ORIGINAL ARTICLE

Development, Management, and Resolution of Biliary Complications After Living and Deceased Donor Liver Transplantation: A Report From the Adult-to-Adult Living Donor Liver Transplantation Cohort Study Consortium

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Adult recipients of living donor liver transplantation (LDLT) have a higher incidence of biliary complications than recipients of deceased donor liver transplantation (DDLT). Our objective was to define the intensity of the interventions and the time to resolution after the diagnosis of biliary complications after liver transplantation. We analyzed the management and resolution of posttransplant biliary complications and investigated the comparative effectiveness of interventions in LDLT and DDLT recipients. For the analysis of biliary complications (leaks or strictures), we used a retrospective cohort of patients who underwent liver transplantation at 8 centers between 1998 and 2006 (median follow-up from onset=4.7 years). The numbers, procedure types, and times to resolution were compared for LDLT and DDLT recipients. Posttransplant biliary complications occurred in 47 of the 189 DDLT recipients (25%) and in 141 of the 356 LDLT recipients (40%). Biliary leaks constituted 38% of the post-DDLT biliary complications (n=18) and 65% of the post-LDLT biliary complications (n=91). The median times to first biliary complications were similar for DDLT and LDLT (11 versus 14 days for leaks, $P=0.63$; 69 versus 107 days for strictures, $P=0.34$). Overall, 1225 diagnostic and therapeutic procedures, including reoperation and retransplantation, were performed (6.5 ± 5.4 per recipient; 5.5 ± 3.6 for DDLT versus 6.8 ± 5.8 for LDLT, $P=0.52$). The median number of months to the resolution of a biliary complication (i.e., a tube-, stent-, and drain-free status) did not significantly differ between the DDLT and LDLT groups for leaks (2.3 versus 1.3 months, $P=0.29$) or strictures (4.9 versus 2.3 months, $P=0.61$). Although the incidence of biliary complications is higher after LDLT versus DDLT, the treatment requirements and the time to resolution after the development of a biliary complication are similar for LDLT and DDLT recipients. ***Liver Transpl 19:259–267, 2013***. © **2013 AASLD.**

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The disparity between the numbers of available donor organs and potential liver transplant recipients led to the development of adult-to-adult living donor liver transplantation (LDLT).[1] As experience has accumulated, it has become evident that biliary complications constitute a large proportion of posttransplant recipient morbidity.[2,3] Several factors have been identified that may contribute to biliary leaks or strictures after LDLT; these include the center volume, the number of graft bile ducts, and the type of anastomosis performed.[4] Furthermore, although endoscopic therapies can be successfully employed to treat the majority of biliary problems in most recipients, LDLT recipients may have less favorable responses.[5]

LDLT recipients have a higher overall incidence of complications than recipients of deceased donor liver transplantation (DDLT). Despite the lower severity of pretransplant disease, the hospitalization requirements for medical and surgical complications are higher after LDLT versus whole organ DDLT.[6] Biliary complications contribute importantly to the excess morbidity of this procedure. Although most biliary complications do not lead to graft loss or patient death, detailed analyses of the management, treatment course, and resolution of biliary complications after LDLT and DDLT across multiple dedicated transplant programs might contribute to our understanding of the differences in and similarities of biliary morbidities according to the allograft type. In this study, we report on the comparative effectiveness of the management of posttransplant biliary complications in LDLT and DDLT recipients who participated in the Adult-to-Adult Living Donor Liver Transplantation Cohort Study (A2ALL).

PATIENTS AND METHODS

Data Sources

Data for this study were derived from the retrospective cohort component of the A2ALL study from 8 of the 9 A2ALL centers. Data were collected via detailed chart reviews and were supplemented with data from the Scientific Registry of Transplant Recipients obtained through a data use agreement. Seven hundred twenty-six transplant candidates who had a potential living donor and completed a history and physical examination between January 1, 1998 and February 28, 2003 were eligible for inclusion in the study. Five hundred forty-five recipients who underwent transplantation between May 1998 and May 2006 for nonfulminant indications were included in the analysis (DDLT, 189; LDLT, 356). Recipients of domino transplants were included in the DDLT group.

