Hypothesis: The true extent of morbidity among live liver donors remains poorly understood. In this unique and often high-profile area of surgery, the development of standards for defining and reporting complications would foster a better understanding of the incidence and magnitude of such adverse events (AEs).

Design: Retrospective review of AEs among live liver donors.

Setting: University-affiliated teaching hospital.

Patients and Methods: Of 202 individuals undergoing evaluation for live liver donation, 42 (20.8%) proceeded to surgery. Thirty-four underwent a right lobectomy without the middle hepatic vein; 3, a left lateral segmentectomy. Any event causing a deviation from a patient’s ideal course was considered an AE and subsequently classified according to a derived framework. Morbidity was defined as 1 or more AEs.

Main Outcome Measures: Incidence, timing, type, severity, and impact of AEs.

Results: No deaths or significant hepatic dysfunction occurred. In 5 (12%) of the 42 donors, the hepectomy was aborted for anatomic reasons before parenchymal transection. Eight (22%) of the remaining 37 experienced 11 AEs, of which 10 completely resolved, whereas 1 AE (3%) resulted in a permanent disability (brachial plexopathy). The overall incidence of AEs was 0.30 per case. Ten (91%) of the 11 AEs presented within the first postoperative month.

Conclusions: Most live liver donations are uncomplicated or do not lead to permanent consequence. The adoption of a standards-based classification framework for AEs in live liver donors would allow for an inclusive, consistent, and universally applicable method to collect, analyze, and report donor morbidity.

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See Invited Critique at end of article
tion, and finally (4) helping to determine the true utility of LDLT.

The purpose of this study was 2-fold: first, to add our experience to the collective literature regarding morbid events in this setting; and second, to offer an improved framework for the classification and reporting of such events toward the ultimate goal of an internationally accepted standards-based scheme.

**METHODS**

In this report, 202 individuals underwent evaluation as potential live liver donors, 42 (21%) of whom proceeded to operation. Pertinent characteristics of these 42 are listed individually in chronological sequence in Table 1. Women outnumbered men by a ratio of more than 2:1 (29:13). Median donor age was 40 years, with a range of 20 to 62 years. Two thirds (28/42 [67%]) were related to their respective recipients by blood,18 marriage,9 or a life-partner relationship.1 One third (14/42 [33%]) were not related and were classified as friends. Right lobectomy (RL) without the middle hepatic vein (RL−) was the planned operation in 39 and left lateral segmentectomy (LLS) in 3. In 37 donors (88%), the planned operation was completed (34 RL− procedures and 3 LLS procedures). Median length of postoperative hospital stay was 7 days, with a range of 5 to 20 days. The median period of follow-up was 1036 days, with a range of 189 to 1868 days.

### Table 1. Individual Donor Characteristics

<table>
<thead>
<tr>
<th>Donor No./Sex/Age, y</th>
<th>Graft Type</th>
<th>Blood Related</th>
<th>Other Relationship</th>
<th>Year of Operation</th>
<th>Length of Follow-up, d</th>
<th>Morbidity</th>
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<td>RL−</td>
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<td>Friend</td>
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</tr>
</tbody>
</table>

Abbreviations: LLS, left lateral segmentectomy; RL−, right lobectomy without middle hepatic vein; RLa, aborted right lobectomy.

**DONOR CANDIDATE EVALUATION AND SELECTION**

From the inception of the LDLT program, all prospective donors underwent evaluation according to a uniform protocol (Table 2), the goals of which were to ensure that the candidate was (1) in good health and fit to withstand the operation, (2) mentally competent, (3) motivated by altruism and free from coercion, (4) biologically compatible, (5) anatomically suit-
Meters.

tions during the course of this series (Imaging protocols during evaluation evolved through 3 itera-
ceptance, all donors were asked to donate2Uo f autologous
be relevant provided all other criteria were fulfilled. After ac-
recipient), relationship to the recipient was not considered to
decceased-donor liver transplantation. Other than proscribing
their respective recipients must have fulfilled listing criteria for
able, and (6) fully informed. As a prerequisite for evaluation,
their respective recipients must have fulfilled listing criteria for
deceased–donor liver transplantation. Other than proscribing
anonymous donation (the donor having no knowledge of the
recipient), relationship to the recipient was not considered to
be relevant provided all other criteria were fulfilled. After ac-
ceptance, all donors were asked to donate 2 U of autologous
blood.

