T-tube or No T-tube in Cadaveric Orthotopic Liver Transplantation: The Eternal Dilemma

Results of a Prospective and Randomized Clinical Trial

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Objective: To compare the incidence and severity of biliary complications due to liver transplantation after choledochocholedochostomy with or without a T-tube in a single-center, prospective, randomized trial.

Summary Background Data: The usefulness of the T-tube for end-to-end biliary anastomosis to reduce the incidence of biliary complications in patients undergoing liver transplantation has been controversial.

Methods: A per-protocol analysis was designed for liver recipients, who were randomly assigned to choledochocholedochostomy with (n = 95) or without (n = 92) a T-tube.

Results: The overall biliary complication rate was 22.5% (n = 42), with no difference between groups ($P = 0.35$). The majority (66.7%) of complications in the T-tube group were types I and II, whereas 50% were type IIIa and 44% were type IIIb in the non–T-tube group ($P < 0.0001$). Fewer anastomotic strictures were found in the T-tube group (n = 2, 2.1%) than in the non–T-tube group (n = 13, 14.1%; $P = 0.002$). No difference in anastomotic biliary leakage was observed between groups. Biliary complication–free survival rates showed that complications appeared earlier in the T-tube group. Graft and patient survival rates were similar in both groups.

Conclusions: Complications in the T-tube group were less severe and required less aggressive treatment. The incidence of anastomotic strictures was higher in patients with no T-tube. We recommend conducting choledochocholedochostomy with a rubber T-tube during liver transplantation in risky anastomosis and when the bile duct diameter is less than 7 mm.

This study is registered at http://www.clinicaltrials.gov: Clinical trial ID# NCT01546064.

Keywords: bile duct anastomosis, liver transplantation, T-tube

(*Ann Surg* 2013;258: 21–29)

Despite the long experience with liver transplantation (LT), biliary complications remain the Achilles' heel of the procedure due to the high rates of morbidity and mortality. The reported morbidity rate for full-size LT is 5% to 30% and the mortality rate is up to 10%.[1–3]

Although several factors can influence the outcome of biliary anastomosis, the bile duct reconstruction technique seems to be one of the most important, with the added advantage that it can be modified to obtain better results.[4] Unfortunately, no evidence is available about the gold standard bile duct reconstruction technique.

Until the 1990s, the most common biliary reconstruction technique for whole-organ deceased donor LT was choledochocholedochostomy (CCS) over a T-tube. In the 1990s, many centers started to perform biliary reconstructions with no T-tube, and several retrospective studies were published that showed good results with this technique.[5,6]

Usage of a T-tube remains controversial because of the different results that have been published in several randomized controlled trials[4,7–9] and in meta-analysis.[10–12]

The aim of this prospective and randomized study was to compare the incidence of biliary complications after CCS performed with or without a T-tube after deceased donor LT. The secondary aims were to evaluate the severity of complications and complication-free survival in both groups.

METHODS

A prospective, randomized, single-center study was designed to evaluate CCS with or without a T-tube in recipients of orthotopic liver transplantation (OLT).

On the basis of the results of previous studies and personal data, we assumed a 30% global incidence of biliary complications after CCS with a T-tube. All types of complication were considered, including life-threatening problems and minor incidents. A pretrial sample size of 100 patients per group is necessary to detect a 50% reduction, with a type 1 error rate of 5% and a type 2 error rate of 20% (PASS® 2008 edition).

This study was a per-protocol analysis trial in which only patients who completed at least 6 months' follow-up were included in the final analysis.

The trial protocol was approved by the committee for patient protection for biomedical research at our hospital. All patients were previously informed in detail about the procedure, and they provided written consent according to Spanish law.

Patients receiving a deceased full-size liver graft and older than 18 years were included. Preoperative exclusion criteria were age younger than 18 years, retransplantation, primary sclerosing cholangitis, fulminant hepatic failure, technical need for a hepaticojejunostomy (HJ), split or reduced-size grafts, transplantation of more than 1 organ, and living donation. Intraoperative reasons for excluding patients from the trial were a finding of a large difference (twice the size) in common bile duct diameters between the graft and the recipient or the technical need for a HJ.

