacing the recipient segment of the portal vein. Absorbable sutures are recommended for continuous end-to-end anastomosis.	2c	B
20	(i) In the classic splitting method, attention should be paid to the venous management of the left hepatic lobe. To ensure smooth return flow, a triangular anastomosis can be employed. For multiple venous openings, integrate them into a common opening as appropriate, anastomose them separately to the recipient inferior vena cava, or use allograft liver vasculature for encirclement.	2b	B

Table 4 (*continued*)

No.	Recommendation	Evidence level	Recommendation strength
	(ii) For complete right and left hemiliver splitting, the management of the middle hepatic vein is critical. The decision should be based on the drainage area and liver volume. For the side without a retained middle hepatic vein, the decision to bridge the hepatic vein stump depends on its diameter. If the middle hepatic vein is split in the middle, donor iliac vasculature can be used to reconstruct the middle hepatic vein on both sides.	2b	B
	(iii) To prevent torsion and stenosis of the outflow tract caused by liver enlargement during childhood growth and development, the use of absorbable sutures for anastomosis is recommended.	2b	B
21	Donor-recipient Roux-en-Y bilioenteric anastomosis is preferred. For bile ducts with similar diameters and no tension, end-to-end anastomosis can be performed. For multiple bile duct openings, if the intervals are small, they can be integrated into a common opening for bilioenteric anastomosis. Otherwise, they should be anastomosed separately. Interrupted anastomosis using absorbable sutures is recommended.	3b	B
22	Recommended portal vein flow is 80–120 mL/100g, not exceeding 250 mL/100g, with a hepatic artery resistance index of 0.4–0.8.	2b	B
23	Intraoperative ultrasound should be used to assess blood flow and position the donor liver in the ideal location. Anticoagulation therapy can be initiated intraoperatively, if necessary. Monitor the blood flow of the transplanted liver both before and after abdominal closure, observing any changes in blood flow. If changes are detected, it is recommended to readjust the position of the new liver.	2b	B

Abbreviations: CT, computed tomography; GRWR, graft-versus-recipient weight ratio; LDLT, living donor liver transplantation; LFSS, large-for-size syndrome; SLT, split liver transplantation.

position of the new liver (Evidence level 2b, Recommendation strength B).

The recommendations of this guideline are detailed in Table 4.

8. Conclusion

To effectively expand the donor liver pool, reduce the waiting time for liver transplantation, and benefit more patients, especially children, we should encourage and increase the proportion of SLT for pediatric liver transplant recipients in light of the characteristics of these patients and the arrival of the era of liver donation from deceased citizens in China. In the implementation of pediatric SLT, careful evaluation of donor and donor liver function, precise preoperative planning, appropriate donor and recipient selection, and meticulous intraoperative procedures and perioperative management are essential to improve its efficacy. At the same time, organ allocation policies should be actively adjusted, multicenter collaboration should be strengthened, and safe and standardized development of pediatric SLT in China should be promoted so that more children can benefit.

This guideline has been developed based on current domestic and international literature and limited clinical experience, aiming to standardize the technical process of split liver pediatric liver transplantation in China. While the guideline provides important references for improving surgical safety and efficacy, there is still a lack of strong medical evidence for some clinical issues, such as the choice of anastomosis method for donor and recipient vessels and blood flow monitoring and control of the transplanted liver. These unsolved questions in clinical practice highlight the limitations of this guideline. In the future, it is necessary to continuously accumulate medical evidence and clinical experience through multicenter studies to further improve and update the guideline to ensure that it can better guide clinical practice and promote the development and improvement of pediatric SLT technology.

Authors' contributions

Yang Yang: Conceptualization, Supervision, Funding acquisition. Shuhong Yi: Conceptualization, Supervision, Project administration, Funding acquisition. Binsheng Fu: Writing – Original draft, Writing – review & editing, Funding acquisition. Xiao Feng: Writing – Original draft, Writing – Review & editing. Jianrong Liu: Supervision. Jie Ren: Supervision. Jin Wang: Supervision. Other experts contributed by reviewing the final draft and offering suggestions for further revisions. All authors read and approved the final manuscript.

Declaration of competing interest

Guihua Chen is an editor-in-chief for *Liver Research*, Yang Yang is an executive associate editor for *Liver Research*, Jin Wang and Ziqing Hei are editorial board members for *Liver Research*. All of them were not involved in the editorial review or the decision to publish this article. The authors declare that there are no conflicts of interest.

List of experts (arranged in alphabetical order by the last name)

Jiaze An (Xijing Hospital, Fourth Military Medical University, Xi'an, Shaanxi, China), Jianqiang Cai (Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China), Jinzhen Cai (The Affiliated Hospital of Qingdao University, Qingdao, Shandong, China), Jie Cao (Renji Hospital of Shanghai Jiao Tong University School of Medicine, Shanghai, China), Liping Cao (Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Guihua Chen (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Huanwei Chen (The First People's Hospital of Foshan, Foshan, Guangdong, China), Xiaoping Chen (Southern Theater of PLA Air Force Hospital, Guangzhou, Guangdong, China), Xinguo Chen (The Third Medical Center of Chinese PLA General Hospital, Beijing, China), Yifa Chen (Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, China), Zheng Chen (The Second Affiliated Hospital of Guangzhou Medical University, Guangzhou, Guangdong, China), Yinan Deng (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Chunqiang Dong (The First Affiliated Hospital of Guangxi Medical University, Nanning, Guangxi Zhuang Autonomous Region, China), Jian Dou (The Third Hospital of Hebei Medical University, Shijiazhuang, Hebei, China), Kefeng Dou (Xijing Hospital, Fourth Military Medical University, Xi'an, Shaanxi, China), Xilin Du (The Second Affiliated Hospital of the Fourth Military Medical University, Xi'an, Shaanxi, China), Binsheng Fu (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China),