Anatomically, lobar volume had to provide at least 8 mL/kg
of recipient weight. Initially, no particular variant of biliary, portal, arterial, and/or hepatic venous anatomy was considered
to be a contraindication to RL donation. However, after
an early experience with postengraftment ischemic necrosis of
a large, right-to-left–crossing segmental bile duct, acceptance
criteria were modified to exclude such anatomy.

EVALUATION IMAGING PROTOCOLS

Imaging protocols during evaluation evolved through 3 iter-
tions during the course of this series (Table 3). Two of these
were implemented before the availability, at our institution, of
high-resolution, 3-dimensional, magnetic resonance imaging
(MRI) with magnetic resonance (MR) angiography and MR chol-
angiography. Initially (protocol 1, cases 1-10), donor candidates
underwent computed tomography (CT) to assess the hepatic pa-
renchyma and provide volumetric analysis, followed by celiac
and superior mesenteric contrast angiography with portal-phase
images and then intraoperative cholangiography at the time of
surgery.

Imaging protocol 2 (cases 11-15) was evolved to include en-
doscopic retrograde cholangiography (ERC) after an unaccept-
ably high incidence of variant biliary anatomy was discovered
at operation. After 2 instances of post-ERC pancreatitis and the subsequent availability of high-resolution MRI, protocol 3 was
introduced (Table 3, cases 16-42).

SURGICAL TECHNIQUES
AND POSTOPERATIVE CARE

Operative steps involved confirmation of biliary anatomy by
intraoperative cholangiography, identification and dissection
of vascular and biliary structures and hepatic vein(s) relevant
to the portion of liver to be donated, followed by lobar or seg-
mental mobilization. Intraoperative ultrasonography was used
to identify the course of the middle hepatic vein as well as any
segment 5 or 8 venous drainage into the middle hepatic vein.
Accessory hepatic veins and segment 5 or 8 veins larger than 5
mm in diameter were preserved for reconstruction in the re-
cipient. High-powered electrocautery, ultrasound surgical as-
piration using the Cavition Ultrasound Surgical Aspirator
(CUSA; Valleylab, Boulder, Colo), and blunt and sharp dissec-
tion techniques were variously used for parenchymal transec-
tion. Great care was exercised at all times to avoid injury to
vascular and biliary structures destined to remain with the do-
nor, and in no instance were reconstructive interventions un-
taken on them. Temporary interruption of hepatic vascular
inflow (Pringle maneuver) was never used. For those cases
performed after donor 35, continuous intraoperative upper ex-
trremity nerve conduction monitoring was used.

After discharge, donors underwent assessment for their state
of recovery, overall health, and liver function at 1 week, 1 and
6 months, 1 year, and annually thereafter by protocol, or at other
intervals as clinically indicated. Imaging was performed at 1
and 6 months by protocol to assess hepatic regeneration or at
other time points as clinically indicated.

DEFINITIONS

An AE was defined as any peri-donation event that caused the
patient’s course to deviate from the ideal. The ideal live-donor
protocol is defined in Table 4. Mortality was defined as the pres-
ence of 1 or more AEs occurring during evaluation, perioper-
atively, and/or postoperatively.