Information from the study database was supplemented by the abstraction of additional data (September 2010 to May 2011) on the course of treatment for all 188 recipients who experienced a biliary complication, which was identified by the recording of a leak or stricture in a patient's chart. A bile leak was defined as a persistent bilious drainage more than 7 days after surgery that was identified by a radiological study or surgical exploration. A biliary stricture was defined as a radiologically identified narrowing of the intrahepatic or extrahepatic bile ducts occurring at any time after donation. Detailed serial data on specific diagnostic and therapeutic interventions related to biliary complications were collected; these included hospitalizations, antibiotic courses, computed tomography or ultrasound (CTUS), endoscopic retrograde cholangiopancreatography (ERCP), magnetic resonance cholangiopancreatography (MRCP), percutaneous transhepatic cholangiography (PTC), reoperation, and retransplantation.

The study was approved by the institutional review boards and privacy boards of the University of Michigan Data Coordinating Center and each of the transplant centers.

Statistical Methods

Study subjects were followed from the time of transplantation to the earliest of retransplantation, death, or biliary complication chart review. Descriptive statistics are given as means and standard deviations for continuous variables and as proportions for categorical

Abbreviations: A2ALL, Adult-to-Adult Living Donor Liver Transplantation Cohort Study; CTUS, computed tomography or ultrasound; DDLT, deceased donor liver transplantation; ERCP, endoscopic retrograde cholangiopancreatography; HCV, hepatitis C virus; HR, hazard ratio; LDLT, living donor liver transplantation; MELD, Model for End-Stage Liver Disease; MRCP, magnetic resonance cholangiopancreatography; PTC, percutaneous transhepatic cholangiography.

The Adult-to-Adult Living Donor Liver Transplantation Cohort Study includes Northwestern University (Chicago, IL), the University of California Los Angeles (Los Angeles, CA), the University of California San Francisco (San Francisco, CA), the University of Colorado Health Sciences Center (Denver, CO), the University of North Carolina (Chapel Hill, NC), the Division of Digestive Diseases and Nutrition (Epidemiology and Clinical Trials Branch) of the National Institute of Diabetes and Digestive and Kidney Diseases (Bethesda, MD), the University of Michigan (Ann Arbor, MI), the Department of Surgery of Columbia Presbyterian Medical Center (New York, NY), the University of Pennsylvania (Philadelphia, PA), the Department of Internal Medicine at the University of Virginia (Charlottesville, VA), and Virginia Commonwealth University (Richmond, VA). This is publication 21 of the Adult-to-Adult Living Donor Liver Transplantation Cohort Study.

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The patients participating in this trial were enrolled in the National Institutes of Health–sponsored Adult-to-Adult Living Donor Liver Transplantation Cohort Study. This study was supported by the National Institute of Diabetes and Digestive and Kidney Diseases through cooperative agreements (grants U01-DK62536, U01-DK62444, U01-DK62467, U01-DK62483, U01-DK62484, U01-DK62494, U01-DK62496, U01-DK62498, U01-DK62505, and U01-DK62531). The trial was also funded by research grants from Schering-Plough through a cooperative research and development agreement with the National Institute of Diabetes and Digestive and Kidney Diseases/National Institutes of Health and through a clinical trial agreement between Ortho-Biotech and the National Institute of Diabetes and Digestive and Kidney Diseases/National Institutes of Health. Additional support was provided by the Health Resources and Services Administration and the American Society of Transplant Surgeons.

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variables. *t* tests were used to compare differences between DDLT and LDLT for continuous characteristics. Chi-square tests were used to compare differences between DDLT and LDLT for categorical characteristics. The numbers of procedures performed for DDLT and LDLT recipients were compared with a *t* test after a log transformation of the procedure counts.

The distributions for the numbers of procedures performed per person overall and for each procedure individually were compared graphically for DDLT and LDLT recipients with box plots. The percentages of outpatient procedures that were performed were examined. A procedure was considered an outpatient procedure if there was no corresponding hospitalization record that included the date of the procedure. We compared the percentages of procedures performed on an outpatient basis for DDLT and LDLT recipients with a logistic regression model to adjust for a potential time trend. This model allowed us to examine the association between the type of transplant (DDLT versus LDLT) and the probability of a procedure being performed on an outpatient basis while we adjusted for the year of transplantation.

