Live Donor Liver Transplantation

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With ever-increasing demand for liver replacement, supply of organs is the limiting factor and a significant number of patients die while waiting. Live donor liver transplantation has emerged as an important option for many patients, particularly small pediatric patients and those adults that are disadvantaged by the current deceased donor allocation system. Ideally there would be no need to subject perfectly healthy people in the prime of their lives to a potentially life-threatening operation to procure transplantable organs. Donor safety is imperative and cannot be compromised regardless of the implication for the intended recipient. The evolution of split liver transplantation is the basis upon which live donor transplantation has become possible. The live donor procedures are considerably more complex than whole organ deceased donor transplantation and there are unique considerations involved in the assessment of any specific recipient and donor. Donor selection and evaluation have become highly specialized. The critical issue of size matching is determined by both the actual size of the donor graft and the recipient as well as the degree of recipient portal hypertension. The outcomes after live donor liver transplantation have been at least comparable to those of deceased donor transplantation. Nevertheless, all efforts should be made to improve deceased donor donation so as to minimize the need for live donors. Transplant physicians, particularly surgeons, must take responsibility for regulating and overseeing these procedures. Liver Transpl 12:499-510, 2006. © 2006 AASLD.

HISTORICAL PERSPECTIVE

For centuries, early anatomists and surgeons attempted procedures on the largest organ in the human body with little success because of the liver’s tremendous vascularity. In the last half-century, however, with remarkable progress in anesthesia and surgical techniques, liver operations long believed to be improbable have become commonplace.³ With better understanding of hepatic anatomy and the segmental nature of the liver, partial resections became possible. Couinaud⁶ best described the segmental nature of the liver as eight independent segments based on the secondary and tertiary branching patterns of the blood supply, each having its own vascular inflow and outflow and biliary drainage (Fig. 2).

The regenerative power of the liver was first described by the Greeks more than 2,500 yr ago.⁷ Greek mythology gives perhaps the most infamous reminder of the liver’s regenerative powers with the mythological account of Prometheus, who stole fire from Zeus and gave it to humankind. As a punishment, he was chained to...
one of the Caucasian Mountains, where every day a voracious bird feasted upon his liver, causing excruciating pain (Fig. 3). Only at night, while the bird slept, did his liver regenerate, so that the process could begin again the next day. Regeneration is a common feature in invertebrates (e.g., worms) but is very limited in the majority of vertebrates. The mechanisms of liver regeneration remain poorly defined, but the process is central to the success of surgical resections and live donor transplantation.

Initially, successful outcomes were achieved with small (wedge) resections of the liver. With experience, larger resections were successfully completed. There is, however, a limit to the safe extent of resection – a gray area beyond which the liver loses its ability to compensate, regenerate, and recover. The greater the resection, the greater the risk that the safe limit will be exceeded. In a given individual, many factors determine hepatic reserve and the ability to regenerate. Age, portal hypertension, steatosis, and other underlying hepatic pathology are critical factors. Experience in adult patients with liver tumors has been the foundation upon which the transplant community assembled the surgical and medical expertise to safely resect a healthy person’s liver and yield a portion adequate to support the life of another.

EVOLUTION OF LIVE DONOR LIVER TRANSPLANTATION

Before the introduction of live donor liver transplantation, the mortality rate among children awaiting transplantation exceeded 25%.8,9 The use of a live donor for liver transplantation was first attempted in 1987, when Raia10 transplanted a small child in Brazil. Although the recipient did not survive, Raia’s attempt established the technical feasibility of the procedure. The first successful live donor liver transplant was reported that same year in Australia by Strong.11 The techniques to perform live donor liver transplantation in children were established and then refined by Broelsch.9 Early successes led directly to significantly decreased mortality for children awaiting liver transplantation.12 Importantly, the left lateral segmentectomy procedure, which involves removal of segments II and III (Fig. 4), was well tolerated by adult donors, most of whom were the parents of the recipients. There was essentially no concern with regard to the donor’s remnant size, because the left lateral segment is generally 20% of the donor’s liver volume.