CLASSIFICATION FRAMEWORK
FOR AEs

A classification framework was derived (Table 5) as an ex-
tension of previous work20 and used to characterize AEs with
respect to the following 5 variables: (1) their sequential num-
ber in a given patient, (2) the type of procedure they pertain
to, (3) the timing of the presentation of clinical manifesta-
tions, (4) their impact severity, and (5) a brief descriptive phrase.
Adverse events were then summarized in the following short-
hand syntax: [AE number], [procedure modifier], [onset modi-
 fier], [grade], [description]. For example: 1, RL−, EP, G1, wound
infection describes the first AE in an RL without the middle he-
patic vein that presented with clinical manifestations between

Table 2. Outline of Donor Evaluation Protocol

| Respective recipient accepted for deceased-donor liver transplantation |
| Screening interview by nurse coordinator |
| Body mass index < 28* |
| Determination of blood-group compatibility |
| Comprehensive history and physical examination by transplantation team physician/surgeon |
| Laboratory testing |
| Imaging† |
| Psychosocial assessment |
| Independent advocate opinion |
| Liver biopsy |
| Final review by transplantation surgeon in absence of recipient |
| Presentation at multidisciplinary selection committee |

*Calculated as weight in kilograms divided by the square of height in meters.  †Described in Table 3.

Table 3. Evolution of Evaluation Imaging Protocols

| Protocol 1 (cases 1-10) |
| CT for assessment of intra-abdominal abnormality, hepatic parenchyma, and lobar volumes |
| Celiac and superior mesenteric artery contrast angiography with portal-phase images |
| IOC |
| Protocol 2 (cases 11-15) |
| CT for assessment of intra-abdominal abnormality, hepatic parenchyma, and lobar volumes |
| Celiac and superior mesenteric artery contrast angiography with portal-phase images |
| ERC during evaluation |
| IOC for confirmation of biliary anatomy |
| Protocol 3 (cases 16-42) |
| High-resolution MRI with MRA, 3-dimensional vascular reconstruction, and MRC |
| Selected use of contrast angiography and ERC during evaluation |
| IOC for confirmation of biliary anatomy |

Abbreviations: CT, computed tomography; ERC, endoscopic retrograde cholangiography; IOC, intraoperative cholangiography; MRA, magnetic resonance (MR) angiography; MRC, MR cholangiography; MRI, MR imaging.
Invasive intervention is defined in Table 6.

**DATA PROCESSING**

A prospective database was used from the inception of the LDLT program. Initially this consisted of a distributed flat-file configuration (FileMaker Pro; FileMaker Inc, Santa Clara, Calif), but was subsequently migrated to a structured query language–based relational database management system architecture (SQL Server 2000; Microsoft Corp, Redmond, Wash) and accessed via a secure Web application interface (ColdFusion MX; Macromedia Inc, San Francisco, Calif). All software applications were developed by one of us (C.R.S.).

We used the unpaired t test and Fisher exact test for statistical comparison of means and proportions, respectively, between groups (SigmaStat; SPSS Inc, Chicago, Ill).

**MORBIDITY DURING EVALUATION**

There was no morbidity related to CT, MRI, contrast angiography, or liver biopsy. Two (10%) of 20 candidates who underwent ERC were hospitalized with pancreatitis that responded to conservative measures without sequelae. These events were thus summarized as 1, RL, EV (presented during the evaluation), G1, post-ERC pancreatitis for each patient.

**OVERALL OPERATIVE MORBIDITY**

Forty-two donors proceeded to surgery, and 13 (31%) manifested 18 AEs, including 4 grade 1 (22%), 12 grade 2 (67%), and 2 grade 3 events (11%). Of the 13 donors with AEs, 10 had 1 AE, 1 had 2 AEs, and 2 had 3 AEs. The overall average was 0.43 AEs per operation. There were no grade 4, 5, or 6 AEs in this series.

**ABORTED HEPATECTOMY MORBIDITY**

Five (45%) of 11 of the grade 2 AEs were aborted RL hepatectomies. Details of these cases are depicted in Table 7. In each instance, the procedure was stopped before parenchymal transection. The overall incidence of aborted hepatectomy was 12%. Three (30%) of 10 cases performed during the era of imaging protocol 1 were aborted because of unfavorable variant biliary anatomy, com-
Among 37 donors who underwent hepatectomy, 8 (21.6%) exhibited 11 AEs, including 3 grade 1 (27%), 7 grade 2 (64%), and 1 grade 3 events (9%). Morbidity in these patients is summarized in Table 8. Six hepatectomized donors had 1 AE, whereas the others had 2 and 3 AEs. The overall incidence of AEs in donors who underwent hepatectomy was 0.30 AEs per case. Seven of the 8 were RL donors and 1 was an LLS donor. The mean ± SD age of donors with AEs was 36 ± 10 years compared with 41 ± 10 years for those without (P= .18). Male donors were more than twice as likely as female donors to experience an AE, although the difference was not statistically significant (4/12 [33%] vs 4/25 [16%]; P= .39).