Zhiren Fu (Shanghai Changzheng Hospital (Second Affiliated Hospital of Naval Medical University), Shanghai, China), Jie Gao (Peking University People's Hospital, Beijing, China), Wenzhi Guo (The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China), Xiaoshun He (The First Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Qiang He (Beijing Chao-Yang Hospital, Capital Medical University, Beijing, China), Ziqing Hei (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Zemin Hu (Zhongshan City People's Hospital, Zhongshan, Guangdong, China), Hua Huang (Fudan University Shanghai Cancer Center, Shanghai, China), Jianzhao Huang (Guizhou Provincial People's Hospital, Guiyang, Guizhou, China), Feng Huo (General Hospital of Southern Theater of Chinese People's Liberation Army, Guangzhou, Guangdong, China), Yi Jiang (The 900th Hospital of the Joint Logistics Support Force of the People's Liberation Army of China, Fuzhou, Fujian, China), Kuirong Jiang (Nanjing First Hospital of Nanjing Medical University, Nanjing, Jiangsu, China), Yanhua Lai (People's Hospital of Guangxi Zhuang Autonomous Region, Nanning, Guangxi Zhuang Autonomous Region, China), Guogang Li (The Second Affiliated Hospital Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Hua Li (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Jian Li (The Fifth Affiliated Hospital of Sun Yat-sen University, Zhuhai, Guangdong, China), Jun Li (The First Affiliated Hospital Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Li Li (The First People's Hospital of Kunming, Kunming, Yunnan, China), Ning Li (Beijing Youan Hospital, Capital Medical University, Beijing, China), Weimin Li (Chinese PLA General Hospital, Beijing, China), Yousheng Li (Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China), Guangming Li (Beijing Youan Hospital, Capital Medical University, Beijing, China), Chao Liu (Sun Yat-sen Memorial Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Jun Liu (Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, Shandong, China), Lei Liu (The Third People's Hospital of Shenzhen, Shenzhen, Guangdong, China), Shichun Lu (Chinese PLA General Hospital, Beijing, China), Xiaoming Lu (Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, China), Weiqi Lu (Zhongshan Hospital of Fudan University, Shanghai, China), Gangjian Luo (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Guoyue Lv (The First Hospital of Jilin University, Changchun, Jilin, China), Yi Lv (The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, China), Nan Ma (The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China), Mingming Nie (Changhai Hospital, Naval Medical University (Second Military Medical University), Shanghai, China), Zhihai Peng (Xiang'an Hospital of Xiamen University, Xiamen, Fujian, China), Haizhi Qi (The Second Xiangya Hospital of Central South University, Changsha, Hunan, China), Jianmin Qian (Huashan Hospital of Fudan University, Shanghai, China), Zhengjun Qiu (Shanghai General Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China), Jie Ren (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Dong Shang (The First Affiliated Hospital of Dalian Medical University, Dalian, Liaoning, China), Baiyong Shen (Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China), Xianbo Shen (Hunan Provincial People's Hospital (The First Affiliated Hospital of Hunan Normal University), Changsha, Hunan, China), Zhongyang Shen (Tianjin First Central Hospital, Tianjin, China), Jun Shi (The First Affiliated Hospital of Nanchang University, Nanchang, Jiangxi, China), Jinghai Song (Beijing Hospital, Beijing, China), Wu Song (The First Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Xiangqian Su (Peking University Cancer Hospital and Institute, Beijing, China), Chengyi Sun (The Affiliated Hospital of Guizhou Medical University, Guiyang, Guizhou, China), Xuyong Sun (The Second Affiliated Hospital of Guangxi Medical University, Nanning, Guangxi Zhuang Autonomous Region, China), Hui Tang (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Kaishan Tao (Xijing Hospital, Fourth Military Medical University, Xi'an, Shaanxi, China), Genshu Wang (Guangdong Provincial Hospital of Chinese Medicine, Guangzhou, Guangdong, China), Bo Wang (The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, China), Jizhou Wang (The First Affiliated Hospital of University of Science and Technology of China, Hefei, Anhui, China), Jiandong Wang (Xinhua Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China), Jin Wang (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Wentao Wang (West China Hospital of Sichuan University, Chengdu, Sichuan, China), Zhengxin Wang (Huashan Hospital of Fudan University, Shanghai, China), Chengze Wei (The Fifth Medical Center of Chinese PLA General Hospital, Beijing, China), Hao Wen (The First Affiliated Hospital of Xinjiang Medical University, Urumqi, Xinjiang, China), Shangeng Weng (The First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian, China), Linwei Wu (Guangdong Provincial People's Hospital, Guangzhou, Guangdong, China), Dequan Wu (The Second Affiliated Hospital of Harbin Medical University, Harbin, Heilongjiang, China), Jian Wu (The First Affiliated Hospital Zhejiang University school of Medicine, Hangzhou, Zhejiang, China), Zhongjun Wu (The First Affiliated Hospital of Chongqing Medical University, Chongqing, China), Qiang Xia (Renji Hospital of Shanghai Jiao Tong University School of Medicine, Shanghai, China), Renpin Xia (Tongji Hospital of Huazhong University of Science and Technology, Wuhan, Hubei, China), Yijun Xia (Inner Mongolia Autonomous Region People's Hospital, Hohhot, Inner Mongolia, China), Jian Xu (The First Affiliated Hospital of Hainan Medical University, Haikou, Hainan, China), Xiao Xu (People's Hospital, Hangzhou Medical College; Institute of Translational Medicine, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Wujun Xue (The First Affiliated Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi, China), Sheng Yan (The Second Affiliated Hospital Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Qiang Yan (The 924th Hospital of the Joint Logistic Support Force of the Chinese People's Liberation Army, Guilin, Guangxi Zhuang Autonomous Region, China), Jiayin Yang (West China Hospital of Sichuan University, Chengdu, Sichuan, China), Jianqing Yang (Liuzhou People's Hospital, Liuzhou, Guangxi Zhuang Autonomous Region, China), Qing Yang (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Yang Yang (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Yijun Yang (Xiangya Hospital of Central South University, Changsha, Hunan, China), Jia Yao (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Jianxin Ye (The First Affiliated Hospital of Fujian Medical University, Fuzhou, Fujian, China), Qifa Ye (Zhongnan Hospital of Wuhan University, Wuhan, Hubei, China), Huimin Yi (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Shuhong Yi (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Wenlong Zhai (The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China), Bingyuan Zhang (The Affiliated Hospital of Qingdao University, Qingdao, Shandong, China), Leida Zhang (Southwest Hospital, Army Medical University, Chongqing, China), Taiping Zhang (Peking Union Medical College Hospital, Beijing, China), Tong Zhang (Xiang'an Hospital of Xiamen University, Xiamen, Fujian, China), Xuewen Zhang (The Second Hospital of Jilin University, Changchun, Jilin, China), Yingcai Zhang (The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China), Hongchuan Zhao (The First Affiliated Hospital of

