Anatomic considerations in evaluation of potential living donor liver allografts

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ISSUE

How does the anatomy of the donor liver affect outcomes for the donor and the recipient?

DATA

Assessment of a potential donor for living liver donation requires consideration of several anatomic factors:

- liver volumetry relative to recipient size and severity of illness (GRWR)
- hepatic vascular anatomy, and
- biliary anatomy.

Volume:

Liver allograft options include:

- Left lateral section (segments 2 and 3) – 10-25% total liver volume
- Left lobe (segments 2-4 with or without caudate) – 20-50% total liver volume
- Right lobe (segments 5-8) – 50-70% total liver volume, may or may not include the middle hepatic vein (MHV) (1).

Typically, a left lateral section graft is donated from an adult to small child. Adult-to-adult living donor liver transplant (LDLT) commonly utilizes right lobe grafts, or left lobe grafts for smaller or less sick adult recipients. Inclusion of the caudate with left lobe grafts to increase functional graft mass has not been well studied. Right posterior sector allografts have been transplanted infrequently and are associated with high biliary complication rates.

The anatomic work up of a potential living donor is dependent on center access to and expertise in high quality imaging techniques. Pre-donation imaging typically includes contrast-enhanced CT or MRI (arterial, portal venous, and delayed venous phases), MRCP, and 3D reconstruction. This imaging is recommended to perform accurate volumetric analysis and assess the presence of anatomic variants. Importantly, the principal objective is always to minimize the risk of harm to a potential donor while trying to provide adequate liver function to the intended recipient. For liver donors, the degree of perioperative risk appears to be associated with the volume of liver resected (2, 3). Donation of left lateral section and left lobe grafts appears to be associated with lower peri-operative risk than donor right hepatectomy (4). Donor right hepatectomy is associated with morbidity rates of 24-40% (Clavien grade 1-4) in large cohorts reported from the U.S. and Canada (2, 5, 6). The donor’s future liver remnant (FLR) ideally should be $\geq$ 30-35% of the total liver volume to minimize risk of post-operative hepatic insufficiency, remnant liver failure, and death (7-10).

Adequate graft size for the recipient is calculated using the graft-to-recipient weight ratio (GRWR in L/kg x 100%). The generally accepted ideal GRWR is $\geq$ 0.8% (7). This GRWR threshold is believed to be associated with better graft function, hepatocellular regenerative capacity, and reduced risk of small-for-size syndrome in the recipient. Recipients with severe portal hypertension might require larger graft size or inflow modification of the graft to reduce portal flow. In select recipients, in deference to donor safety, grafts with GRWR 0.6-0.8% can be carefully considered in association with efforts to optimize inflow and outflow (11, 12).

Anatomy:

Historically, it has been shown that partial liver allografts have higher associated risk of technical complications (e.g., vascular thrombosis and biliary leak, stricture) compared with whole liver allografts. The presumed association is due, in part, to more delicate nature of smaller segmental components used for anastomosis with recipient structures. For partial grafts with conventional vascular and biliary anatomy, this may be less of a concern. However, liver allografts with unconventional anatomy, such as multiple accessory vessels or ducts, present unique challenges for reconstruction. It is at the discretion of the donor and recipient transplant surgeons to determine whether potential graft anatomy is acceptable and amenable to reconstruction.

<u>Hepatic Venous Outflow</u>:

Hepatic venous outflow of living donor grafts requires careful consideration to minimize venous congestion in both the allograft and the remnant liver. For right lobe grafts, many centers prefer to preserve the middle hepatic vein (MHV) with the donor left lobe remnant. Studies have demonstrated that MHV drainage is necessary to support regeneration of segment 4 in the liver remnant (13-15). However, transplantation of the right lobe without MHV can result in venous congestion of the graft. To ensure adequate drainage of a right lobe graft without MHV, reconstruction of segmental venous branches (5 and/or 8) is recommended if a segmental venous branch is >5mm diameter, comprises >10% total venous outflow, or if loss of that region would result in a suboptimal GWRW. In contrast, it is recommended that left lobe grafts contain the middle hepatic vein (7).