With the success of living donor liver transplantation using small grafts for children, surgeons began to offer the procedure to adult recipients. The first such transplants in adults were performed in Japan, where cadaveric donation is nil because of traditional beliefs. Indeed, the Japanese pioneered living donor liver
transplants in adults, first with the left lobe and then with right lobes.\textsuperscript{13-15}

The initial experiences in the U.S. with left-lobe live donor liver transplantation yielded generally poor results.\textsuperscript{16} Many of the failures resulted from underappreciation of the importance of size matching between donors and recipients. Often, recipients of relatively small partial grafts developed what became known as small-for-size syndrome, characterized by synthetic dysfunction, elevated aminotransferases, and prolonged cholestasis.\textsuperscript{17,18} Small-for-size syndrome may resolve with supportive care and time, with resolution of the transaminitis within days and the cholestasis within weeks. However, in the presence of continued transaminitis, acidosis, hypoglycemia, encephalopathy, renal failure, cholestasis, and finally the onset of septic complications, the damage may be irreversible and, without prompt retransplantation, even deadly. Histologically, these grafts have characteristics that include severe hepatocyte ballooning, cholestasis, and centrilobular necrosis.

With occasional patient deaths from small-for-size syndrome impeding the wider use of living donor liver transplantation in adults, many centers began to use the right lobe from the donor to provide more actual graft mass for the recipient. The first U.S. series were reported in the late 1990s.\textsuperscript{19-21} Even with significantly larger grafts, however, small-for-size syndrome may still occur.\textsuperscript{16,22,23} The dichotomy of small-for-size syndrome occurring despite adequate actual graft volume led to the understanding of the critical importance of graft hemodynamics in the ultimate determination of functional graft size.

It is now better understood that excessive portal inflow can result in overperfusion of the partial graft and thereby result in poor graft function. Partial liver grafts may receive three or more times the amount of portal flow and often have compromised venous drainage (i.e., outflow).\textsuperscript{24} Assuring perfect venous outflow and preventing portal venous overflow and resultant graft flooding are the most important factors, along with actual graft size, in the determination of functional graft size and outcome. Just as an automobile engine’s horsepower can be increased by adding more exhaust and by changing a carburetor to a fuel injector, assuring perfect outflow and modulating portal inflow will improve a partial graft’s hemodynamics and function. An expert understanding of hepatic anatomy and physiology is essential for success with partial liver transplantation. With advanced surgical techniques and experience, living donor liver transplantation has become widespread (Fig. 5).

ADVANTAGES OF LIVE DONORS

Organs from living donors offer many potential advantages over organs from brain-dead donors. The most important advantages of live donation are that it optimizes the timing of transplantation and frees patients from the waiting list. These factors have become especially helpful for patients who are disadvantaged by the cadaver organ allocation scheme, including patients with tumors, cholestatic diseases, or blood type O, as well as those who are retransplantation candidates.

Preservation time is minimal in live donor transplants, so there is significantly less ischemic damage to the liver. Live donors are by definition healthy, and therefore the quality of the donated liver is much better. Brain death results in many adverse pathophysiologic effects that damage the liver. Perhaps most importantly, live donor transplantation increases the global pool of transplantable organs, allowing more people to benefit from this potentially life-saving therapy.

DISADVANTAGES OF LIVE DONORS

There are, however, a number of disadvantages to live donor transplantation which must be considered carefully. The donor, a perfectly healthy volunteer, faces unequivocal risks of morbidity and even mortality which put the procedure at odds with the very basic tenets of medicine and the oath that all physicians pledge to keep: \textit{Primum non nocere} – First, cause no harm. The risk of death for donors of a left lateral segment or a left lobe is estimated to be approximately 0.1\%, whereas the risk for donors of a right lobe is estimated to be approximately 0.4 to 0.5\%.\textsuperscript{25} Exact
risks have been difficult to quantify because no formal international registry exists to follow these donors. Liver surgery is a significant undertaking, even in the best of hands. The morbidity of these procedures is significant and directly correlates with the extent of the resection.\textsuperscript{26–30} Thus, in terms of both morbidity and mortality, right lobectomy is riskier than left lobectomy. To the authors’ knowledge, there have been 12 deaths of right-lobe donors and three deaths of left-lobe donors worldwide. Additionally, two donors have required liver transplantation themselves as the result of operative complications. Live donor liver transplantation also carries certain increased risks for the recipients. It is technically more complex than whole-organ cadaveric transplantation. The incidence of biliary complications increases with partial grafts. In addition, the small-for-size syndrome is essentially seen only with partial grafts, when the recipient does not receive enough functional liver mass (see below).