Anhui Medical University, Hefei, Anhui, China), Yunzhao Zhao (General Hospital of Eastern Theater Command, Nanjing, Jiangsu, China), Zuojun Zhen (The First People's Hospital of Foshan, Foshan, Guangdong, China), Jinfang Zheng (Hainan Provincial People's Hospital, Haikou, Hainan, China), Shusen Zheng (The First Affiliated Hospital Zhejiang University School of Medicine, Hangzhou, Zhejiang, China), Jian Zhou (Zhongshan Hospital of Fudan University, Shanghai, China), Jie Zhou (Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong, China), Anlong Zhu (The First Affiliated Hospital of Harbin Medical University, Harbin, Heilongjiang, China), Jiye Zhu (Beijing Friendship Hospital, Capital Medical University, Beijing, China), Zhijun Zhu (Beijing Friendship Hospital, Capital Medical University, Beijing, China), Li Zhuang (Shulan (Hangzhou) Hospital, Hangzhou, Zhejiang, China), Yan Zhuang (Peking University First Hospital, Beijing, China).

Acknowledgement

This work was supported by grants from National Key Research and Development Program of China (2017YFA0104304); National Natural Science Foundation of China (81972286 and 82073171); Natural Science Foundation of Guangdong Province (2020A1515010574 and 2020A1515010302); Guangdong Science and Technology Program (2019B020236003 and 2020B1212060019).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.livres.2024.11.002.

