ORIGINAL ARTICLE

Incidence of Death and Potentially Life-Threatening Near-Miss Events in Living Donor Hepatic Lobectomy: A World-Wide Survey

Yee Lee Cheah, Mary Ann Simpson, James J. Pomposelli, and Elizabeth A. Pomfret
Department of Transplantation and Hepatobiliary Diseases, Lahey Clinic Medical Center, Tufts Medical School, Burlington, MA

The incidence of morbidity and mortality after living donor liver transplantation (LDLT) is not well understood because reporting is not standardized and relies on single-center reports. Aborted hepatectomies (AHs) and potentially life-threatening near-miss events (during which a donor's life may be in danger but after which there are no long-term sequelae) are rarely reported. We conducted a worldwide survey of programs performing LDLT to determine the incidence of these events. A survey instrument was sent to 148 programs performing LDLT. The programs were asked to provide donor demographics, case volumes, and information about graft types, operative morbidity and mortality, near-miss events, and AHs. Seventy-one programs (48%), which performed donor hepatectomy 11,553 times and represented 21 countries, completed the survey. The average donor morbidity rate was 24%, with 5 donors (0.04%) requiring transplantation. The donor mortality rate was 0.2% (23/11,553), with the majority of deaths occurring within 60 days, and all but 4 deaths were related to the donation surgery. The incidences of near-miss events and AH were 1.1% and 1.2%, respectively. Program experience did not affect the incidence of donor morbidity or mortality, but near-miss events and AH were more likely in low-volume programs ($\leq$50 LDLT procedures). In conclusion, it appears that independently of program experience, there is a consistent donor mortality rate of 0.2% associated with LDLT donor procedures, yet increased experience is associated with lower rates of AH and near-miss events. Potentially life-threatening near-miss events and AH are underappreciated complications that must be discussed as part of the informed consent process with any potential living liver donor. ***Liver Transpl 19:499–506, 2013***. © **2012 AASLD.**

Received June 13, 2012; accepted October 29, 2012.

See Editorial on Page 467

Living donor liver transplantation (LDLT) is an accepted treatment for individuals with end-stage liver disease. The results are equivalent or superior to those achieved with deceased donor liver transplantation.[1-4] In areas in which deceased donor organs are in short supply or culturally unacceptable, LDLT assumes greater importance as the only effective treatment for liver failure. The obvious benefits for the recipient and the probability of death without a transplant may produce a coercive atmosphere. Donors may face familial or societal pressure to provide a lifesaving organ, and it is against this background that transplant professionals must provide potential donors with the information necessary for them to make an informed decision regarding donation.

Providing potential liver donors accurate and timely information regarding the risks associated with hepatic lobe donation is hampered by the lack of standardized reporting systems and the emphasis on patient/donor death and graft loss as the ultimate benchmarks of successful LDLT. Reports of adverse events in donors vary widely in terms of which events are considered serious enough to be reported and in the incidence of those that are reported.[5-7] Potentially life-threatening events such as donor aborted hepatectomy (AH) or intraoperative hemorrhage are rarely reported if they are successfully managed. These

Additional Supporting Information may be found in the online version of this article.

Abbreviations: AH, aborted hepatectomy; LDLT, living donor liver transplantation.

Address reprint requests to Elizabeth A. Pomfret, M.D., Ph.D., F.A.C.S., Department of Transplantation and Hepatobiliary Diseases, Lahey Clinic Medical Center, 41 Mall Road, 4 West, Burlington MA 01805. E-mail: elizabeth.a.pomfret@lahey.org

DOI 10.1002/lt.23575
View this article online at wileyonlinelibrary.com.
LIVER TRANSPLANTATION.DOI 10.1002/lt. *Published on behalf of the American Association for the Study of Liver Diseases*

near-miss events constitute a real risk to LDLT donors, but we currently are unable to provide them with a realistic estimate of their occurrence.

We undertook a Web-based, worldwide survey of liver transplant programs with the aim of improving our knowledge of the actual incidence of events that increase risk for hepatic lobe donors. Participants were asked to report the percentage of specific events occurring in their programs and to rate their severity according to the validated Clavien scale.[8] For near-miss and Clavien grade III-V events, details of the incidents were requested. There are obvious shortcomings associated with self-reported data. However, we believe that this report constitutes the most comprehensive assessment of living liver donor risks currently available and will provide potential living liver donors and the transplant teams advising them with more accurate information as they consider the decision to donate.