There are also many unanswered questions with regard to the impact of liver regeneration on recipient risk. It has been speculated that the regenerating liver may be fertile ground for viral replication (particularly hepatitis C) or tumor growth and therefore lead to earlier, and perhaps more aggressive, recurrence after transplantation. Reports so far are conflicting.\textsuperscript{31–33} More investigation is needed to determine the validity of these concerns.

Finally, live donor liver transplant procedures are considerably more labor-intensive efforts than are cadaveric transplants. Two highly experienced teams of surgeons are necessary, one to perform the donor procedure and the other to perform the recipient procedure concurrently. In the bigger picture of health-care issues, these are also considerably more expensive procedures.

**INDICATIONS**

Potential candidates for living donor liver transplants generally meet at least the minimal listing criteria of the United Network for Organ Sharing. Exceptions have been made, however, for a small number of tumor patients with malignancy characteristics (e.g., size, lobar distribution, and number) that have historically hindered prioritization for cadaveric transplantation and are even considered contraindications to transplantation in a system in which organs are rationed. Whether these patients should be able to receive living donor transplants is somewhat controversial, because some might later be placed on the cadaveric waiting list due to hepatic artery thrombosis, chronic rejection, etc. Although there may truly be no biologic difference between a 4.9-cm tumor (within the criteria) and one that is 5.1 cm (outside the criteria), there are patients with considerably bigger tumors who present with potential donors. This type of issue raises important and difficult ethical questions.

The indications for live donor liver transplantation are continually being expanded. Although the use of living donors for pediatric patients with fulminant hepatic failure has generally been accepted, most programs have been reluctant to use live donors for adult patients with acute hepatic failure. There are some unique ethical considerations when a potential live donor is faced with the decision to donate to a patient with acute hepatic failure. In particular, the decision must be made relatively quickly—within days, rather than weeks. Donation under these circumstances has been widely considered to be acceptable for dying children, because small cadaver organs are less likely to become available, and left lateral segmentectomy has considerably lower morbidity and mortality for the donor than does lobectomy. In Japan, where few cadaveric organs are available, live donors are often the only option for adult patients as well. As a result, the Japanese have aggressively pursued live donation for all indications in both pediatric and adult patients. Clearly, if a cadaver organ is available, it should be used preferentially, and all efforts should be made to split appropriate cadaver organs. Split-liver transplantation remains underused and is an excellent means of increasing the number of available cadaveric organs.\textsuperscript{34,35}

There are several critical issues that ultimately determine the success of live donor liver transplantation; these include recipient selection, donor selection and safety, and size matching between the potential donor and recipient.

**DONOR SELECTION**

Potential donors must be healthy volunteers between the ages of 18 and 55 yr. Donors should have normal liver function and no medical comorbidities. Liver biopsy, although not mandatory, is recommended to ensure that there is no occult hepatic pathology and to establish the degree of steatosis.\textsuperscript{36} The donor’s absolute age is less important than physiologic age. Older donors, however, do have an increased risk of occult medical problems. There is also the concern that livers from older donors will have diminished regenerative capacity, which can affect both recipient and donor outcomes.

Donor safety is paramount. There can be no exceptions to this rule, regardless of the consequences for the recipient, even death. A separately designated donor team should evaluate each potential donor medically, surgically, emotionally, psychologically, and financially.\textsuperscript{37} Donors must be fully informed, and there cannot be any element of coercion. Potential donors should be informed from the outset that they can back out at any time, right up to the time they undergo anesthesia. They should be formally offered a “medical out”—that is, a medical excuse so that the recipient may back out with dignity and without repercussions . . . and without family members realizing the donor has decided to back out. It is important, however, not to fabricate any medical condition that might become a part of the donor’s medical records. In addition, there should be a formal and deliberate “time out” period between the completion of the donor’s evaluation and the actual surgery, so the donor can reflect upon his or her decision and not get caught up in the urgency to get the recipient transplanted.

Initially, only relatives were allowed to be donors. More recently, donors have included friends, colleagues, and even people completely unknown to the recipient. It is preferable that donors be at least emotionally related to the recipient, although occasionally
there are truly altruistic, Good Samaritan donors. These individuals should undergo intense psychiatric evaluations to ensure that there are no underlying issues of secondary gain. Donors must be able to comprehend the risks of liver resection and should understand the possible benefits and outcomes for their intended recipient. This includes understanding of the etiology of their recipient’s liver disease and the expected outcome with transplantation for that specific indication. There can be considerable disparity in expected outcome for patients with different disease processes. Many liver diseases that lead to transplantation are often recurrent (e.g., hepatitis B, hepatitis C, and hepatocellular carcinoma), and donors must be informed of these risks for their intended recipients so they can be truly informed with regard to their own decision whether to donate.