References

1. Fan X, Fu Z, Ma K, et al. Chinese expert consensus on minimally invasive interventional treatment of trigeminal neuralgia. *Front Mol Neurosci*. 2022;15:953765. https://doi.org/10.3389/fnmol.2022.953765.
2. Reichman TW, Fiorello B, Carmody I, et al. Using on-site liver 3-D reconstruction and volumetric calculations in split liver transplantation. *Hepatobiliary Pancreat Dis Int*. 2016;15:587–592. https://doi.org/10.1016/s1499-3872(16)60155-8.
3. Bekki Y, Fenig Y. Letter to the editor: the impact of donor liver fibrosis on early allograft dysfunction and ischemia-reperfusion injury. *Hepatology*. 2022;75:754. https://doi.org/10.1002/hep.32138.
4. Liao CC, Chen TY, Tsang LC, et al. The acoustic radiation force impulse elastography evaluation of liver fibrosis in posttransplantation dysfunction of living donor liver transplantation. *Transplant Proc*. 2014;46:876–879. https://doi.org/10.1016/j.transproceed.2013.12.012.
5. Argani H. Expanded criteria donors. *Exp Clin Transplant*. 2022;20:13–19. https://doi.org/10.6002/ect.DonorSymp.2022.L13.
6. Sakamoto S, Kasahara M, Ogura Y, Inomata Y, Uemoto S. Current status of deceased donor split liver transplantation in Japan. *J Hepatobiliary Pancreat Sci*. 2015;22:837–845. https://doi.org/10.1002/jhbp.292.
7. Moussaoui D, Toso C, Nowacka A, et al. Early complications after liver transplantation in children and adults: are split grafts equal to each other and equal to whole livers? *Pediatr Transplant*. 2017;21. https://doi.org/10.1111/petr.12908.
8. Liu H, Li R, Fu J, He Q, Li J. Technical skills required in split liver transplantation. *Ann Transplant*. 2016;21:408–415. https://doi.org/10.12659/aot.896351.
9. Broering DC, Kim JS, Mueller T, et al. One hundred thirty-two consecutive pediatric liver transplants without hospital mortality: lessons learned and outlook for the future. *Ann Surg*. 2004;240:1002–1012. https://doi.org/10.1097/01.sla.0000146148.01586.72. discussion 1012.
10. Saleh AM, Hassan EA, Gomaa AA, et al. Impact of pre-transplant infection management on the outcome of living-donor liver transplantation in Egypt. *Infect Drug Resist*. 2019;12:2277–2282. https://doi.org/10.2147/IDR.S208954.
11. Mouloudi E, Massa E, Papadopoulos S, et al. Bloodstream infections caused by carbapenemase-producing Klebsiella pneumoniae among intensive care unit patients after orthotopic liver transplantation: risk factors for infection and impact of resistance on outcomes. *Transplant Proc*. 2014;46:3216–3218. https://doi.org/10.1016/j.transproceed.2014.09.159.
12. Santoro-Lopes G, Gde Gouvea EF. Multidrug-resistant bacterial infections after liver transplantation: an ever-growing challenge. *World J Gastroenterol*. 2014;20:6201–6210. https://doi.org/10.3748/wjg.v20.i20.6201.
13. Group of Surgical Operation, Society of Surgery. Chinese medical association, group of organ transplantation, society of surgery, Chinese medical association, South China league of split liver transplantation. Chinese expert consensus on vascular segmentation and reconstruction of split liver transplantation (in Chinese) *Chin J Hepat Surg (Electronic Edition)*. 2023;12:167–172. https://doi.org/10.3877/cma.j.issn.2095-3232.2023.02.009.
14. Uraoka M, Funamizu N, Sogabe K, et al. Novel embryological classifications of hepatic arteries based on the relationship between aberrant right hepatic arteries and the middle hepatic artery: a retrospective study of contrast-enhanced computed tomography images. *PLoS One*. 2024;19:e0299263. https://doi.org/10.1371/journal.pone.0299263.
15. Rastogi A, Gupta AA, Piplani T, et al. Hilar anatomy in 3035 living liver donors: a novel classification for donor surgery and suitability, hepatic surgeries, and hepatobiliary interventions. *Transplantation*. 2024;108:455–463. https://doi.org/10.1097/TP.0000000000004807.
16. Choi TW, Chung JW, Kim HC, et al. Anatomic variations of the hepatic artery in 5625 patients. *Radiol Cardiothorac Imaging*. 2021;3:e210007. https://doi.org/10.1148/ryct.2021210007.
17. Khalid A, Saleem MA, Ihsan-Ul-Haq, Khan Y, Rashid S, Dar FS. Anatomical variations in living donors for liver transplantation-prevalence and relationship. *Langenbecks Arch Surg*. 2023;408:323. https://doi.org/10.1007/s00423-023-03066-1.