Five (45%) of 11 AEs presented clinically in the perioperative period, 5 (45%) within 1 to 30 days, and 1 (9%) beyond the first postdonation month.

The peak posthepatectomy values (mean ± SD) for donor aspartate aminotransferase, alanine aminotransferase, international normalized ratio, and total serum bilirubin were 370 ± 223 U/L, 383 ± 209 U/L, 1.7 ± 0.3, and 2.6 ± 1.4 mg/dL (44.5 ± 23.9 µmol/L), respectively. At a median of 10 days after hepatectomy (range, 3-86 days), the respective values were 62 ± 34 U/L, 91 ± 65 U/L, 1.2 ± 0.2, and 0.9 ± 0.6 mg/dL (15.4 ± 10.3 µmol/L).

## PERIOPERATIVE AEs

Perioperative AEs consisted of cut-surface bile leaks (2 instances, in donors 25 and 34), positioning-related upper extremity neuropathies (2 instances, in donors 34 and 35), and allogeneic blood transfusion (1 instance, in donor 37). Because the bile leaks were repaired with surgery, these were classified as grade 2. The overall incidence of bile leak in the 37 hepatectomized patients was 5.4%. One of the 2 positioning-related neuropathies was a bilateral, incomplete ulnar nerve palsy that resolved after several days. However, the second evolved into a chronic unilateral brachial plexopathy of the individual’s dominant upper extremity and resulted in a permanent disability (grade 3).

Among male donors undergoing hepatectomy, the incidence of positioning-related neuropathies was 2 (17%) of 12 compared with none in female donors (P= .1).

## EARLY POSTOPERATIVE AEs

Four AEs in 3 patients presented in the early postoperative period. Donor 1 had a narcotic-related acute respiratory depression on day 2, which required reintubation and an intensive care unit readmission (grade 2).

The onset of mild-to-moderate dyspnea in a young female RL donor (donor 16) prompted readmission at 1 week after discharge. No abnormality was identified, and her symptoms resolved spontaneously.

A 36-year-old male donor (donor 19) with a body mass index greater than 30 (calculated as weight in kilograms divided by the square of height in meters) experienced 3 AEs. Although CT findings were unremarkable, he underwent exploration on posthepatectomy day 5 for persistent low-grade fever, leukocytosis, and failure to progress clinically. A thick abdominal pannus had
masked a subcutaneous, suprafascial purulent wound infection. Exploration revealed that the ascending colon had been incorporated in the closure of abdominal wall during the original operation, and a primary repair was performed. Both of these AEs were managed primarily by operation and thus were classified as grade 2. He was discharged 20 days after his original operation, but an incisional hernia developed that was repaired 8 months after hepatectomy (grade 2).

A 28-year-old woman who had donated her LLS to her son was readmitted 4 days after discharge with nausea and vomiting. No abnormality was identified and the symptoms resolved with bowel rest (grade 1).

**LATE POSTOPERATIVE AEs**

The incisional hernia in donor 19 (Table 8) was the only late-presenting AE in the completed hepatectomy group.