To study the time to the resolution of biliary complications, the time from the placement of a biliary tube, stent, or drain until the removal of all tubes, stents, and drains was examined with survival models. The follow-up for this analysis started at the time of the initial placement of the tube, stent, or drain and continued until the earliest of the following: the patient became tube-, stent-, and drain-free; the patient underwent retransplantation; the patient died; or the study ended. The earliest date by which all tubes, stents, and drains had been removed was considered the time of resolution (event). Follow-up was censored at retransplant, death, and the end of the study. The time from the onset to the resolution of biliary complications was examined with Kaplan-Meier survival curves by the transplant type (DDLT versus LDLT) and by the complication type (leak and/or stricture). Differences between DDLT and LDLT recipients were compared for each type of complication with log-rank tests. Potential factors associated with resolution were tested via the fitting of multivariate Cox proportional hazards regression models stratified by the complication type. Time-dependent Cox regression models were used to examine the effects of developing a biliary complication on long-term graft and patient outcomes. Each of the variables in Table 1 was tested in the survival models, and the best subset selection method was used to look for a parsimonious model.

The rates of procedures performed by the months since transplantation were compared for DDLT and LDLT recipients. The rates were calculated as the number of procedures performed during a month divided by the number of patients in the risk set during that month. To test factors that might be associated with the number of procedures performed per unit of time, negative binomial regression models were fit to the data. Because the rate of procedures decreased rapidly soon after transplantation and changed very little after approximately 2 years, 2 separate models were fit. The first model was fit for the first 2 years after transplantation and included a quadratic term for time. The second model was fit for the time beyond 2 years after transplantation and modeled time as a linear term.

All analyses were performed with SAS 9.2 (SAS Publishing, SAS Institute, Inc., Cary, NC).

RESULTS

Patient Characteristics and Nature of Biliary Complications

Forty-seven of the 189 DDLT recipients (25%) suffered a biliary complication during the follow-up period, and 141 of the 356 LDLT recipients (40%) had a posttransplant biliary complication. The baseline characteristics are shown in Table 1. LDLT recipients had significantly lower Model for End-Stage Liver Disease (MELD) scores ($P<0.001$) in comparison with the DDLT group. The number of biliary anastomoses was significantly higher in the LDLT group ($P<0.001$), and so was the proportion of patients undergoing complete Roux-en-Y reconstruction ($P<0.001$). Although the cold ischemia time was shorter in the LDLT group ($P<0.001$), the duration of the recipient operation was significantly longer ($P<0.001$).

Overall, a higher percentage of LDLT patients had a biliary complication (40% versus 25%, $P<0.001$; Table 2). Among those with biliary complications, biliary leaks predominated in the LDLT group (64.5% versus 38.3%, $P=0.005$). However, the median times from transplantation to the onset of a biliary leak were not different for the 2 groups (11 days for DDLT and 14 days for LDLT, $P=0.63$). Conversely, biliary strictures were the predominant type of biliary complication in the DDLT group (59.6% versus 32.6%). Again, the median times to onset were not significantly different (69 days for DDLT and 107 days for LDLT, $P=0.34$). Although the risk of any biliary complication was higher after LDLT, the risk of strictures did not differ (14.8% after DDLT and 12.9% after LDLT, $P=0.54$). Five subjects had a simultaneous biliary leak and stricture (DDLT, 1; LDLT, 4).

Procedures for Biliary Complications

Overall, 1225 diagnostic and therapeutic procedures were performed for the management of biliary complications. The proportions of procedures performed exclusively for diagnostic purposes (without therapeutic interventions) were similar in the DDLT and LDLT groups [90/258 (34.9%) and 368/599 (38.1%), respectively, $P=0.35$]. The overall number of procedures performed per patient, including diagnostic imaging, therapeutic interventions, reoperation, and retransplantation, was 5.5±3.6 for DDLT recipients and 6.8±5.8 for LDLT recipients ($P=0.52$; Fig. 1). There were significantly more PTC procedures performed per patient in the LDLT group ($P=0.004$), and there were significantly more ERCP procedures performed per patient in the DDLT group ($P<0.001$). Figure 2 shows that the proportions of diagnostic and therapeutic procedures