18. Imam A, Karatas C, Mecit N, et al. Anatomical variations of the hepatic artery: a closer view of rare unclassified variants. *Folia Morphol (Warsz)*. 2022;81:359–364. https://doi.org/10.5603/FM.a2021.0024.
19. Fonseca-Neto OCLD, Lima HCS, Rabelo P, Melo PSV, Amorim AG, Lacerda CM. Anatomic variations of hepatic artery: a study in 479 liver transplantations. *Arq Bras Cir Dig*. 2017;30:35–37. https://doi.org/10.1590/0102-6720201700010010.
20. Malviya KKVerma A. Importance of anatomical variation of the hepatic artery for complicated liver and pancreatic surgeries: a review emphasizing origin and branching. *Diagnostics (Basel)*. 2023;13:1233. https://doi.org/10.3390/diagnostics13071233.
21. Teegen EM, Globke B, Denecke T, et al. Vascular anomalies of the extrahepatic artery as a predictable risk factor for complications after liver transplant. *Exp Clin Transplant*. 2019;17:522–528. https://doi.org/10.6002/ect.2018.0201.
22. Karakoyun R, Romano A, Yao M, Dlugosz R, Ericzon BG, Nowak G. Impact of hepatic artery variations and reconstructions on the outcome of orthotopic liver transplantation. *World J Surg*. 2020;44:1954–1965. https://doi.org/10.1007/s00268-020-05406-4.
23. Kim DS, Yoon YI, Kim BK, et al. Asian pacific association for the study of the liver clinical practice guidelines on liver transplantation. *Hepatol Int*. 2024;18:299–383. https://doi.org/10.1007/s12072-023-10629-3.
24. Borhani AA, Elsayes KM, Catania R, et al. Imaging evaluation of living liver donor candidates: techniques, protocols, and anatomy. *Radiographics*. 2021;41:1572–1591. https://doi.org/10.1148/rg.2021210012.
25. Tutkuviene J, Navakauskaite A, Narutyte R, Brazaitis A, Barkus A, Tamosiunas A. Hepatic portal vein branching patterns according to different liver assessment methods and classifications of branching type. *Ann Anat*. 2024;252:152204. https://doi.org/10.1016/j.aanat.2023.152204.
26. Li JY, Dai WD, Hu JX, et al. Newly found variations of the right posterior portal vein identified radiologically in 1,003 Chinese patients: a cross-sectional study. *Ann Transl Med*. 2022;10:1237. https://doi.org/10.1016/j.aanat.2023.152204.
27. Najah H, Ammar H, Gupta R, et al. Segmental branching pattern of the left portal vein: anatomical characteristics and clinical implications. *Clin Anat*. 2018;31:1122–1128. https://doi.org/10.1002/ca.23009.
28. Sureka B, Patidar Y, Bansal K, Rajesh S, Agrawal N, Arora A. Portal vein variations in 1000 patients: surgical and radiological importance. *Br J Radiol*. 2015;88:20150326. https://doi.org/10.1259/bjr.20150326.
29. Shang ZX, Yu QJ, Luo FZ, Zhuang L, Zheng SS, Yang Z. Split liver transplantation with complicated portal vein variations in graft. *Hepatobiliary Pancreat Dis Int*. 2023;3(23):S1499–S3872. https://doi.org/10.1016/j.hbpd.2023.08.001, 00120-0.
30. Guler N, Dayangac M, Yaprak O, et al. Anatomical variations of donor portal vein in right lobe living donor liver transplantation: the safe use of variant portal veins. *Transpl Int*. 2013;26:1191–1197. https://doi.org/10.1111/tri.12190.
31. Na BG, Park GC, Hwang S, et al. Biliary complications after single- and dual-graft living-donor liver transplantation using a right posterior section graft of donor with a type III portal vein variation. *Transplant Proc*. 2020;52:1838–1843. https://doi.org/10.1016/j.transproceed.2020.01.142.
32. Operative Surgical Group. Branch of surgery of Chinese medical association transplantation group, branch of surgery of Chinese medical association. Expert consensus on split-liver transplantation (in Chinese). *Chin J Hepat Surg (Electronic Edition)*. 2020;9:429–434. https://doi.org/10.3877/cma.j.issn.20953232.2020.05.008.
33. Iqbal S, Iqbal R, Iqbal F. Surgical implications of portal vein variations and liver segmentations: a recent update. *J Clin Diagn Res*. 2017;11:AE01–AE05. https://doi.org/10.7860/JCDR/2017/25028.9453.
34. Shehta A, Elshobari M, Salah T, et al. Feasibility and outcomes of living-donor liver transplantation utilizing the right hemi-liver graft with portal vein anatomical variations. *Langenbecks Arch Surg*. 2023;408:387. https://doi.org/10.1007/s00423-023-03115-9.