**COMMENT**

Minimizing surgical risk is important in any setting, but perhaps even more so when the procedure offers no direct health benefit to the patient. The incidence of complications in reported LDLT series ranges from 0% to 67%. Although accurate numbers may never be known, in part because of the absence of a central data repository, it is widely believed within the transplant community that there have been at least 9 deaths in live liver donors, and at least 3 have required liver transplantsations themselves.7 The risk of death or need for transplantation in LDLT donors has been estimated to be approximately 0.3% to 0.4%.7

In addition to death and hepatic insufficiency leading to liver transplantation, the spectrum of reported donor complications in LDLT includes postoperative hemorrhage, de novo hepatitis, liver abscess, prolonged ileus, bile duct stricture, bile leak, infected biliary, portal vein thrombosis, intractable ascites, prolonged ileus, small-bowel obstruction, gastritis, peptic ulcer, dyspepsia, nausea and vomiting, contrast-induced chronic renal failure, venous thrombosis, pulmonary embolism, pleural and pericardial effusion, pneumothorax, atelectasis, pneumonia, upper and lower extremity nerve palsy, wound and other nonhepatobiliary infection, incisional hernia, pressure sore, asymptomatic thrombocytopenia, cognitive and other psychological impairment, altered body image, persistent wound pain, and nonspecific persistent abdominal discomfort.7 In their meta-analysis of reported series of RL donor morbidity, Beavers et al17 estimated the crude overall morbidity rate to be 31%, although these authors cautioned against overinterpretation because of the inconsistencies in the data they reviewed.

There is no doubt that the wide range in the reported incidence of LDLT AEs can be attributed to a variety of factors, but central is a lack of accepted standards for defining, classifying, and reporting such occurrences.7 17 In the present report, we have attempted to be precise by defining morbidity as the presence of 1 or more AEs and an AE as any deviation from the ideal course, which we have also attempted to define (Table 4). The utility of any classification scheme must be that it stratifies AEs in terms of their outcome impact and thus allows interpretation with an appropriate perspective.

The Clavien classification for complications in solid-organ transplantation is based on a combination of the threat to life, the interventions required, and finally, the outcome impact.19 Its adaptation to the context of LDLT has been previously outlined by our group20 and at least 3 others.12-14 Although it represents the seminal effort in the move toward standards-based AE reporting in transplantation, its application appears vulnerable because of its complexity and its subjective nature. In addition, it fails to accurately define invasive and noninvasive interventions. Finally, it is not a framework that could be easily adapted to a relational database model for the purpose of morbidity registries.

This current derivation of the Clavien system bases the impact severity grading on outcome and provides a strict definition of what constitutes invasive intervention. Grades 1 and 2 refer to AEs that produce no long-term consequences but are distinguished on the basis of required interventions. Grades 3 and 4 are those that result in chronic disease or disability that is nonhepatobiliary and hepatobiliary, respectively. Within these grades, the addition of interventional qualifiers was considered unnecessary by definition. Grades 5 and 6 are catastrophic and self-explanatory.

We have also extended the classification framework with the addition of sequential numbering for a given patient and by the use of procedural and temporal modifiers. Together these elements, combined with grade and a short phrase that describes the event, produce a shorthand syntax that efficiently encapsulates any AE. Although we arbitrarily chose to define the temporal modifiers as relative to particular periods, the framework could easily be adjusted in this aspect, eg, days from the index procedure to onset of symptoms. Similarly, the procedure modifier list could be adapted to encompass a wider spectrum and/or alternate list of operations. Taken together, we believe that these features allow our approach to be more uniform, yet versatile in its application and better suited to integration with relational database management systems.

Although the present study is by no means a large series of live liver donors, we have attempted to be precise in definition and inclusive in our reporting of AEs. One or more AEs occurred in 31% of all patients undergoing operation and 22% of those who underwent hepatectomy. The crude morbidity (total AEs/total cases) for these 2 analysis sets was 0.43 event per case and 0.30 event per case, respectively. Within the hepatectomy group, younger age and male sex appeared to be associated with an increased risk of AEs, although the numbers were too small to permit firm conclusions. However, when analyzed from the perspective of the whole series or just those who underwent hepatectomy, 91% of these AEs (10/11) resolved without permanent consequences (grades 1 and 2). Within the entire series, 2 AEs went on to chronicity, the most serious of which was persistent neurologic deficit in the donor's dominant upper extremity. Ninety percent of all morbidity...
presented in the perioperative period or within the first postoperative month. There were no instances of chronic hepatobiliary disease, liver transplantation, or patient death. Overall, these results compare favorably with those reported by others.9-17

Neurapraxias, presumably related to positioning and operative time, have been reported by several groups,12,13,16 with an incidence of 0.1% to 5%, and these observations together with results of the present study indicate that they may evolve into permanent disability. In addition, our results suggest that young, fit men may be at greater risk. This readily preventable cause of potentially permanent disability must therefore not be underemphasized in any risk-reduction strategy, and operating room team personnel responsible for patient positioning must be educated accordingly.