TABLE 1. Characteristics of Recipients With Biliary Complications

	DDLT (n=47)	LDLT (n=141)	*P* Value*
Recipient age at transplant (years)†	49.4±10.3	49.5±10.0	0.95
Recipient sex [n (%)]			0.67
Male	30 (63.8)	85 (60.3)	
Female	17 (36.2)	56 (39.7)	
Recipient race [n (%)]			0.39
White	39 (83.0)	124 (87.9)	
Nonwhite	8 (17.0)	17 (12.1)	
Recipient body mass index (kg/m^2)†	27.1±4.9	26.3±5.5	0.37
Diagnosis [n (%)]‡			
HCV	18 (38.3)	63 (44.7)	0.44
Hepatocellular carcinoma	10 (21.3)	20 (14.2)	0.25
Alcohol	7 (14.9)	19 (13.5)	0.81
Cholestatic liver disease	8 (17.0)	31 (22.0)	0.47
Noncholestatic cirrhosis other than HCV or alcohol	14 (29.8)	33 (23.4)	0.38
Other	7 (14.9)	13 (9.2)	0.79
MELD score at transplant†	22.0±9.5	15.4±6.3	<0.001
Donor age (years)†	37.5±13.4	37.1±9.9	0.83
Donor type [n (%)]			
Donation after brain death	45 (95.7)	Not applicable	
Donation after cardiac death	2 (4.3)	Not applicable	
Bile ducts from donor graft [n (%)]			<0.001
Missing		6 (4.3)	
1	47 (100)	65 (46.1)	
2		56 (39.7)	
>2		14 (9.9)	
Biliary anastomoses [n (%)]			<0.001
Missing	12 (25.5)		
1	35 (74.5)	88 (62.4)	
2		45 (31.9)	
3		8 (5.7)	
Biliary anastomosis type [n (%)]			<0.001
Missing	12 (25.5)		
Not all Roux	28 (59.6)	78 (55.3)	
All Roux	7 (14.9)	63 (44.7)	
Cold ischemia time (minutes)†	446.4±167.7	93.7±99.1	<0.001
Duration of recipient operation (minutes)†	386.0±119.1	533.5±129.9	<0.001
Era of transplantation [n (%)]			0.08
1998-1999	6 (12.8)	23 (16.3)	
2000-2001	19 (40.4)	76 (53.9)	
2002-2003	21 (44.7)	42 (29.8)	
2004-2006	1 (2.1)		

*The *P* values were derived from 2-sample *t* tests for continuous characteristics and from chi-square tests for categorical characteristics.
†The data are presented as means and standard deviations.
‡Multiple diagnoses were possible.

performed in an outpatient setting increased dramatically over time ($P<0.001$). Across the entire study period, the proportion of outpatient procedures was significantly higher in the LDLT group ($P<0.001$).

Probability of Resolution After a Biliary Complication

The cumulative probability of the resolution of biliary complications (i.e., the definitive removal of a percutaneously or operatively placed tube, stent, or drain or retransplantation) is shown in Fig. 3. In this analysis, the time to resolution was initialized on the day on which the biliary complication was diagnosed and/or first treated. Within 6 months of diagnosis, the majority of the biliary leaks (79% for DDLT and 92% for LDLT) were resolved, and by 24 months, all had been resolved. In comparison with biliary leaks, the probability of resolution for biliary strictures was lower for recipients of both transplant groups. Nevertheless, 24 months after diagnosis, 95% of DDLT recipients with biliary strictures and 94% of LDLT recipients with biliary strictures were tube-, stent-, and drain-free.

The median time to a tube-, stent-, and drain-free status after a biliary leak was 1 month longer for DDLT recipients (2.3 months) versus LDLT recipients

(1.3 months); there was a 75% probability of resolution after 4.7 and 2.7 months for DDLT and LDLT recipients, respectively (log-rank $P=0.29$). After the development of a biliary stricture, the median time to a tube-, stent-, and drain-free status was 4.9 months for the DDLT group and 2.3 months for the LDLT group; there was a 75% probability of resolution after 6.6 months for DDLT recipients and 5.0 months for LDLT recipients (log-rank $P=0.61$). Among LDLT recipients, the median time to biliary leak resolution was not significantly different for those without a Roux-en-Y anastomosis (1.5 months) and those with a Roux-en-Y anastomosis (1.2 months).

When they were tested with multivariate Cox models stratified by the complication type (leak/stricture), none of the factors, including LDLT [hazard ratio (HR)=1.2, $P=0.37$], had a significant influence on the time to being tube-, stent-, and drain-free. When LDLT was analyzed exclusively, the overall number of biliary complication cases per center influenced the time to being tube-, stent-, and drain-free. Experience with more than 15 biliary complications at a center was associated with a significantly shorter time to resolution (HR=1.68, $P=0.04$).