Active smokers should not be considered for donation. Truly committed potential donors will agree to stop smoking, often with medical assistance, to decrease their own increased perioperative risks. For females, oral contraception should be temporarily stopped perioperatively as well. Alcohol intake should be minimal. A body mass index greater than 30 should probably be considered at least a relative contraindication to donation.

Donors derive a significant amount of satisfaction from donation, despite the hardship of undergoing a major abdominal operation. Donors have a significant sense of well-being. The act of donation is truly altruistic and is the opportunity to save someone else’s life, as well as to be of benefit to society by increasing the donor pool.

DONOR EVALUATION

At a minimum, the potential donor should be evaluated by a multidisciplinary team that includes a hepatologist, surgeon, and social worker. Additional consultations, including psychiatry, should be considered on an individual basis as needed. An assessment must be made to ensure that there are no elements of coercion. Complete laboratory evaluation, including blood-type testing, serologies, and liver function tests, should be performed. In general, donors must have a compatible, but not necessarily identical, blood type with their intended recipient. Screening for subclinical coagulation disorders is also important, regardless of cost-effectiveness. Most potential donors never actually donate, and this evaluation will likely be the most thorough of their life. Potential donors should only proceed with more invasive testing as the likelihood of donation increases.

Imaging studies should be performed only after the basic evaluation has been completed. These are used mostly as a “road map” for surgical planning, not for screening. In early experiences with living donor liver transplants, all donors were subjected to invasive testing, including angiography and endoscopic retrograde cholangiography. These invasive procedures, however, were associated with a certain amount of risk. Today, we generally employ advanced noninvasive methods – in particular, magnetic resonance imaging and/or computed tomography – which can accomplish the same results as the invasive tests, with excellent accuracy and almost no morbidity. Computed tomography angiography is better for detailed evaluation of the segmental hepatic arteries, whereas contrast-enhanced magnetic resonance imaging cholangiography is better for depicting the biliary tree.

In addition to these imaging studies, software approved by the U.S. Food and Drug Administration is now available which allows three-dimensional reconstructions and modeling for planning liver surgery (MeVis LiverAnalyzer and LiverViewer, Bremen, Germany). Using this technology, the surgeon is able to visualize virtual resections splitting the liver and can define vascular territories supplied or drained by the hepatic venous, portal venous, and hepatic arterial branches (Fig. 6).
This state-of-the-art technology is reliable for both surgical planning and calculating graft and remnant volumes.\textsuperscript{48} As discussed above, liver biopsy is recommended but not mandatory. Biopsy is mandatory in potential donors with a history of significant alcohol use, imaging study findings suggestive of steatosis, history of hyperlipidemia, or physical appearance suggestive of obesity.

It is best that the team evaluating the donor not be primarily involved in evaluating the recipient also, so as to avoid any unnecessary bias. The risks and benefits of the planned procedure should be reiterated a number of times and on separate occasions.

**RECIPIENT EVALUATION**

Recipients for live donor liver transplantation are evaluated in a fashion similar to that for whole-organ, deceased donor transplantation. Particular attention needs to be paid to the degree of underlying portal hypertension. A thorough evaluation of recipient hemodynamics should be done. The presence of varices and/or shunts can be important indications of the presence of portal hypertension. Portal vein thrombosis, although not an absolute contraindication to partial graft transplantation, must also be carefully evaluated.\textsuperscript{49} Portal overflow of the partial graft, even with seemingly adequate graft volume, can have significant consequences for recipients. Size matching between the potential donor and the intended recipient is an essential component of the evaluation (see below). The surgical approach to the recipient of a partial graft must be well thought out in advance.