Portal Venous Inflow:

The recipient portal vein (PV) should be assessed preoperatively to evaluate for stenosis or thrombosis. The donor portal vein should also be assessed to determine branch anatomy: standard left-right bifurcation; trifurcation of the left, right anterior, and right posterior; early branching of the right posterior (or origination of the right anterior from the left PV). Primary anastomosis with a single allograft PV may be completed with the recipient's main PV trunk, branch patch, or the left or right PV branch (16). Several options exist for venous reconstruction of a right lobe graft with separate right anterior and right posterior PV branches: a backtable venoplasty into one lumen; individual anastomoses to the recipient left and right PV branches (may be performed as a backtable reconstruction to the recipient PV bifurcation "graft")(17), or with end-to-end and end-to-side anastomoses to the recipient main PV. Interposition grafts may be used in cases with short recipient PV due to stenosis or thrombosis(18).

Portal venous hyperperfusion can cause graft injury and result in small-for-size syndrome or early allograft dysfunction. Patients with severe portal hypertension are at increased risk. Therefore, intraoperative measurement of portal venous pressure is recommended. Options for inflow modification include splenic artery ligation, splenectomy, or hemi-portocaval shunt (19).

Hepatic Artery Inflow:

For grafts with two arteries, options for reconstruction include side-to-side arterioplasty to create a single artery, implantation of dual arteries using the recipient left and right arterial branches, or an end-to-end and end-to-side anastomoses with the recipient proper hepatic artery (17, 18). Limited evidence suggests that for left lobe grafts with 2 arteries (e.g., left + middle hepatic artery), only one reconstruction might be required if there is back-bleeding from the smaller branch (20). Transplant surgeon and center experience clearly influence the incidence of donor and recipient complications, with more experienced centers (>20 cases) having significantly lower incidence of complications overall; this is shown to also include approach to reconstruction with donor vascular or biliary anomalies. (11)

Biliary Reconstruction:

Biliary reconstruction of partial allografts continues to be associated with higher risk of complications (leak or stricture) than whole liver allografts. Preoperative MRCP or intraoperative cholangiogram may be used to determine biliary anatomy of an allograft. The presence of more than one bile duct is not prohibitive to transplant, but can present reconstruction challenges. Several options exist for biliary reconstruction: single duct-to-duct (utilizing recipient common hepatic duct), Roux-en-Y hepaticojejunostomy to single or multiple ducts, duct-to-biliary radical (such as right or left hepatic branch, cystic duct), allograft ductoplasty-to-recipient duct (in case of multiple allograft ducts), or a combination of approaches if multiple ducts are present. Observational data from the Adult to Adult Living Donor Liver Transplantation (A2ALL) Cohort Study suggest that duct-to-duct and RYHJ reconstructions have similar risk of biliary complications (42%), but use of RYHJ is associated with higher risk of hepatic artery thrombosis. In comparison, reconstruction to a higher order biliary radical has increased risk of early bile leaks and late strictures (21).

Even with thorough pre-operative evaluation and imaging, LDLT surgeons must be prepared for discovery and management of anatomic variants intra-operatively.

RECOMMENDATIONS

1. The donor should ideally have a functional liver remnant $\geq$30% of pre-resection total liver volume.
2. The ideal living donor allograft provides a GRWR $\geq$0.8%.
3. Hepatic venous reconstruction might enhance allograft function and regenerative capacity in right lobe grafts without the middle hepatic vein.
4. Intraoperative portal pressure measurements with inflow modification may reduce risk of early allograft dysfunction.
5. Biliary anatomy and line of transection of the appropriate bile duct intraoperatively should be confirmed prior to transection with an intraoperative cholangiogram or similar pre-operative contrast enhanced imaging. Despite different biliary reconstruction techniques, rates of biliary complications (leak and stricture) remain high and are the “Achilles heel” of LDLT (21).

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