The rate of biliary-related procedures declined rapidly during the first 24 months after transplantation and then remained relatively constant in both the DDLT and LDLT groups (Fig. 4). The rates never fell to zero, even 10 years after transplantation. During the first 24 months, the procedure rates for DDLT and LDLT recipients were similar, whereas an older recipient age, a higher recipient body mass index, and a recipient diagnosis of hepatitis C virus (HCV) were associated with a higher rate of procedures in all patients (Table 3). More than 24 months after transplantation, the procedure rates were higher for LDLT recipients versus DDLT recipients, but not to the point of statistical significance by conventional standards ($P=0.06$). The rate of procedures was significantly higher for recipients who had at least 1 Roux-type biliary anastomosis (risk ratio=2.97, $P=0.02$) or whose initial biliary complication was a stricture or a simultaneous leak and stricture (risk ratio=2.90, $P=0.02$).

TABLE 2. Types of Initial Biliary Complications and Times From Transplantation to Their Onset

	DDLT (n=189)	LDLT (n=356)*
No complication [n (%)]	142 (75.1)	215 (60.4)
Complication type [n (%)]	47 (24.9)	141 (39.6)
Leak [n/N (%)]	18/47 (38.3)	91/141 (64.5)
Stricture [n/N (%)]	28/47 (59.6)	46/141 (32.6)
Both [n/N (%)]	1/47 (2.1)	4/141 (2.8)
Time to onset (days)†		
Leak	11 (3-39)	14 (6-24)
Stricture	69 (32-217)	107 (55-278)
Both	80 (80-80)	19 (18-42)

*Chi-square tests were used for the proportions of each type of complication among recipients with biliary complications ($P=0.005$ for DDLT versus LDLT).
†According to *t* tests, there were no significant differences in the mean time to onset for any of the complication types between DDLT and LDLT. The data are presented as medians (with first and third quartiles in parentheses).

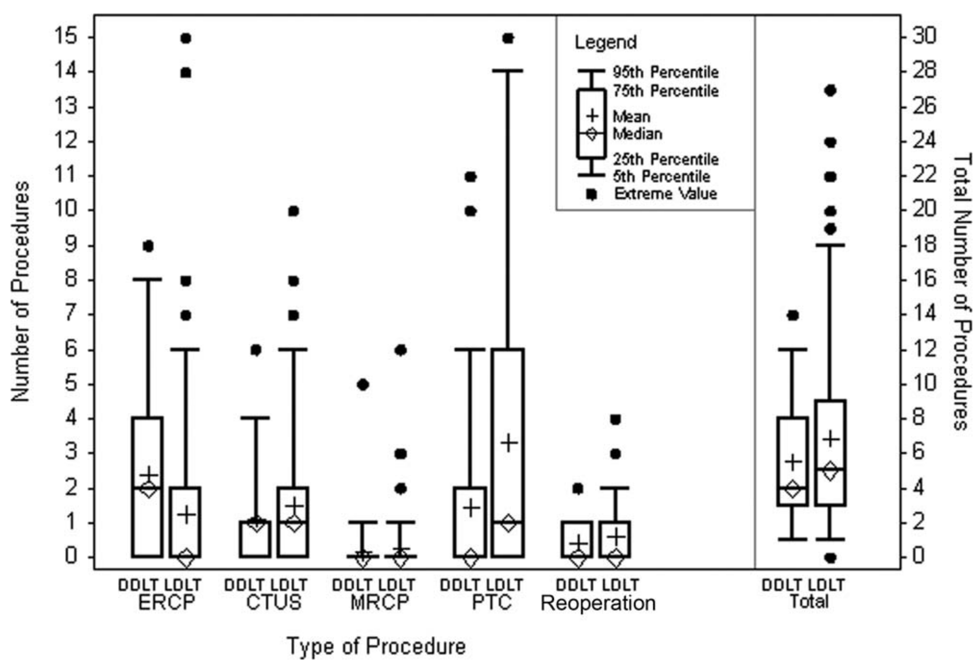

Figure 1. Number of procedures performed per patient to diagnose and/or treat biliary complications.