35. Shehata MR, Kim DS, Jung SW, Yu YD, Suh SO. Use of right lobe graft with type IV portal vein accompanied by type IV biliary tree in living donor liver transplantation: report of a case. *Ann Surg Treat Res*. 2014;86:331–333. https://doi.org/10.4174/astr.2014.86.6.331.
36. Operative Surgical Group. Branch of surgery of Chinese medical association; transplantation group, branch of surgery of Chinese medical association. Chinese expert consensus on evaluation of donor and donor liver for split liver transplantation. *Liver Res*. 2022;6:59–65. https://doi.org/10.1016/j.livres.2022.03.002.
37. Shankar S, Rammohan A, Gunasekaran V, et al. Anatomical variations of left hepatic vein and outflow reconstruction techniques in pediatric living donor liver transplantation. *Am J Transplant*. 2023;23:786–793. https://doi.org/10.1016/j.ajt.2023.03.004.
38. da Fonseca EA, Feier FH, Costa CM, et al. Hepatic venous reconstruction of the left lateral segment with emphasis on anomalous hepatic vein in pediatric liver transplantation. *Liver Transpl*. 2023;29:827–835. https://doi.org/10.1097/LVT.0000000000000108.
39. Goldaracena N, Vargas PA, McCormack L. Pre-operative assessment of living liver donors' liver anatomy and volumes. *Updates Surg*. 2024;25. https://doi.org/10.1007/s13304-024-01806-6.
40. Chan KM, Hung HC, Lee JC, et al. A review of split liver transplantation with full right/left hemi-liver grafts for 2 adult recipients. *Medicine (Baltimore)*. 2021;100:e27369. https://doi.org/10.1097/MD.0000000000027369.
41. Na BG, Hwang S, Jung DH, et al. Long-term patency of all-in-one sleeve patch graft venoplasty in 16 patients who underwent living donor liver transplantation with a right liver graft: a 10-year, single-center, retrospective study. *Ann Transplant*. 2022;27:e936888. https://doi.org/10.12659/AOT.936888.
42. Durairaj MS, Shaji Mathew J, Mallick S, et al. Middle hepatic vein reconstruction in adult living donor liver transplantation: a randomized clinical trial. *Br J Surg*. 2021;108:1426–1432. https://doi.org/10.1093/bjs/znab346.
43. Hong SY, Kim T, Kim M, Lee HY, Wang HJ, Kim BW. Strategy for selective middle hepatic vein reconstruction in living donor liver transplantation using right lobe graft: a retrospective observational study. *Transplant Proc*. 2021;53:2318–2328. https://doi.org/10.1016/j.transproceed.2021.07.042.
44. Jaganathan S, Ray B, Velaga J. Our experience in tracking the tract: normal biliary anatomy and variants on magnetic resonance cholangiopancreatography in living donor liver transplantation. *Cureus*. 2023;15:e34695. https://doi.org/10.7759/cureus.34695.
45. Hecht EM, Kambadakone A, Griesemer AD, et al. Living donor liver transplantation: overview, imaging technique, and diagnostic considerations. *AJR Am J Roentgenol*. 2019;213:54–64. https://doi.org/10.2214/AJR.18.21034.
46. Li Z, Rammohan A, Gunasekaran V, et al. Biliary complications after adult-to-adult living-donor liver transplantation: an international multicenter study of 3633 cases. *Am J Transplant*. 2024;24:1233–1246. https://doi.org/10.1016/j.ajt.2024.02.023.
47. Matsushima H, Fujiki M, Sasaki K, et al. Biliary complications following split liver transplantation in adult recipients: a matched pair analysis on single-center experience. *Liver Transpl*. 2023;29:279–289. https://doi.org/10.1097/LVT.0000000000000058.
48. Angelico R, Nardi A, Adam R, et al. Outcomes of left split graft transplantation in Europe: report from the European Liver Transplant Registry. *Transpl Int*. 2018;31:739–750. https://doi.org/10.1111/tri.13147.
49. Jain AK, Anand R, Lerret S, et al. Outcomes following liver transplantation in young infants: data from the SPLIT registry. *Am J Transplant*. 2021;21:1113–1127. https://doi.org/10.1111/ajt.16236.
50. Yamada N, Sanada Y, Hirata Y, et al. Selection of living donor liver grafts for patients weighing 6kg or less. *Liver Transpl*. 2015;21:233–238. https://doi.org/10.1002/lt.24048.
51. Venick RS, Farmer DG, Soto JR, et al. One thousand pediatric liver transplants during thirty years: lessons learned. *J Am Coll Surg*. 2018;226:355–366. https://doi.org/10.1016/j.jamcollsurg.2017.12.042.
52. Zhang R, Zhu ZJ, Sun LY, Wei L, Qu W. Outcomes of liver transplantation using pediatric deceased donor livers: a single-center analysis of 102 donors. *Chin Med J (Engl)*. 2018;131:677–683. https://doi.org/10.4103/0366-6999.226901.
53. Spada M, Angelico R, Trapani S, et al. Tailoring allocation policies and improving access to paediatric liver transplantation over a 16-year period. *J Hepatol*. 2024;80:505–514. https://doi.org/10.1016/j.jhep.2023.11.031.
54. Luo Y. Technical specification for pediatric liver transplantation in China (2019 edition (in Chinese). *Chin J Transplant (Electronic Edition)*. 2019;13:181–186. https://doi.org/10.3877/cma.j.issn.1674-3903.2019.03.005.
55. Yu WF, Huang WQ, Yang LQ. Expert consensus on anesthesia management for pediatric liver transplantation (in Chinese) *J Clin Anesthesiol*. 2021;37:424–429. https://doi.org/10.12089/jca.2021.04.022.
56. Azoulay D, Salloum C, Llado L, et al. Defining surgical difficulty of liver transplantation. *Ann Surg*. 2023;277:144–150. https://doi.org/10.1097/SLA.0000000000005017.
57. Ross MW, Cescon M, Angelico R, et al. A matched pair analysis of multicenter longterm follow-up after split-liver transplantation with extended right grafts. *Liver Transpl*. 2017;23:1384–1395. https://doi.org/10.1002/lt.24808.