The incidence of aborted hepatectomy in this series was 12%, which is high although not disproportionate compared with rates reported by others;12,13 and we suspect that there are more unreported instances. Broering et al12 reported an overall incidence of aborted hepatectomy of 2% in a combined series of all living-donor graft types, but the incidence within the right-lobe donor group was 12%. Reasons to abort in the Hamburg series12 included unexpected steatosis and concerns regarding lobar volume and vascular configuration. The principal reason for aborting in the present series was concern about biliary anatomy. This in turn resulted from (1) our early bad experience with a segmental bile duct crossing Cantle’s line, (2) a failure to appreciate the frequency of such biliary variants, and (3) an evaluation imaging protocol that failed to identify these variants before the operation, leading to poor patient selection. By changing our imaging protocol to identify such variants during the course of evaluation and select them out, we eliminated this as a cause and the impact was statistically significant. No additional grafts were lost in recipients because of bile duct necrosis, despite the need to anastomose as many as 3 ducts.

It could be argued that our attitudes regarding crossing bile ducts were an overreaction to an isolated case, and that the right lobes from these 3 donors (and those from other donor candidates who were eliminated on this basis) might well have been transplanted successfully. Indeed, little in the literature supports our concerns. In this setting, an aborted laparotomy obviously represents a major violation to be avoided, and our results underscore the learning curve associated with living-donor right hepatectomy and the fundamental importance of accurate preoperative evaluation and patient selection. On the other hand, these events transpired early in our series and the collective RL LDLT experience. Even now, more information is required regarding the outcomes of particular anatomic variants in transplanted RL grafts. It would be equally futile to have completed a hepatectomy and transplantation, only to subsequently lose the graft.

Although we have emphasized the importance of obtaining accurate anatomic information, we have also shown that invasive tests performed during this phase are not devoid of risk and should be used selectively with full consideration of the risks and benefits. Although imaging can provide estimates of hepatic steatosis, we have previously demonstrated a significant false-negative rate of MRI-derived hepatic fat estimates compared with that demonstrated on liver biopsy results.21 We therefore continue to include this invasive test in our evaluation protocol. However, high-resolution MRI has otherwise markedly reduced the need for other invasive studies.

Any full disclosure of LDLT morbidity must include considerations of psychosocial and occupational issues. Although we acknowledge that the present report focuses on physical morbidity, we have partially addressed these other aspects within our LDLT population in a previous communication22 and are working toward a more comprehensive survey.

In summary, this report contributes to a growing body of literature indicating a wide spectrum of morbidity associated with live liver donation. When viewed in aggregate, the incidence is considerable, although the centerspecific incidence varies widely. Although most of the AEs in LDLT resolve without permanent sequelae, there remains a significant risk of sustained disease or disability ranging from 3% to 10%. Finally, albeit low, the risk of death or need for transplantation is real. We encourage all LDLT programs to fully report their donor-related morbidity. More work is required before standards for AE classification and reporting in LDLT are universally accepted. It is our sincere hope that the approach used herein represents an incremental step toward that end.

References


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DISCUSSION

Ronald W. Busuttil, MD, Los Angeles, Calif. I would like to thank the authors for the opportunity to discuss this paper, which deals with the morbidity of adult living liver donors. In this operation, the right lobe of the liver is retrieved for transplantation.

The need for adult living liver donation stems from the severe organ shortage and the exponential increases in the number of potential recipients awaiting transplantation. Furthermore, the recent adoption of the MELD [Model for End-Stage Liver Disease] system for organ allocation has hindered our ability to transplant nonurgent recipients where the outcomes of transplantation are excellent. As an example, in region 5, of which California is a part, most patients who received deceased donor organs are intensive care unit bound. On these grounds, one can justify the need for adult donation. However, the principle of nonmaleficence remains to be validated for living donors, in both physiological and quality-of-life issues.