MATERIALS AND METHODS

Program Participants

Surveys were sent to all liver transplant programs known to have performed LDLT at least once. Program lists were obtained from the published literature, the American Society of Transplant Surgeons, the Japanese Liver Transplant Society, the European Liver Transplant Registry, and the China Liver Transplant Registry. Additional programs were included if they were known by us to be performing LDLT. Respondents were assured that the results would be reported in a blinded fashion. After initial blast e-mail requests for participation, follow-up e-mails (n = 4), phone calls, and personal interactions were used to increase survey completion.

Survey Instrument

SurveyMonkey, a commercially available Web-based tool, provided the format for our internally created survey. The length of the survey was respondent-driven. At the end of sections describing critical events, participants were asked if they had additional relevant cases. An affirmative answer generated an additional report form, whereas a negative response moved the respondent to the next section.

Participants were asked to provide program demographics, donor evaluation information, donor morbidity and mortality data, and the incidence of near-miss events and donor AH. Near-miss events were defined in the e-mail containing the link to the survey as follows:

> We are particularly interested in the occurrences of "near miss" events. For the purpose of this survey, we are defining "near miss" as an event or events with potentially fatal consequences. Severe bradycardia or displacement of an arterial clip are examples of such events. We would like you to report this type of event even though the situation was successfully managed and the donor suffered no lasting ill effects.

To help to standardize the morbidity data, respondents were asked to use the Clavien system, which was modified for living donors (Table 1) and was provided with the survey, for all events reported.[8] We reviewed the reported events and designated as near-miss events those that were nonfatal but had a significant risk of death.

Statistical Analysis

Statistical analysis was performed with SPSS for Windows (PAWS Statistics 18). The overall variance within groups was assessed with an analysis of variance. Categorical variables were assessed with the chi-square test or Fisher's exact test where applicable. Means between groups were compared with the Student t test. A P value < 0.05 was considered significant.

Appropriate institutional approval was obtained before the start of the study.

RESULTS

Survey Completion and Geographic Distribution

Survey completion was defined by American Survey Research Organization standards, according to which >80% of items must be completed. Surveys were sent to 148 programs and were completed by 71 (48%); 64 currently perform LDLT. The respondents represented 21 countries, and the programs were distributed as follows: 39 in North America, 13 in Asia, 13 in Europe, 4 in South America, 1 in the Middle East, and 1 in New Zealand. Most of the current programs perform both adult-to-adult and adult-to-pediatric LDLT procedures (n = 54), although 5 centers perform only adult procedures, and 5 centers perform only pediatric procedures.

Center Volume and Graft Type

The experience of the centers varied widely and ranged from 2 to 2785 LDLT procedures. For analytical purposes, the programs were categorized as (1) low-volume (≤50 LDLT procedures), (2) moderate-volume (51-200 LDLT procedures), or (3) high-volume (>200 LDLT procedures). Group 3 included 6 centers that performed more than 500 LDLT procedures and 2 centers that performed more than 1000 LDLT procedures.

The centers varied greatly in the length of time that they had performed various types of liver transplantation. The start dates for any type of liver transplantation ranged from 1983 to 2007; the start dates for centers performing pediatric LDLT ranged from 1990 to 2007. The earliest centers performing adult-to-adult LDLT began in 1997, and the most recent began in 2007.

Right hepatic lobes were the most common graft type, with 95.6% reporting their use in some or all procedures. More than 50% of reporting programs had performed >60 right lobe procedures. The use of left hepatic lobe or left lateral segment graft types was

TABLE 1. Clavien Surgical Morbidity Scale Modified for Living Donors

Grade I. Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions. The allowed therapeutic regimens are drugs such as antiemetics, antipyretics, analgesics, and diuretics; electrolytes; and physiotherapy. This grade also includes wound infections opened at the bedside.
Grade II. Requiring pharmacological treatment with drugs other than those allowed for grade I complications. Blood transfusions and total parenteral nutrition are also included.
Grade III. Requiring surgical, endoscopic, or radiological intervention.
IIIa. Intervention not under general anesthesia.
IIIb. Intervention under general anesthesia.
Grade IV. Life-threatening complication (including central nervous system complications such as brain hemorrhaging, ischemic stroke, and subarachnoid bleeding but excluding transient ischemic attacks) requiring intermediate care/intensive care unit management.
IVa. Single-organ dysfunction (including dialysis).
IVb. Multiorgan dysfunction.
Grade V. Death of the patient.