**PLANNING THE OPERATION**

Once an appropriately evaluated donor has been identified, attention is directed to the results of the imaging studies for surgical planning. Graft selection (i.e., the extent of resection) is guided almost solely by anatomic constraints based on the segmental anatomy of the liver. In general, the common grafts that can be used from a living donor for transplantation include the left lateral segment, the left lobe (with or without the caudate lobe), and the right lobe (Fig. 7). For most people, the left lateral segment comprises 20\% of their total liver volume, the left lobe 40\%, and the right lobe 60\%. There can, though, be considerable individual variation. In some rare instances, right lateral sector (segments VI and VII), extended right-lobe (segments IV-VIII), and extended left-lobe (segments II-V, and VIII ± I) grafts have been used for transplantation.\textsuperscript{50} Very rarely, monosegment grafts have been used.\textsuperscript{51,52} Interestingly, there is also a large and growing body of experience in Korea using double left-lobe grafts for a single recipient so as to maximize donor safety while increasing recipient actual graft volume.\textsuperscript{53}

In early experiences, graft selection was dictated almost completely by graft size, particularly for adult recipients. Over time, surgeons have realized that the needs of a specific recipient are determined not only by
size and volume calculations but by the physiologic needs of that recipient. More recently, better understanding of portal hemodynamics, pharmacologic and surgical inflow manipulation, and improved imaging studies have allowed the successful use of smaller grafts.

In all cases, the segment(s) to be removed must have dual vascular inflow from a branch of the portal vein and a branch of the hepatic artery, vascular outflow from one or more of the hepatic veins, and biliary drainage.

SIZE MATCHING

The critical issue of size matching is determined by the size of the recipient and the degree of portal hypertension. Recipients with little or no portal hypertension, as is often the case for patients with tumors, require significantly less graft volume than do patients with more significant portal hypertension, massive ascites, and significant varices.

A number of formulas have been developed to estimate the volume of the graft. With these equations, it is possible to calculate the expected graft-to-recipient body weight ratio, which should be at least 0.8%. Alternatively, the graft weight ratio can be calculated by dividing the graft weight by the standard liver volume of the recipient. Graft weight ratio and graft-to-recipient body weight ratio have repeatedly been identified as independent predictors of survival after live donor liver transplantation. In the absence of cirrhosis and portal hypertension, even grafts that are less than 30% of the intended recipient’s standard liver volume can be successfully transplanted. In the presence of severe portal hypertension, however, at least 40 to 45% is usually required.

Planned recipient inflow modification (e.g., shunting and splenic artery ligation) can also influence these decisions by ameliorating venous congestion in relatively small grafts.

The causes of graft failure and success are multifactorial. There is even experimental evidence that donor gender may be an important determinant of outcome in small-for-size recipients. It is essential that the live donor liver surgeon be versatile and have experience with all potential resections so that donor morbidities can be minimized and recipient outcomes maximized. The first successful right-lobe liver transplant ever done occurred when surgeons planning to remove the left lobe encountered anatomy that led to the decision to remove the right lobe instead.

PERIOPERATIVE CONSIDERATIONS

On the morning of the planned surgeries, both the donor and recipient should be evaluated prior to beginning either procedure and logistic plans should be reviewed by the donor and recipient teams in concert. One of the benefits of live donor transplantation is that it is usually at least semi-elective and therefore could be rescheduled if necessary. In certain cases, however, the transplant is performed under emergent circumstances. Care should be taken to ensure that the appropriate perioperative prophylaxis is administered to both donor and recipient, including antibiosis, stress ulcer prophylaxis, and deep venous thrombosis prophylaxis.

DONOR TECHNICAL CONSIDERATIONS

Liver resections are technically demanding procedures, and this is especially true for the live donor hepatectomy. Unlike resections for pathology (e.g., tumors), the portion to be removed must be handled with extreme care. It is imperative to preserve the integrity of the anatomic structures in the donor remnant AND in the removed portion that is to be transplanted. The liver has the most complicated and variable anatomy of any organ. These variations of the arterial, venous, and biliary anatomy have important implications for transplantation. Multiple arteries, double portal veins, and multiple bile ducts have all been successfully used. Vascular anomalies exist in approximately 10% of cases and multiple bile ducts in approximately 60%. Whereas alone each variation is manageable, in combination they may be a relative contraindication, particularly in cases with marginally sized grafts.

The donor operation is a meticulous procedure that usually lasts 4 to 8 hours, less for a left lateral segmentectomy and more for a right lobectomy. A right subcostal incision with midline extension is adequate for all types of resections and spares the donor the morbidity of dividing the rectus muscles bilaterally. Donors should always be informed preoperatively if the gallbladder is to be removed, which is necessary for right or left lobectomy, and then reminded postoperatively. Although the need for cholecystectomy seems intuitive for surgeons, it is not so for donors, who are often quite startled to learn of it if they were not prepared in advance. The use of intermittent inflow occlusion (i.e., Pringle maneuver) has been demonstrated to be beneficial. Donors rarely require banked blood transfusions. Some programs have donors donate their own blood preoperatively for autologous transfusion, but this may be unnecessary with cell saver and hemodilution technologies.