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Disclosure: The authors declare no sources of support for this work, including grants, equipment, and drugs. No funding was received for this work from any organization.

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ISSN: 0003-4932/13/25801-0021
DOI: 10.1097/SLA.0b013e318286e0a0

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Surgical Procedure

The surgical procedure was highly standardized. The same team recovered all grafts with the standard classic technique described by Starlz et al.[13] The bile duct was flushed with 150 mL of saline before perfusion. Celsior (Genzyme® polyclonals S.A.S.) preservation solution was used; 3 L was used for portal perfusion and 4 L for aortic perfusion before procurement.

All OLTs were performed exclusively by 4 surgeons with personal experience of more than 200 LTs by the beginning of the study.

A total hepatectomy with caval preservation was performed in all patients. The graft was flushed with 500 mL of 37°C saline solution 0.9% (Grifols®) immediately before portal reperfusion. After arterial anastomosis and the assessment of portal and arterial flow and donor and recipient bile duct diameters, each patient was randomly assigned to 1 of 2 groups (CCS with or without a T-tube). Randomization was performed with sealed envelopes, which were opened by a scrub nurse.

The CCS was performed by an end-to-end anastomosis in the non–T-tube group. The posterior face was made with a 6/0 polydiaxanone running suture, and the anterior face was performed with 6/0 polydiaxanone interrupted sutures. The CCS was performed in the same way in the T-tube group, but once the posterior face was finished, a T-tube was placed into the biliary duct through the recipient's bile duct, with the short branch extending into the recipient side and the long branch stenting both the anastomosis and the graft bile duct. The patency of the anastomosis was always tested with saline after suturing the small perforation in the bile duct around the tube with interrupted sutures. The T-tube was externalized through the abdominal wall in the middle line under the xiphoid, fixed to the skin, and connected to a collecting bag. An 8-Fr latex tube (Portex® Ltd. Hythe, Kent, United Kingdom) or a 2.5-mm rubber tube (Teleflex® Medical, Willy Rüsch GmbH) was used. The allocation of T-tubes was sequential: the first 57 patients received a latex tube and the remaining 43, a rubber tube.

All patients underwent daily liver function tests during the first week after surgery, and Doppler ultrasonography was performed during the first postoperative 24 to 48 hours and repeated on postoperative days 7 to 10. In patients with no T-tube, the abdominal drain was removed on postoperative day 4 if no bile was found in the collecting bag. A cholangiography was performed on postoperative day 7 in patients with a T-tube. If the postoperative course was uneventful, the cholangiography demonstrated a sufficient outflow into the duodenum, no leakage was present, and the bilirubin levels had decreased adequately, the T-tube was closed and the abdominal drain was removed 24 hours later if no bile was found in the collecting bag. Patients were discharged with the T-tube closed, and a second cholangiography was performed routinely after 12 weeks. The T-tube was removed if no abnormality was detected. Our follow-up protocol in the outpatients also includes a Doppler ultrasound every 3 months for the first year and once a year after the second follow-up year to rule out arterial stenosis or thrombosis. Vascular computed tomography and arteriography are complementary radiological tests available to confirm the diagnosis. Cholangiomagnetic resonance imaging was ordered for all patients at month 6 posttransplantation.

Definitions

All primary, secondary, and inherent T-tube complications were recorded prospectively. Only the most severe complication for each patient was considered in evaluating the results for the main endpoint.

Primary complications included bile duct anastomosis leaks and stenosis.

A bile leak was diagnosed in the presence of fever and abdominal pain and confirmed by intra-abdominal biliary collection via ultrasound-guided puncture. Bile drainage into intraoperatively placed drains was also considered to be diagnostic of a bile leak. A contrast extravasation radiological image during x-ray cholangiography through the T-tube was also considered to indicate a bile leak, even if it was not associated with clinical symptoms or abdominal collection detected on an abdominal ultrasound.