NOTE: Please refer to the Clavien system for the grading of surgical complications (modified for living donation) to answer questions about the severity of donor complications. If your program is required by institutional policy or state/national law to provide all living donors with a period of intensive care unit observation, please do not upgrade complications that otherwise would be considered grades I, II, and III solely on the basis of the intensive care unit location at the time of occurrence. This table has been adapted with permission from *Transplantation*.[8] Copyright 2006, Transplantation Society.

reported by 77% of respondents. Thirty-eight adult programs (53.5%) reported the use of left lobes in appropriate recipients. Extended right hepatectomy or right trisegmentectomy grafts with the inclusion of the middle hepatic were relatively infrequent (8 programs or 11.3%).

Donor Mortality

The survey revealed 23 donor deaths among 11,553 donor hepatectomy procedures (0.2%); 18 were reported directly by centers, and 5 additional reports were received from the European Liver Transplant Registry (Table 2). Single deaths were reported by 8 centers, 2 centers reported 2 deaths each, and 2 centers reported 3 deaths each. These deaths spanned the entire spectrum of donor follow-up and included 4 deaths unlikely to be related to the donation surgery (2 deaths from lung cancer at 22 months and 3.4 years, 1 from asthma at 5 years, and 1 from myocardial infarction at 6 years). With these deaths excluded, the mortality incidence was 0.16%. The relationship of 2 additional donor deaths to donation was questionable (suicides at 4 and 5 years after donation). The majority of the deaths (15/23) occurred within 60 days of donation and ranged from an intraoperative death to suicide at 60 days. Two donors died when liver transplants performed to rescue them from acute hepatic insufficiency failed. There was no association between the type of donor hepatectomy (right versus left versus left lateral segment) and the incidence of death (P = not significant for all groups). Calculations performed without the deaths unlikely to be related to donation (3 right lobes and 1 left lobe) also failed to show significance between groups. Another 11 donor deaths not captured in the survey have been reported in the literature. They are listed in Table 2.

Donor AH

AH was defined as any procedure that was stopped after the donor entered the preoperative holding area. One hundred thirty-six AHs (1.2%) were reported by 44 of the responding programs (62%). The majority occurred after the incision but before the bile duct transection (n = 98 or 72%). Aborted cases were also reported after the hepatic transection (n = 12), in the preoperative holding area (n = 12), and after anesthesia but before the incision (n = 8). After AH, 45% (n = 61) eventually donated, whereas 55% (n = 75) did not. Procedure-related complications were experienced by 13% of the patients after AH, with incisional hernias and wound infections occurring most frequently.

The reasons for most AHs were donor-related (n = 106 or 77.9%), but 30 (22.1%) were related to recipient events (Table 3). The most common donor-related reasons were unexpected vascular or biliary anatomies and unexpected pathologies. The most common recipient-related reasons were hemodynamic instability and recipient malignancies more advanced than expected.

Near-Miss Events

Survey results indicated that 126 near-miss events occurred in 125 patients, so the incidence was 1.1% (Table 4). Hemorrhaging requiring surgical intervention was cited most frequently, and this was followed by thrombotic events, biliary reconstruction procedures, life-threatening sepsis, and iatrogenic injury to the bowel or vasculature. Six instances of transient hepatic insufficiency were reported.

Donor Morbidity

The overall reported donor morbidity rate was 23.9% ± 13.9%, with most events (85.8%) occurring within the first 30 postoperative days. The most common complications were bile leaks, wound infections, incisional hernias, and unplanned surgical re-exploration. The majority were mild and self-limited (Clavien