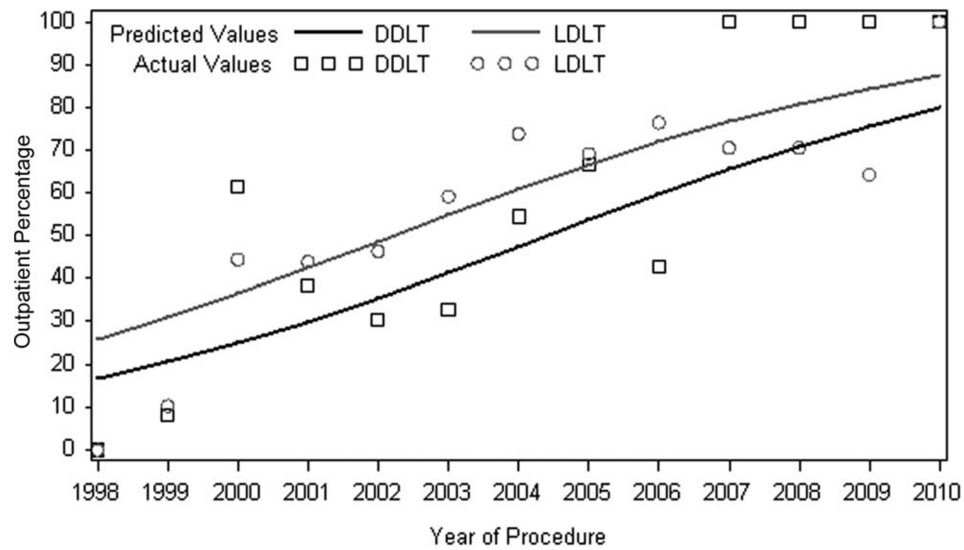

Figure 2. Procedures performed on an outpatient basis by year. The actual values were calculated by the calendar year; the predicted percentages are based on a logistic regression model.

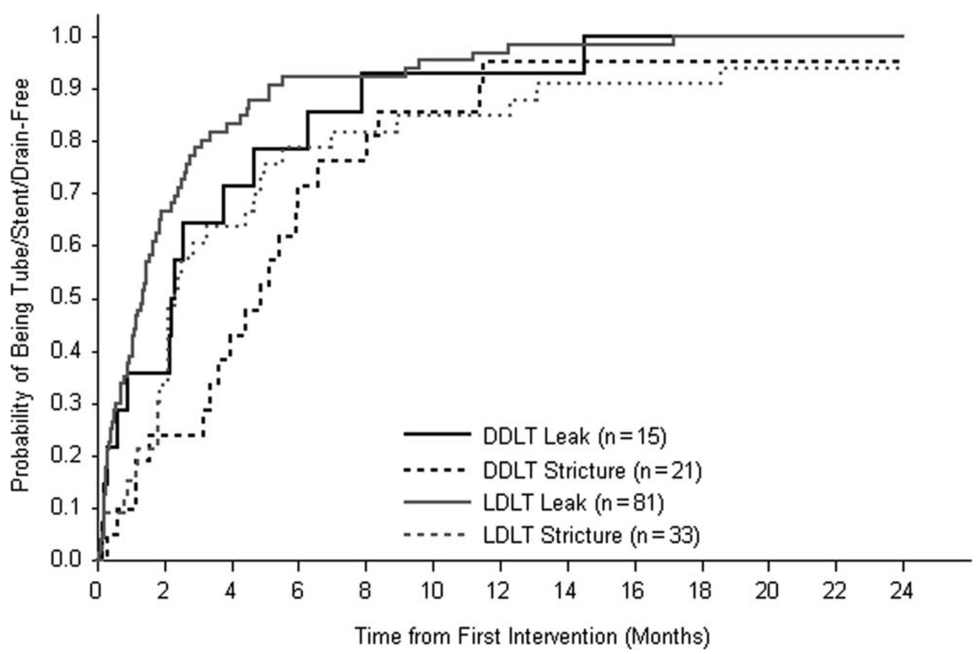

Figure 3. Probability of becoming tube-, stent-, and drain-free after the initial placement by the type of biliary complication and the type of transplant.