58. Lau NS, Jacques A, McCaughan G, Crawford M, Liu K, Pulitano C. Addressing the challenges of split liver transplantation through technical advances. a systematic review. *Transplant Rev (Orlando)*. 2021;35:100627. https://doi.org/10.1016/j.trre.2021.100627.
59. Busuttil RW, Goss JA. Split liver transplantation. *Ann Surg*. 1999;229:313–321. https://doi.org/10.1097/00000658-199903000-00003.
60. Gao W, Song Z, Ma N, et al. Application of pediatric donors in split liver transplantation: is there an age limit? *Am J Transplant*. 2020;20:817–824. https://doi.org/10.1111/ajt.15641.
61. Gül-Klein S, Dziodzio T, Martin F, et al. Outcome after pediatric liver transplantation for staged abdominal wall closure with use of biological mesh-Study with long-term follow-up. *Pediatr Transplant*. 2020;24:e13683. https://doi.org/10.1111/petr.13683.
62. Sakamoto S, Kanazawa H, Shigeta T, et al. Technical considerations of living donor hepatectomy of segment 2 grafts for infants. *Surgery*. 2014;156:1232–1237. https://doi.org/10.1016/j.surg.2014.05.003.
63. Gavriilidis PHidalgo E. Alternatives to left lateral sector in paediatric liver transplantation-a systematic review on monosegmental and reduced grafts. *Hepatobiliary Surg Nutr*. 2022;11:567–576. https://doi.org/10.21037/hbsn-20-792.
64. Li JJ, Zu CH, Li SP, Gao W, Shen ZY, Cai JZ. Effect of graft size matching on pediatric living-donor liver transplantation at a single center. *Clin Transplant*. 2018;32. https://doi.org/10.1111/ctr.13160.
65. Kitajima T, Sakamoto S, Sasaki K, et al. Impact of graft thickness reduction of left lateral segment on outcomes following pediatric living donor liver transplantation. *Am J Transplant*. 2018;18:2208–2219. https://doi.org/10.1111/ajt.14875.
66. Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. *Ann Surg*. 1994;220:50–52. https://doi.org/10.1097/00000658-199407000-00008.
67. Yi S, Zhang T, Fu B, et al. Hepatic artery segmentation and reconstruction in children organ donor liver transplantation by split liver transplantation (in Chinese). *Chin J Organ Transplant*. 2019;40:392–395.
68. Yi S, Yang Y, Yi H, et al. Clinical research of deceased-donor split liver transplantation in pediatric recipients (in Chinese). *Chin J Organ Transplant*. 2019;40:22–25. https://doi.org/10.3760/cma.j.issn.0254-1785.2019.01.006.
69. Mabrouk Mourad M, Liossis C, Kumar S, et al. Vasculobiliary complications following adult right lobe split liver transplantation from the perspective of reconstruction techniques. *Liver Transpl*. 2015;21:63–71. https://doi.org/10.1002/lt.24015.
70. Operative Surgical Group. Branch of Surgery of Chinese Medical Association, Transplantation Group, Branch of Surgery of Chinese Medical Association. Expert consensus on split-liver transplantation. *Liver Res*. 2021;5:1–6. https://doi.org/10.1016/j.livres.2020.12.003.
71. Li S, Sun C, Ma N, et al. Portal vein reconstruction in 175 cases of pediatric liver transplantation: a single center experience (in Chinese). *Prac J Organ Transplant (Electronic Version)*. 2014;2:279–282. https://doi.org/10.3969/j.issn.2095-5332.2014.05.004.
72. Zeng K, Yang Q, Yao J, et al. Diagnosis and treatment of the portal vein complications for children undergoing spilt liver transplantation (in Chinese). *Organ Transplant*. 2024;15:63–69. https://doi.org/10.3969/j.issn.1674-7445.2023241.
73. Noujaim HM, Mirza DF, Mayer DA, De Ville De Goyet J. Hepatic vein reconstruction in ex situ split-liver transplantation. *Transplantation*. 2002;74:1018–1021. https://doi.org/10.1097/00007890-200210150-00021.
74. Urata K, Kawasaki S, Matsunami H, et al. Calculation of child and adult standard liver volume for liver transplantation. *Hepatology*. 1995;21:1317–1321.
75. Yi S, Yang Q, Fu B, et al. Design and clinical application of simplified "All in one" hepatic vein reconstruction in right split liver transplantation (in Chinese). *Organ Transplant*. 2022;13:764–769. https://doi.org/10.3969/j.issn.1674-7445.2022.06.011.
76. Wilms C, Walter J, Kaptein M, et al. Long-term outcome of split liver transplantation using right extended grafts in adulthood: a matched pair analysis. *Ann Surg*. 2006;244:865–873. https://doi.org/10.1097/01.sla.0000247254.76747.f3.
77. Doyle MB, Maynard E, Lin Y, et al. Outcomes with split liver transplantation are equivalent to those with whole organ transplantation. *J Am Coll Surg*. 2013;217:102–114. https://doi.org/10.1016/j.jamcollsurg.2013.03.003.
78. Shen C, Tao Y, Li R, et al. Reconstruction of hepatic artery in liver transplantation in children (in Chinese). *J Hepa Surg*. 2019;27:416–418.
79. Marwan IK, Fawzy AT, Egawa H, et al. Innovative techniques for and results of portal vein reconstruction in living-related liver transplantation. *Surgery*. 1999;125:265–270.
80. Marcos A, Orloff M, Mieles L, Olzinski AT, Renz JF, Sitzmann JV. Functional venous anatomy for right-lobe grafting and techniques to optimize outflow. *Liver Transpl*. 2001;7:845–852. https://doi.org/10.1053/jlts.2001.27966.
81. Yersiz H, Renz JF, Hisatake G, et al. Technical and logistical considerations of in situ split-liver transplantation for two adults: Part II. Creation of left segment I-IV and right segment V-VIII grafts. *Liver Transpl*. 2002;8:78–81. https://doi.org/10.1053/jlts.2002.31036.
82. Noujaim HM, Gunson B, Mayer DA, et al. Worth continuing doing ex situ liver graft splitting? A single-center analysis. *Am J Transplant*. 2003;3:318–323. https://doi.org/10.1034/j.1600-6143.2003.00047.x.
83. Lee WC, Chan KM, Chou HS, et al. Feasibility of split liver transplantation for 2 adults in the model of end-stage liver disease era. *Ann Surg*. 2013;258:306–311. https://doi.org/10.1097/SLA.0b013e3182754b8e.