TABLE 2. Causes of Death

Causes	Location	Lobe	Timing	Study*
	Deaths Captured in Survey			
Intraoperative				
Bleeding/cardiac failure/cardiac arrest	North America	Right	0 days	
Early postoperative (≤60 days)				
Anaphylaxis†	North America	Left lateral segment	1 day	Pomfret et al.[9]
Pulmonary embolism‡	Europe	Left lateral segment	2 days	Malagó et al.[10]
Gastric necrosis (*Clostridium perfringens)*	North America	Right	3 days	Miller et al.[11]
Cardiac arrest	North America	Right	4 days	
Myocardial infarction	Asia	Right	10 days	Polido et al.[12]
Sepsis/multiorgan failure‡	Europe	Right	11 days	Boillot et al.[13] and Adam et al.[14]
Sepsis/multiorgan failure‡	Europe	Right	21 days	Adam et al.[14]
Fall at home	Asia	Right	28 days	
Cardiac failure/liver transplantation‡	Europe	Right	32 days	Adam et al.[14] and Ringe et al.[15]
Subarachnoid hemorrhage	Asia	Right	42 days	
Multiorgan failure‡	Europe	Right	49 days	Adam et al.[16]
Complications of multiple myeloma	Europe	Right	56 days	Melloul et al.[17]
Bile peritonitis/sepsis/multiorgan failure	Middle East	Right	60 days	Khalaf et al.[18]
Suicide	North America	Left	60 days	
Late postoperative (>60 days)				
Duodenal–inferior vena cava fistula (ulcer)/air embolism	Asia	Right	2.3 months	Chan et al.[19]
Nonalcoholic steatohepatitis/liver failure/liver transplantation	Asia	Right	9 months	Akabayashi et al.[20]
Lung cancer	Asia	Right	22 months	
Lung cancer	Asia	Right	3.4 years	
Suicide	South America	Right	4 years	
Suicide	South America	Left lateral segment	5 years	
Asthma	Asia	Right	5 years	
Myocardial infarction	Asia	Left	6 years	
	Previously Reported Deaths Not Captured in Survey			
	Location	Lobe	Timing	Study*
Causes Early postoperative (<60 days)				
Cardiac arrest/persistent vegetative state	Asia	Right	2 days	Srinivas[21]
Cardiac arrhythmia	South America	Right	2 days	Coelho et al.[22]
Massive bleeding	Europe	Right	4 days	Broering et al.[23]
Subarachnoid hemorrhage	South America	Right	7 days	Wiederkehr et al.[24]
Unknown	Asia	Unknown	10 days	Soin[25]
Bile leak/sepsis/multiorgan failure	North America	Right	3 weeks	Zagier et al.[26] and Ochs et al.[27]
Berardinelli-Seip/liver transplantation/cardiac failure	Europe	Right	32 days	Malagó et al.[28]
Pulmonary embolism	North America	Left	Unknown	Renz and Busuttil[29]
Late postoperative (>60 days)				
Suicide	North America	Right	22 months	Trotter et al.[30]
Suicide	North America	Right	23 months	Trotter et al.[30]
Acute Budd-Chiari syndrome	Europe	Unknown	Unknown	Trotter et al.[31]

*Studies are cited if they were previously reported.
†James Eason, M.D., University of Texas Health Science Center, oral communication, August 19, 2010.
‡Adam Rene, M.D., European Liver Transplant Registry, written communication, April 25, 2010.

TABLE 3. Reasons for Donor AH

Donor Reasons	Centers (n)	Cases (n)
Vascular anatomy	14	22
Biliary anatomy	10	20
Vascular and biliary anatomy	2	2
Hepatic steatosis	10	14
Intraoperative pathology	11	20
Hemodynamic instability	7	10
Pre-anesthesia event	3	4
Airway issue	3	3
Tumor	2	2
Intraoperative liver injury	2	2
Small graft or remnant volume	3	3
Other*	4	4
Recipient Reasons	**Centers (n)**	**Cases (n)**
Malignancy	9	10
Hemodynamic instability	7	10
Death	4	4
AH	1	3
Other†	3	3

*Includes anaphylaxis (1), donor withdrawal (1), a urethral stricture requiring a suprapubic tube (1), and right hepatic artery dissection (1).
†Includes tuberculosis (1), gangrenous bowel (1), and disseminated intravascular coagulation (1).

TABLE 4. Near-Miss Events

Near-Miss Events	Centers (n)	Events (n)
Reoperation for bleeding	20	39
Biliary reconstruction	11	17
Thrombotic events		
Portal vein thrombosis	10	10*
Inferior vena cava/hepatic vein thrombosis	4	5
Pulmonary embolism†	7	9
Reoperation for intra-abdominal sepsis	6	7
Transient liver insufficiency	5	6
Transient hemodynamic instability	1	1
Vascular reconstruction for injury	4	4
Reoperation for bowel injury	3	3
Myocardial infarction	3	3
Transplantation		
Liver	2	2
Kidney	1	1
Massive intraoperative bleeding‡	5	5
Anaphylaxis/systemic inflammatory response syndrome	2	2
Respiratory failure requiring mechanical ventilation	3	3
Reoperation for diaphragmatic hernia	2	2
Parietal transient ischemic attack with motor weakness and foot drop	1	1
Gastric volvulus§	2	2
Cardiac arrest	1	1
Endocarditis	1	1
Reoperation for perforated gastric ulcer	1	1

*One patient had both clamp failure and portal vein thrombosis.
†One case was attributed to a factor V Leiden mutation.
‡All cases were secondary to clamp failure.
§Both cases occurred after left lobe donation.

grade I or II). However, 5 donors required transplantation after donation: 4 required livers, and 1 required a kidney (0.03% and 0.009%, respectively).