The way we approach the diagnosis of biliary strictures is as follows: when results of blood tests are abnormal (i.e, increased bilirubin, increased cholestasis enzymes), the first radiological exploration we run is a Doppler abdominal ultrasound to rule out any hepatic artery problem, mainly thrombosis, and a cholangiography through T-tube when present, to map the bile duct. To patients with no T-tube and high suspicion of bile duct stenosis, a cholangiomagnetic resonance imaging is asked. Simultaneously, other causes of cholestasis are ruled out, such as cytomegalovirus/hepatitis C virus infections, by determining the viral load. The immunosuppressive blood levels are also ordered and when in doubt, a biopsy is requested to confirm a rejection. The endoscopic retrograde cholangiopancreatography is used mainly for treatment purpose or exceptionally as the last step in the diagnose algorithm.

Referring to radiological findings, we take 2 situations: (1) An increase in the donor bile duct diameter with no increase in the recipient bile duct diameter, when both are compared with the initial size at the time of transplant procedure. (2) A decrease of the lumen in the bile duct anastomosis, with an increase in the donor bile duct size. Therefore, to demonstrate the presence of an anastomotic stricture, we always compared the donor and recipient posttransplant bile ducts diameters with those at the moment of transplantation procedure (measured and written in the surgical record). Any significant increase in the donor bile duct size with no variation of recipient bile duct size is considered due to an anastomotic stenosis.

Secondary complications included nonanastomotic bile leakage or stenosis were confirmed by imaging procedures.

Ischemic-type biliary strictures were diagnosed by cholangiomagnetic resonance imaging or endoscopic retrograde cholangiopancreatography and were characterized by intrahepatic strictures in the absence of hepatic artery thrombosis.

Other secondary complications included choledocholitiasis or Vater papilla dysfunction; they were diagnosed by the increase in bilirubin and cholestatic enzyme levels and confirmed by imaging.

Complications inherent to the T-tube were bile leaks after T-tube removal and cholangitis after x-ray cholangiography through the T-tube.

A bile leak after T-tube removal was suspected symptomatically by peritoneal irritation and/or fever in the first 24 hours after removal of the T-tube and confirmed by ultrasonography.

Cholangitis was defined by elevated infectious parameters or the presence of fever in combination with elevated cholestatic parameters after an x-ray cholangiography through the T-tube.

All complications were recorded for each patient and stratified according to the Clavien-Dindo[14] classification: grade I included complications inducing any deviation from the normal postoperative course; grade II included complications requiring pharmacological treatment; grade III included complications requiring surgical, endoscopic, or radiological intervention; grade IV included life-threatening complications requiring intermediate or intensive care unit management; and grade V denoted the death of the patient.

Thus, complication severity was defined not by the diagnosis of the complication but by the treatment required.

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Data Collection

Demographic data, pathological conditions, comorbidities in donors and recipients, etiology and severity of cirrhosis in recipients, and technical and surgical variables were recorded prospectively. Postoperative complications, biliary complication–free survival period, and the treatment required to resolve the complication were also recorded.

Statistical Analyses

Data were analyzed by descriptive statistical tests using the SPSS® software (version 12.0; SPSS Inc., Chicago, IL). Quantitative variables are presented as means with standard deviations or medians. Comparisons of data were performed with the Fisher exact probability test, the χ^2 test, and the Mann-Whitney test, as appropriate. $P < 0.05$ (2-sided) was considered statistically significant.

The probability of being free of a biliary complication and patient and liver graft survival curves were estimated by the Kaplan-Meier method. Survival rates were compared between the 2 groups using the log-rank test. Logistic regression and Cox regression were used in the specific study of anastomosis stenosis. Data are expressed as means ± standard deviations in the text and tables. Categorical variables are expressed as numbers frequencies/percentages).