Intense interest has been focused upon graft venous congestion. In right-lobe grafts, for instance, drainage is imperfect unless the middle hepatic vein is included with the graft, a procedure that increases donor risk. The left lobe, on the other hand, is designed extremely well for outflow (i.e., venous drainage) but is limited by its smaller volume. For large middle hepatic venous tributaries (i.e., greater than 5 mm in diameter) from segments V and/or VIII (i.e., anterior segments), reconstruction is recommended to avoid segmental venous congestion. Venous outflow is essential to both function and regeneration. Inadequate outflow results in decreased segmental portal flow and poor segmental regeneration. To add insult to injury, the unrestricted segments become overperfused as a result of reversal of portal flow. The portal venous channels act as venous conduits for the hepatic arterial flow in the restricted segments. Even when grafts grossly appear...
not to be congested, regeneration can be significantly impaired.68

**RECIPIENT TECHNICAL CONSIDERATIONS**

The recipient operation for a partial graft is quite different and technically more demanding than that for standard whole-organ transplantation. Considerable challenges, including biliary, arterial, and venous reconstructions, make these procedures exceptional. The recipient hepatectomy must be conducted in a manner such that the length and integrity of the vessels and biliary tree are preserved. Maintaining implantation options is essential. Reconstructions are often performed with vessels that are much smaller than in standard transplantation. The caliber of the segmental hepatic arteries is considerably smaller than that of the common hepatic artery and, therefore, may require a formal microvascular approach.

Biliary complications, both leaks and strictures, are referred to as the Achilles’ heel of live donor liver transplantation. These remain a major cause of morbidity and mortality.69 Smaller and often multiple bile ducts, all cut flush with the graft parenchyma, make these reconstructions technically challenging. Because of the success with Roux-en-Y hepaticojejunostomies in pediatric left lateral segment transplants, Roux reconstructions have generally been regarded as the standard for adult living donor cases. More recently, however, the native bile duct has been used for bile duct reconstruction in partial liver grafts by preserving the native bile ducts’ supraduodenal blood supply. Syndactylizing multiple ducts (Fig. 8) and stenting small ducts – techniques generally unnecessary in standard whole-organ liver transplantation – are more commonly used in these procedures.

Bile leaks more commonly occur after Roux-en-Y reconstruction, generally present in the early postoperative period, are associated with significant morbidity and mortality, and frequently require operative intervention. Biliary strictures, on the other hand, are more common after duct-to-duct reconstruction, usually occur much later, and are often amenable to nonoperative interventions such as percutaneous transhepatic cholangiography or endoscopic retrograde cholangiopancreatography with dilatation and/or stenting. The reported incidence of biliary complications among recipients of live donor liver transplants is as high as 60%.69 Biliary complications are generally higher when reconstruction of multiple ducts is required.

**IMMUNOSUPPRESSION**

Interestingly, the dosing of immunosuppressants can be significantly different between recipients of living donor and cadaveric grafts. Living donor recipients often require lower doses of tacrolimus than do cadaveric recipients to maintain similar tacrolimus trough concentrations.70 Living donor recipients achieve higher trough concentrations of tacrolimus than do cadaveric recipients at the same dose.71 These findings substantiate the clinical suspicion that immunosuppressants must be dosed differently in living donor recipients. There are many potential explanations for this finding, the most plausible of which is that hepatic clearance and hepatic metabolism may be reduced in partial liver grafts.

**REGENERATION**

Hepatic regeneration – of the graft in the recipient and the remnant in the donor – is central to the success of live donor liver transplantation. The graft and the remnant both regenerate to adequate volumes. Many factors influence this process. Subclinically, at the cellular level, regeneration begins immediately. Whereas the majority of the process is complete within the first week or two, the process of remodeling likely continues up to 1 yr.72-74

**DONOR COMPLICATIONS**

Morbidity rates associated with donation are directly related to the extent of resection.23 Most complications, including wound infections, pleural effusions, alopecia areata, and transient hyperbilirubinemia, are minor. More serious complications requiring reoperation have been reported: bile leaks, bile duct strictures, and...
bleeding. Bleeding and bile leaks most often present in the immediate-postoperative period. Most bile leaks occur from the cut surface of the liver and are easily managed conservatively with drainage. Most biliary strictures are identified late and often require endoscopic and/or surgical interventions. Also reported have been all of the usual culprits that can complicate any major abdominal procedure done with general anesthesia: deep venous thrombosis, pulmonary embolism, urinary tract infection, and pneumonia.