Among the donors requiring liver transplantation, 2 cases were secondary to hepatic failure related to hepatic vein thrombosis. Notably, 1 of these cases was heterozygous for factor V Leiden. The other 2 liver recipients died despite transplantation. The kidney recipient developed contrast nephropathy after angiography.

Influence of Program Volume on Donor Outcomes

Table 5 shows the influence of program volume on donor outcomes. The overall morbidity rate and the incidence of Clavien grade III-V complications did not appear to be related to the center volume. Similarly, the incidence of donor death and the need for transplantation were not related to the center volume. However, the incidence of near-miss events was significantly increased at low- and moderate-volume centers in comparison with high-volume centers. The incidence of AH was related to the center volume and was significantly higher in group 1 versus both groups 2 and 3 and in group 2 versus group 3.

DISCUSSION

Although LDLT is a lifesaving procedure for the recipient, it carries a significant risk of morbidity and mortality for the otherwise healthy donor. We conducted the survey to obtain comprehensive data concerning the incidence and outcomes of adverse events following hepatic lobe donation. We particularly wished to evaluate the prevalence of near-miss events and AHs, which are events rarely captured in standard reports. This information may then be used to provide potential donors with realistic estimates of the risks associated with being a living liver donor. It may also be used to identify areas of practice in need of refinement.

In order to encourage complete disclosure, the respondents were assured that the results would be de-identified and reported only in aggregate and that no individual or center would be identified. Self-reported data have obvious drawbacks such as selective reporting of poor outcomes and open interpretation of what constitutes a reportable event.

TABLE 5. Influence of Program Volume on Donor Outcomes

	Incidence (%)*			*P* Value†		
	Group 1	Group 2	Group 3	Group 1 Versus Group 2	Group 1 Versus Group 3	Group 2 Versus Group 3
Near-miss events	2.9 ± 15.7	1.8 ± 6.5	0.5 ± 0.3	0.11	<0.001	<0.001
Overall morbidity	23.2 ± 15.4	24.1 ± 12.2	25.0 ± 15.3	0.81	0.74	0.85
Clavien grades III-V	8.1 ± 11.8	8.3 ± 9.4	10.7 ± 12.1	0.95	0.54	0.51
AH	3.8 ± 23.1	1.5 ± 0.9	0.7 ± 0.8	<0.001	<0.001	<0.001
Transplantation (liver)	0.15 ± 0.2	0.03 ± 0.03	0.02 ± 0.1	0.59	0.73	0.61
Death	0	0.2 ± 0.03	0.1 ± 0.9	0.52	0.78	0.40

NOTE: Programs in group 1 performed ≤50 LDLT procedures, programs in group 2 performed 51-200 LDLT procedures, and programs in group 3 performed >200 LDLT procedures.
*The data are presented as means and standard deviations.

Nevertheless, we believe that this report contains a representative snapshot of LDLT and its attendant complications as it currently exists. The results represent 64 currently active LDLT centers on 5 continents. Approximately 65% have performed more than 50 procedures, and 12 have performed more than 200 LDLT procedures; the latter group includes 1 center that reported its experience with 2785 completed donor hepatectomies.

The overall response rate was relatively low at 48%, but the nature of the nonrespondents is important. The rate was calculated with the initial mailing list, which included all centers known to ever have performed LDLT rather than those currently performing the procedure. For example, the United Network for Organ Sharing Web site indicates that 23 of the nonresponding US programs performed <5 LDLT procedures in the previous 5 years. Similar data are not available for non-US programs, but it is likely that inactive programs in other locations did not respond. The active centers that did respond represent significant experience in the field, as evidenced by published literature and activity in professional societies. We, therefore, believe that our sample represents currently active and reasonably experienced LDLT centers.

The mortality rate observed in this survey was consistent with the rates previously reported.[11,17,20,22,24,31,32] This survey documented 23 deaths in 11,553 procedures for an incidence of 0.2%. This calculation was based on all reported deaths, including some temporally remote from the donor surgery and probably unrelated. However, because this cannot be established with certainty, our data do not support altering current descriptions of the risk of donor death.