Association of Biliary Complications With Subsequent Graft Failure and Death

In the absence of biliary complications, the risk of graft failure was not significantly different for LDLT recipients versus DDLT recipients (HR=1.26, P=0.25). Once a biliary complication occurred, the risk of subsequent graft loss, adjusted for recipient age and diagnosis, donor age, and packed red blood cell use, increased (HR for DDLT=2.78, P<0.001; HR for LDLT=1.41, P=0.06). After a biliary complication, the rate of graft failure or death among DDLT recipients was approximately twice the rate among LDLT recipients (HR for graft failure=1.98, P=0.04; HR for mortality=1.99, P=0.05). However, when LDLT cut-surface leaks were excluded from the analysis, the rates of graft failure and death were no longer significantly different for LDLT and DDLT recipients (HR for

TABLE 3. Models of Rates of Biliary Complication Procedures per Month

	Estimate	Risk Ratio	*P* Value
Rates within first 2 years after transplantation			
Time since transplantation (per month)	−0.28	0.76	<0.001
Time since transplantation (per month^2)	0.01	1.01	<0.001
LDLT (with DDLT as reference)	0.19	1.21	0.15
Stricture or stricture plus leak as initial biliary complication (with leak only as reference)	0.26	1.30	0.045
Recipient age (per 10-year increase)	0.13	1.14	0.045
Recipient body mass index (per unit increase)	0.02	1.02	0.01
Recipient diagnosis of HCV	0.28	1.33	0.03
Rates more than 2 years after transplantation			
Time since transplantation (per month)	−0.02	0.98	0.02
LDLT (with DDLT as reference)	1.05	2.85	0.06
Stricture or stricture plus leak as initial biliary complication (with leak only as reference)	1.07	2.90	0.02
At least 1 Roux-type biliary anastomosis (with no Roux type as reference)	1.09	2.97	0.02

NOTE: The following variables were tested in the models but were not statistically significant: recipient sex and race, MELD score, medical condition at transplant, encephalopathy, ascites, donor age, and number of arterial anastomoses.

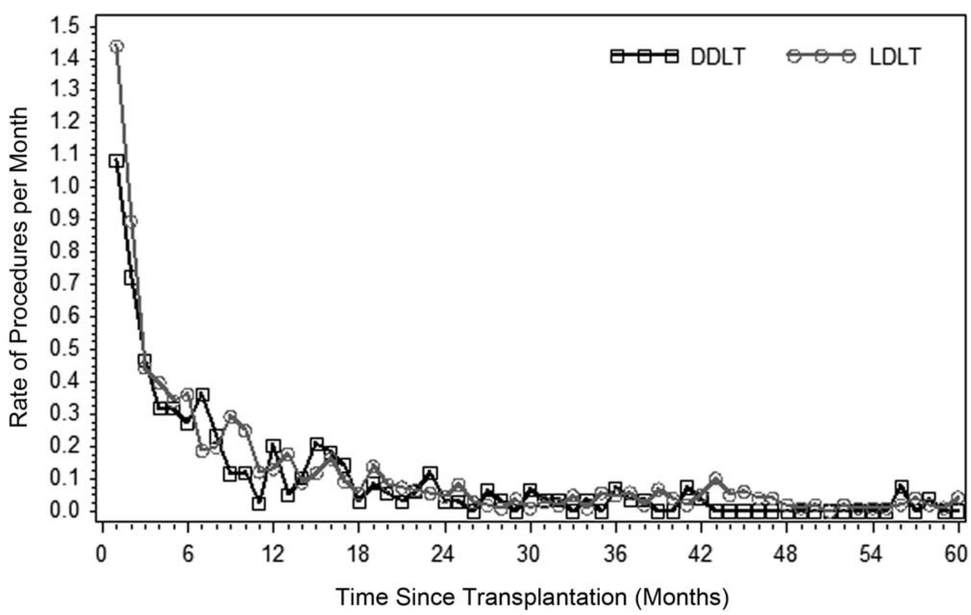

Figure 4. Rate of procedures by the time since transplantation.

graft failure=1.75, *P*=0.10; HR for mortality=1.69, *P*=0.15). All patients in this cohort who developed a biliary leak were at increased risk of developing a subsequent stricture (HR=1.79, *P*=0.01).

DISCUSSION

Biliary complications are the major cause of morbidity following LDLT.[7] Although these complications can be intractable and potentially fatal, the incidence varies widely among transplant centers.[8,9] The overall incidence of biliary complications ranges from 5% to 40%, and they are associated with aberrant donor anatomy and biliary ischemia.[10,11] At present, most biliary complications are diagnosed and treated with nonoperative techniques.[8] Several studies have retrospectively analyzed the long-term complete resolution of biliary leaks and/or strictures after therapeutic interventions.[5,12-14] However, the cumulative morbidity to the recipient in the form of the total number of procedures (invasive and noninvasive) and the time from the onset of the complication to its resolution have not been well documented. Most studies to date have evaluated the clinical efficacy of a specific procedure type and have not quantified all procedures required per patient as a result of a biliary complication. In this study, we sought to document the pathway to the resolution of biliary complications and to quantify the related procedures in LDLT and DDLT recipients.