Although the potential for psychological complications is important to consider, a number of quality-of-life studies among live liver donors have documented good psychological outcomes in these individuals. Overall, donors perform well on standardized quality-of-life questionnaires, frequently significantly above the general population. In general, donors have an increased sense of self-esteem; in addition, family bonds are often strengthened by donation. Donors rarely regret their decision to donate. They often report, however, that the return to normalcy took a significant amount of time even when no serious medical complications were experienced. The extent of resection is also an important factor in donor psychological recovery.

Nearly all reports, however, cite financial difficulties related to donation. In addition, recipient outcome may be a strong determinant of donor well-being. Donors whose recipients do well clinically are significantly more likely to do well psychologically themselves. It cannot be stressed enough that live donors are a unique type of patient. The traditional endpoints of medical and surgical therapy (e.g., disease control, cure, and palliation) do not apply to living donors, who were in perfect or nearly perfect health before the surgery. For donors, the benefit of donation is primarily psychological. Were it not for their selflessness, these donors would not be patients and would not be having major abdominal surgery. Their expectations, therefore, are considerably different from those of the typical patient with some form of pathology. This alone underscores the importance of comprehensive preoperative patient education and also of careful postoperative observation for depression or other psychiatric disorders.

There have been many reports of large single-center experiences and their complication rates. In 2002, Beavers et al. conducted an extensive review of the literature published between 1995 and 2001 and identified 12 reports covering more than 400 right-lobe donors. Morbidity rates in these reports ranged from 0 to 67%. Obviously, how “morbidity” is defined influences how centers report their complications and calculate the incidence of morbidities. Although the definition of mortality is relatively straightforward, few teams have reported their donor deaths in a timely or formal fashion. These issues highlight the need for a national/international registry to collect accurate and consistent data so that potential donors can give truly informed consent.

**FOLLOW-UP**

Although there are no standard recommendations for following living donors after hospital discharge, most large centers continue to follow donors on an annual basis for life. Clearly, donors should be seen frequently during the immediate-postoperative discharge period and then with less frequency over the following months and years. Liver function tests should be monitored at least until they normalize. Protocols for postoperative imaging are perhaps even more variable and often depend upon the extent of resection. Donors should probably undergo some form of imaging (computed tomography or magnetic resonance imaging) within the first year of donation. The vast majority of liver regeneration is completed within the first month. Without clinical indications, imaging studies should probably not be performed any earlier than this.

**OUTCOMES**

Live donor liver transplantation offers many advantages over cadaveric transplantation. Live donors have not been adversely affected by the pathophysiologic changes that occur with brain death. Cold ischemia times, in general, are very short with live donor organs, which are procured in the same hospital, often in an adjoining operating room. Perhaps most important, the timing of the transplant procedure can be controlled. This luxury is a particular benefit to patients with tumors and preserved synthetic function who have historically been disadvantaged by allocation algorithms. The waiting time for living donor transplantation is significantly shorter than for cadaver transplant.

The results of live donor transplantation for hepatocellular carcinoma are very encouraging, even for patients with tumors that did not meet the standard criteria for transplantation but were still confined to the liver. There are, however, inherent dangers with the use of live donors for recipients with malignancies. What considerations should be made with respect to recurrence rates and realistic chances for cure when considering a live donor? Does merely having a willing donor justify transplantation for any tumor? Do the same considerations apply for recurring diseases such as hepatitis C? Should they?

For pediatric recipients of live donor grafts, the results have been excellent. Data from the U.S. Scientific Registry of Transplant Recipients show that the results for small children (<2 yr old) with living donor grafts exceed the results with cadaver grafts. For recipients of all ages, 1-, 3- and 5-yr patient and graft survival rates for recipients of live donor liver grafts compare very favorably with those for recipients of cadaveric grafts (Fig. 9). Overall, the many large series and reviews of pediatric and adult recipients of live donor grafts report favorable results, often better than those observed with cadaveric organs.
mum. Transplant physicians, particularly surgeons, must take responsibility for regulating and overseeing these procedures. All efforts should be made to improve cadaveric donation and to make the best use of this precious and, unfortunately, limited resource.

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