We did not find a correlation between center experience and the incidence of donor death. This is similar to reports from the Adult-to-Adult Living Donor Liver Transplantation Cohort Study consortium[6] but is at odds with reports based on general surgical data suggesting a relationship between hospital/surgeon volume and patient outcomes.[33,34] However, the living donor population cannot be directly compared to general surgical patients. They are healthy and are undergoing an elective procedure rather than one for cause. There also exist national mandates that require only experienced hepatobiliary surgeons to perform living donor hepatectomy. The reported deaths occurred in all geographic areas and in both moderate- and high-volume programs. Low-volume programs did not report any donor deaths. One possible explanation is that most deaths in this relatively ideal patient population are truly random and that a critical number of cases must be performed before the random event is encountered.

In contrast, the incidence of donor AH did show an association with center experience (Table 4). Prospective donors faced a 1.16% overall risk of experiencing AH. However, donors at high-volume centers experienced significantly fewer AHs (0.7%) than donors at low-volume (3.84%) and moderate-volume centers (1.54%). An analysis of the reasons stated for discontinuing the procedure reveals that many were potentially preventable with more rigorous donor and recipient evaluation protocols. For example, 44 cases were discontinued when the vascular or biliary anatomy was deemed unsafe after the procedure was under way; another 34 cases were stopped when an unexpected hepatic pathology was encountered intraoperatively.

State-of-the-art imaging techniques should be used to visualize vascular and biliary structures before surgery, and a close working relationship with radiologists skilled in these techniques is an important part of ensuring overall donor safety.[28,35] In our opinion, the use of these techniques has the potential to greatly reduce the occurrence of significant abnormalities discovered at the time of surgery and, therefore, to reduce the risks associated with unnecessary surgery and anesthesia. An unexpected hepatic pathology is rarely found in programs that routinely include liver biopsy as part of the predonation evaluation, but this may not be necessary in all donors. Algorithms for

selecting evaluation liver biopsy for patients deemed to be at increased risk exist,[36,37] and they have reduced or eliminated pathology-related AHs in programs in which they are used routinely.

The aforementioned incidents are most likely distinct from AHs that occur because donors, despite passing rigorous cardiac evaluations, develop HD instability after the induction of anesthesia or donors with no known drug allergies develop anaphylactic reactions after antibiotic administration. The former are more likely associated with programmatic learning curves, whereas the latter are probably random events that cannot be ascribed to a particular cause.

The other category of AH reported was the result of issues arising with the recipient (n = 30) after the initiation of donor surgery. Twelve of the reported cases aborted for recipient reasons were associated with recipient malignancies (n = 10) or infections (n = 2). Some centers routinely explore high-risk recipients before the initiation of donor surgery to ensure the absence of extrahepatic malignancies. This seems to be a reasonable strategy for avoiding the subjection of a healthy donor to unnecessary anesthesia and surgery.

We were especially interested in obtaining data concerning the occurrence of near-miss events, that is, those with the potential for catastrophic outcomes. This type of event is not necessarily captured in complication data but is frequently discussed informally at transplant meetings. For example, a vascular clip displaced during surgery, if it is seen and quickly replaced, is unlikely to be counted as a donor complication. This is in contrast to the same type of event when it is unnoticed and results in a blood loss requiring transfusions. However, the events and the risks associated with them are potentially equivalent.

In this study, 126 near-miss events were reported (approximately 1 in every 92 procedures). There were no differences associated with geographic regions. This rate is likely an underestimation representing those most memorable to the reporting individuals, but this report does represent the first comprehensive report of actual risks faced by donors across various health care systems and practice models. The actual reported events are those commonly reported after liver resection, such as bleeding, biliary injury, and thrombotic events. High-volume centers reported larger numbers of near-miss events, but when they were indexed to the number of LDLT procedures, the rates at high-volume centers were significantly lower than those at either low- or moderate-volume centers. This suggests that a prolonged learning curve, significantly greater than the previously reported 20 LDLT cases,[3] is needed to maximize donor safety.