Percutaneous strategies can be used to repeatedly dilate strictures, place and remove biliary stents, perform sphincterotomy, and update ductal imaging. Unfortunately, the cumulative morbidity to the recipient is generally not studied in a comparative timeline based on the graft type with anatomic and clinical management details used to provide a comparison of disability and/or human cost. Shah et al.[15] recently reported a series of 41 LDLT recipients who had biliary complications. They noted that all but 4 patients with strictures were managed with nonoperative interventions and that 96% were free of any biliary complications at the time of publication. However, 13 of 19 patients with a bile leak required reoperation. A similar study reported the outcomes of 1062 recipients, including 106 LDLT recipients; 224 developed a biliary complication treated by ERCP.[5] During the 10-year study period, more than 700 ERCP procedures were performed, with definitive success achieved in only 64% of the cases. Patients who received an LDLT graft or had both a leak and a stricture were less likely to respond to endoscopic therapy. Finally, a recent review from Korea reported that the success rate of endoscopic treatment for biliary strictures after LDLT ranged from 37% to 71%.[14]

We believe that the current study is the first to quantify the cumulative morbidity of biliary complications following LDLT in terms of the diagnostic and therapeutic procedures performed and the time to the resolution of complications. In the A2ALL cohort, the incidence of biliary complications was higher in the LDLT group. However, the average numbers of procedures performed per patient were similar for DDLT and LDLT recipients, and so were the average times from transplantation to complications and the times from the onset of complications to their resolution. The majority of biliary complications in all recipients were resolved within 6 months. However, 2 LDLT recipients had persistent unresolved biliary leaks after 24 months of treatment, and 1 DDLT recipient had an unresolved stricture after 2 years.

In this cohort, the incidence of biliary complications was higher in the LDLT group. Biliary strictures were the predominant manifestations of biliary complications in the DDLT group. Conversely, among LDLT recipients, nearly two-thirds of the complications were combinations of cut-surface bile leaks, which are a unique feature of the LDLT procedure, and anastomotic bile leaks. In DDLT and LDLT recipients, the occurrence of biliary leaks was associated with a significantly increased risk of subsequent strictures.

It is not surprising that the majority of invasive and noninvasive procedures were performed in the first 2 years after transplantation. In fact, this study revealed a learning curve of biliary complication management as increased experience was directly associated with a shorter time to resolution. Although there was a marked decline in the monthly rate of procedures after 24 months, it is important to note that it was not zero. Several LDLT and DDLT patients continued to require interventions for biliary complications up to 10 years after transplantation. As experience has accumulated over time, the rate of procedures performed to treat these complications on an outpatient basis has dramatically increased for both LDLT and DDLT.

We have identified several factors associated with a significantly higher rate of procedures in the first 2 years, including an older recipient age, a higher body mass index, and a primary diagnosis of HCV. However, the donor source (DDLT versus LDLT) was not significantly associated with procedure rates in this model. The occurrence of a biliary complication per se was associated with a higher risk of graft loss in both groups. This effect was greater in DDLT recipients when all biliary complications were considered, but it was not statistically significant when cut-edge leaks (which occur in LDLT but not with whole organ DDLT grafts) were excluded from the analysis.

Although these data were derived from 8 large transplant centers across North America via detailed chart reviews at each center, as well as the Scientific Registry of Transplant Recipients database, we acknowledge several limitations. The current data set is derived from a retrospective component of the A2ALL study and is of moderate size. During the 13-year study period, clinical practice patterns may have changed with respect to the ways in which these difficult problems are treated. Furthermore, the diagnostic/therapeutic approach to a specific problem, as well as the surgical techniques employed, may vary across centers. These differences may have influenced our results, but they are difficult to study.

Biliary complications are a formidable problem in liver transplantation, and their incidence is higher after LDLT. However, once a complication has occurred, we have shown that the number of required interventions and the time to complete resolution are similar for LDLT and DDLT recipients. These findings highlight the ongoing challenges of biliary complications after liver transplantation regardless of the donor source. Overall, these data refute the common impression that biliary complications are a more protracted problem and are less likely to be resolved after LDLT versus DDLT.

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