Following the early reports of adult LDLT in the late 1990s in the United States, the American Society of Transplant Surgeons (ASTS) surveyed centers doing live-donor transplants to determine the clinical outcomes of both donors and recipients. They found that donors exhibited a reportedly low complication rate of 10%. Another survey published in the New England Journal of Medicine by Brown et al reported complications to be 14.5%. On the other hand, single centers have reported complication rates ranging between 9% to 67%. In 2002, we reported our results from UCLA in our first 20 living donors, who had a complication rate of 20%. Furthermore, we were the first to emphasize the need for standardized reporting, such as a modification of the Clavien scoring system, to more accurately reflect the scope and severity of complications. Dr Shackleton and his group have adapted this system in their paper and have attempted to put into perspective the true risk-benefit ratio for the donor.

Regardless of the improvements in the technical execution of the procedure, complications will occur, and donor mortality is at least 0.5%. It is therefore incumbent upon us, when we consider this procedure, to have the most accurate assessment of its morbidity and mortality for a previously healthy person who does not need an operation.

I have the following questions for the authors. The first concerns the rate of aborted donor operations, which was 5 out of 42 (12%). In your series, the reasons for abortion in 3 donors were unfavorable biliary anatomy. Can you elaborate on the type of biliary anatomy that you consider unfavorable and why?

The fourth aborted donor was because of concerns regarding right lower mass as well as residual left lobe volume, despite preoperative CT volumetric analysis suggesting they were sufficient. How was this underestimated, or was the liver of poor quality, and how can we avoid that in the future? What liver volumes do you consider sufficient for the recipient, and what residual volumes do you consider safe for the donor? Can you also elaborate on the operative hepatic venous anatomy that caused the abortion of the fifth donor? In my view, an unfavorable anatomy should be an extremely uncommon reason to back out of the operation with the new modalities that we employ.

Finally, are you still doing screening liver biopsies on donors, and if yes, what are your indications? What role do you feel that high-resolution CT scanning has in avoiding biopsy?

Dr Shackleton: I would like to thank Dr Busuttil both for his insightful remarks regarding the rationale and need for LDLT in general and his comments and questions specifically pertaining to our presentation.

With regard to aborted hepatectomy, we are obviously not proud of the relatively high incidence. As described in the presentation, the principal reason to abort related to concerns about the posttransplant viability of the biliary tree in the engrafted right lobe when the anatomic configuration was such that major right-sided segmental ducts crossed the proposed plane of parenchymal transection. This, in turn, stemmed from a case of posttransplant segmental bile-duct necrosis, which occurred in our early experience. In this case, the segment 6 bile duct crossed Cantle’s line to drain into the left duct system. Following transplantation, and despite excellent allograft function, this ultimately culminated in ischemic necrosis of that segmental biliary system, refractory cholangitis, retransplantation, and graft loss. That event colored our perspective regarding acceptable biliary anatomy and, combined with an underappreciation of the frequency of such biliary variants and the inadequacy of our early imaging protocol, led to the additional biliary-aborted cases. Improved preoperative imaging and hence better patient selection effectively eliminated this as a reason to abort in the remainder of the series.

With respect to the bile leaks, these were both cut-surface bile leaks on the remnant liver, both for small duct radicals that had not been identified at the time of surgery. It might be argued that they could have easily been managed with continued external biliary drainage, but we elected to reoperate, and we simply overrode the duct radicals in question with fine monofilament suture, which was successful in both instances.

Regarding the question of liver biopsy, I agree it is an invasive test, and certainly one can obtain semiquantitative information on the extent of intrahepatic fat using noninvasive means, CT scanning, and MRI. However, a previous study from our institution by Dr Tran indicated that the correlation between MR estimates of hepatic fat and those seen on biopsy are not necessarily all that close.