The LDLT volume did not affect the reported incidence of Clavien grade III-V complications. This is consistent with some published reports,[3,38,39] although the complication rate reported here was slightly lower. Respondents were asked for estimates of the incidence of Clavien grade III-V complications instead of the detailed descriptions for deaths or AHs. This type of data is retrospective and subject to variations imposed by each center's definition and classification of surgical complications and explains in part the lower reported rates observed in this study versus contemporaneous reports.[3,40]

This survey has generated reliable data on near-miss events, AHs, complications, and deaths in living liver donors that can be used to better inform prospective donors. It appears that program experience can significantly reduce the incidence of donor AH and near-miss events, but donor deaths occur randomly with a consistent rate of 0.2%. The living liver donor community must develop a universally accessible reporting system that will allow a critical analysis of all events so that donor safety can be maximized. For example, risks such as the increased incidence of thrombotic events in donors with factor V Leiden have been identified by several groups and are reported in this survey, but testing for the defect is not a routine part of all donor evaluations. It is our opinion that this testing increases the margin of donor safety, but LDLT would benefit from studies designed to validate the clinical utility and cost-effectiveness of donor evaluation protocols. Lessons learned from near-miss events and complications should be consistently classified and systematically shared.

REFERENCES

1. Pomposelli JJ, Verbesey J, Simpson MA, Lewis WD, Gordon FD, Khettry U, et al. Improved survival after live donor adult liver transplantation (LDALT) using right lobe grafts: program experience and lessons learned. Am J Transplant 2006;6:589-598.
2. Pomfret EA, Fryer JP, Sima CS, Lake JR, Merion RM. Liver and intestine transplantation in the United States, 1996-2005. Am J Transplant 2007;7(pt 2):1376-1389.
3. Olthoff KM, Merion RM, Ghobrial RM, Abecassis MM, Fair JH, Fisher RA, et al.; for A2ALL Study Group. Outcomes of 385 adult-to-adult living donor liver transplant recipients: a report from the A2ALL consortium. Ann Surg 2005;242:314-323.
4. Broelsch CE, Whitington PF, Emond JC, Heffron TG, Thistlethwaite JR, Stevens L, et al. Liver transplantation in children from living related donors. Surgical techniques and results. Ann Surg 1991;214:428-437.
5. Hwang S, Lee SG, Lee YJ, Sung KB, Park KM, Kim KH, et al. Lessons learned from 1,000 living donor liver transplantations in a single center: how to make living donations safe. Liver Transpl 2006;12:920-927.
6. Ghobrial RM, Freise CE, Trotter JF, Tong L, Ojo AO, Fair JH, et al.; for A2ALL Study Group. Donor morbidity after living donation for liver transplantation. Gastroenterology 2008;135:468-476.
7. Lo CM, Fan ST, Liu CL, Wong J. Hepatic venoplasty in living-donor liver transplantation using right lobe graft with middle hepatic vein. Transplantation 2003;75:358-360.
8. Barr ML, Belghiti J, Villamil FG, Pomfret EA, Sutherland DS, Gruessner RW, et al. A report of the Vancouver Forum on the care of the live organ donor: lung, liver, pancreas, and intestine data and medical guidelines. Transplantation 2006;81:1373-1385.
9. Pomfret EA, Pomposelli JJ, Jenkins RL. Live donor liver transplantation. J Hepatol 2001;34:613-624.
10. Malagó M, Rogiers X, Burdelski M, Broelsch CE. Living related liver transplantation: 36 cases at the University of Hamburg. Transplant Proc 1994;26:3620-3621.