84. Yang Q, Yi S, Fu B, et al. Clinical application of 203 cases of split liver transplantation (in Chinese). *Zhonghua Wai Ke Za Zhi*. 2024;62:324–330. https://doi.org/10.3760/cma.j.cn112139-20231225-00297.
85. Nickel KJ, Staples J, Meeberg G, et al. The transition to microsurgical technique for hepatic artery reconstruction in pediatric liver transplantation. *Plast Reconstr Surg*. 2021;148:248e–257e. https://doi.org/10.1097/PRS.0000000000008169.
86. Feng MX, Zhang JX, Wan P, et al. Hepatic artery reconstruction in pediatric liver transplantation: experience from a single group. *Hepatobiliary Pancreat Dis Int*. 2020;19:307–310. https://doi.org/10.1016/j.hbpd.2020.06.014.
87. Lee JM, Lee KW. Techniques for overcoming atretic changes of the portal vein in living donor liver transplantation. *Hepatobiliary Pancreat Dis Int*. 2020;19:311–317. https://doi.org/10.1016/j.hbpd.2020.06.016.
88. Hou Y, Wan P, Feng M, et al. Modified dual hepatic vein anastomosis in pediatric living-donor liver transplantation using left lateral segment grafts with two wide orifices. *Front Pediatr*. 2021;9:685956. https://doi.org/10.3389/fped.2021.685956.
89. Sun C, Song Z, Dong C, et al. Outflow reconstruction of left lateral graft with two widely spaced hepatic veins in pediatric living donor liver transplantation. *Surgery*. 2022;172:391–396. https://doi.org/10.1016/j.surg.2022.01.026.
90. Szymczak M, Kaliciński PJ, Kowalewski G, et al. Inferior vena cava and venous outflow reconstruction in living donor liver transplantation in children: a single-center retrospective study and literature review. *Ann Transplant*. 2021;26:e926217. https://doi.org/10.12659/AOT.926217.
91. Yilmaz C, Karaca CA, Ferecov R, et al. Duct-to-duct biliary reconstruction in pediatric split-liver transplantation. *Liver Transpl*. 2018;24:432–435. https://doi.org/10.1002/lt.24970.
92. Berrocal T, Parrón M, Alvarez-Luque A, Prieto C, Santamaría ML. Pediatric liver transplantation: a pictorial essay of early and late complications. *Radiographics*. 2006;26:1187–1209. https://doi.org/10.1148/rg.264055081.
93. Verhagen MV, de Kleine RH, Groen H, van der Doef HPJ, Kwee TC, de Haas RJ. Doppler-ultrasound reference values after pediatric liver transplantation: a consecutive cohort study. *Eur Radiol*. 2023;33:6404–6413. https://doi.org/10.1007/s00330-023-09522-2.
94. Dammann E, Steinmeister L, Groth M, et al. Hepatic artery delineation on ultrasound volumes comparing B-flow and color Doppler for postoperative monitoring of pediatric liver transplants. *Diagnostics (Basel)*. 2024;14:617. https://doi.org/10.3390/diagnostics14060617.
95. Monti L, Soglia G, Tomà P. Imaging in pediatric liver transplantation. *Radiol Med*. 2016;121:378–390. https://doi.org/10.1007/s11547-016-0628-3.
96. Humphrey T, Bainbridge C, Stringer M. Reproducibility of measurements of hepatic artery and portal vein diameter and flow velocity in paediatric liver transplant recipients. *Pediatr Radiol*. 2007;37:813–817. https://doi.org/10.1007/s00247-007-0509-y.
97. Rossignol G, Muller X, Couillerot J, et al. From large-for-size to large-for-flow: a paradigm shift in liver transplantation. *Liver Transpl*. 2024;30:277–287. https://doi.org/10.1097/LVT.0000000000000150.
98. Spitzer AL, Dick AA, Bakthavatsalam R, et al. Intraoperative portal vein blood flow predicts allograft and patient survival following liver transplantation. *HPB (Oxford)*. 2010;12:166–173. https://doi.org/10.1111/j.1477-2574.2009.00137.x.
99. Marambio A, Tuñon JMC, Gómez LMM, et al. Intraoperative portal vein flow > 123 mL/min per 100 g predicts a better survival of patients after liver transplantation. *Transplant Proc*. 2018;50:3582–3586. https://doi.org/10.1016/j.transproceed.2018.06.032.
100. Matsushima H, Sasaki K, Fujiki M, et al. Too Much, too little, or just right? The importance of allograft portal flow in deceased donor liver transplantation. *Transplantation*. 2020;104:770–778. https://doi.org/10.1097/TP.0000000000002968.
101. Kong L, Lv T, Yang J, Jiang L, Yang J. Adult split liver transplantation: a PRISMA-compliant Chinese single-center retrospective case-control study. *Medicine (Baltimore)*. 2020;99:e23750. https://doi.org/10.1097/MD.0000000000023750.
102. Perkins JD, Dick AA, Healey PJ, et al. New evidence supporting increased use of split liver transplantation. *Transplantation*. 2020;104:299–307. https://doi.org/10.1097/TP.0000000000002853.
103. Caruso S, Miraglia R, Maruzzelli L, Gruttadauria S, Luca A, Gridelli B. Imaging in liver transplantation. *World J Gastroenterol*. 2009;15:675–683. https://doi.org/10.3748/wjg.15.675.