11. Miller C, Florman S, Kim-Schluger L, Lento P, De La Garza J, Wu J, et al. Fulminant and fatal gas gangrene of the stomach in a healthy live liver donor. Liver Transpl 2004;10:1315-1319.
12. Polido W Jr, Hoe LK, Siang NK, Chah TK. Acute myocardial infarction after live donor liver surgery. Liver Transpl 2007;13:154-156.
13. Boillot O, Belghiti J, Azoulay D, Gugenheim J, Soubrane O, Cherqui D. Initial French experience in adult-to-adult living donor liver transplantation. Transplant Proc 2003;35:962-963.
14. Adam R, McMaster P, O'Grady JG, Castaing D, Klempnauer JL, Jamieson N, et al. Evolution of liver transplantation in Europe: report of the European Liver Transplant Registry. Liver Transpl 2003;9:1231-1243.
15. Ringe B, Xiao G, Sass DA, Karam J, Shang S, Maroney TP, et al. Rescue of a living donor with liver transplantation. Am J Transplant 2008;8:1557-1561.
16. Adam R, Karam V, Delvart V, Fischer L, Kilic M, Lerut J, et al. Live donor liver transplantation: a European liver transplant registry (ELTR) report on 2634 cases [abstract]. Transpl Int 2009;22:3.
17. Melloul E, Dondero F, Paugam-Burtz C, Bouadma L, Arnulf B, Belghiti J. Living liver donor death related to complications of myeloma. Liver Transpl 2009;15:326-329.
18. Khalaf H, El-Meteini M, El-Sefi T, Hamza AF, El-Gazaz G, Saleh SM, et al. Evolution of living donor liver transplantation in Egypt. Saudi Med J 2005;26:1394-1397.
19. Chan SC, Fan ST, Lo CM, Liu CL, Wong J. Toward current standards of donor right hepatectomy for adult-to-adult live donor liver transplantation through the experience of 200 cases. Ann Surg 2007;245:110-117.
20. Akabayashi A, Slingsby BT, Fujita M. The first donor death after living-related liver transplantation in Japan. Transplantation 2004;77:634.
21. Srinivas AV. Living donor liver transplantation. Indian J Med Ethics 2005;2:89-90.
22. Coelho JC, de Freitas AC, Matias JE, de Godoy JL, Zeni Neto C, Parolin MB, Okawa L. Donor complications including the report of one death in right-lobe living-donor liver transplantation. Dig Surg 2007;24:191-196.
23. Broering DC, Sterneck M, Rogiers X. Living donor liver transplantation. J Hepatol 2003;38(suppl 1):S119-S135.
24. Wiederkehr JC, Pereira JC, Ekermann M, Porto F, Kondo W, Nagima I, et al. Results of 132 hepatectomies for living donor liver transplantation: report of one death. Transplant Proc 2005;37:1079-1080.
25. Soin AS. Ethical dilemmas in living donor liver transplantation. Issue Med Ethics 2003;11:104-105.
26. Zagier AS. Liver donor's death sets transplant specialists abuzz. Health man succumbs, gives life to half-brother. p. A1. News & Observer. October 3, 1999:14.
27. Ochs R. A widow's transplant warning: woman on a mission to stop future transplant nightmares. Newsday. August 19, 2002:8. Available at: http://archive.mail-list.com/hbv_research/message/20020819.101850.04dcc63a.en.html.
28. Malagó M, Testa G, Frilling A, Nadalin S, Valentin-Gamazo C, Paul A, et al. Right living donor liver transplantation: an option for adult patients: single institution experience with 74 patients. Ann Surg 2003;238:853-862.
29. Renz JF, Busuttil RW. Adult-to-adult living-donor liver transplantation: a critical analysis. Semin Liver Dis 2000;20:411-424.
30. Trotter JF, Hill-Callahan MM, Gillespie BW, Nielsen CA, Saab S, Shrestha R, Talamantes MM, Weinrieb RM; A2ALL Study Group. Severe psychiatric problems in right hepatic lobe donors for living donor liver transplantation. Transplantation 2007;83:1506-1508.
31. Trotter JF, Adam R, Lo CM, Kenison J. Documented deaths of hepatic lobe donors for living donor liver transplantation. Liver Transpl 2006;12:1485-1488.
32. Chan SC, Fan ST. Live liver donor mortality. Liver Transpl 2006;12:1437.
33. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. Hospital volume and surgical mortality in the United States. N Engl J Med 2002;346:1128-1137.
34. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med 2003;349:2117-2127.
35. Pomfret EA, Pomposelli JJ, Lewis WD, Gordon FD, Burns DL, Lally A, et al. Live donor adult liver transplantation using right lobe grafts: donor evaluation and surgical outcome. Arch Surg 2001;136:425-433.
36. Simpson MA, Verbesey JE, Khettry U, Morin DS, Gordon FD, Burns DL, et al. Successful algorithm for selective liver biopsy in the right hepatic lobe live donor (RHLD). Am J Transplant 2008;8:832-838.
37. Pomfret EA, Feng S. Striving for perfection: evaluation of the right lobe live liver donor. Am J Transplant 2006;6:1755-1756.
38. Hashikura Y, Ichida T, Umeshita K, Kawasaki S, Mizokami M, Mochida S, et al.; for Japanese Liver Transplantation Society. Donor complications associated with living donor liver transplantation in Japan. Transplantation 2009;88:110-114.
39. Lee SG. Living-donor liver transplantation in adults. Br Med Bull 2010;94:33-48.
40. Fernandes R, Pacheco-Moreira LF, Enne M, Steinbrück K, Alves JA, Filho GD, et al. Surgical complications in 100 donor hepatectomies for living donor liver transplantation in a single Brazilian center. Transplant Proc 2010;42:421-423.