RESULTS

Between May 2008 and July 2010, 233 patients underwent LT at La Fe University Hospital, and 200 OLT patients were randomly assigned to the 2 groups (Fig. 1).

Thirty-three patients were excluded from randomization because of pediatric LT (n = 11), liver hepatic failure (n = 4), retransplantation (n = 6), primary sclerosing cholangitis (n = 2), multiple-organ transplantation (n = 5), and discrepancy in bile duct size or the technical need for a HJ (n = 5).

Thirteen patients were excluded from the final analysis because the main variable did not last long enough to be studied. Causes of patient exclusion were primary graft dysfunction and urgent retransplantation (n = 4), hepatic artery thrombosis and urgent retransplantation (n = 1), and postoperative mortality (n = 8). Finally, 187 patients were included. In the first group (n = 95), an end-to-end CCS with a T-tube was performed, whereas the same CCS technique was performed but with no T-tube insertion in the second group (n = 92). All patients allocated to T-tube group, succeeded in the insertion of a T-tube. In the first 53 patients of the T-tube group, a latex T-tube was inserted and in the remaining 42, a rubber T-tube was used.

The median follow-up period was 22.5 (range, 6–35 months) months, with no significant difference between the groups.

Baseline demographic characteristics and disease-related donor and recipient data were similar between the groups. No difference in intraoperative technical aspects was observed between the groups (Table 1).

Biliary Complications

The overall biliary complication rate was 22.5% (n = 42); it was 25.5% (n = 24) in the T-tube group and 19.6% (n = 18) in the non–T-tube group ($P = 0.35$) (Table 2).

The classification of biliary complications according to severity showed that the majority (66.7%) of complications in the T-tube group were types I and II, whereas 50% were type IIIa and 44% were type IIIb in the non–T-tube group ($P < 0.0001$; Table 3).

Primary Complications

Fifteen patients (8%) developed an anastomotic biliary stenosis: 2 (2.1%) in the T-tube group and 13 (14.1%) in the non–T-tube group ($P = 0.002$). In the T-tube group, the absolute risk reduction for anastomotic stenosis was 12% [95% confidence interval (CI): 4–20] and the relative risk was 0.15 (95% IC: 0.03–0.64). The relative risk reduction was 85% (95% CI: 36–96). The number needed to treat was 8 (95% CI: 5–23).

A difference in donor and recipient bile duct diameters was observed between the groups of patients with and without an anastomotic stenosis. The median donor bile duct diameter was 5.6 ± 2.6 mm in the group of patients with stenosis (n = 15) and 7 ± 2.6 mm in the group of patients without stenosis (n = 172; $P = 0.018$). The median recipient bile duct diameter was 5.8 ± 2 mm in the group of patients with stenosis and 7.4 ± 2.8 mm in the group without stenosis ($P = 0.036$).

In the Cox regression, the 2 variables with an independent risk factor for anastomotic stenosis are the diameter of bile duct (either of donor or recipient) and the use of T-tube in bile duct anastomoses (Table 4).

When a categorization of patients according to the donor bile duct and/or recipient bile duct diameter was done, in the group with any of the diameters less than 7 mm, stenosis was detected in 9.4% (3% in T-tube group and 15.3% in non–T-Tube group) ($P = 0.014$). The percentage of anastomosis stenosis detected among patients with any of the bile duct diameters more than 7 mm was 3.3% (7.4% in the group with non-T-tube and 0 in the patients with T-tube) ($P = 0.107$). In the logistic regression, donor bile duct less than 7 mm is a risk factor (odds ratio >1) (Table 5).

An HJ was conducted in 10 patients: 2 (100%) in the T-tube group and 8 (61.5%) in the non–T-tube group. The other 5 patients in the non–T-tube group were treated by endoscopic dilatation and temporary prosthesis in 3 cases (23.1%) and percutaneous dilatation in 2 cases (15.4%).

A bile anastomotic leak was diagnosed in 7 patients (4%): 4 (4.2%) in the T-tube group and 3 (3.2%) in the non–T-tube group, with no difference between the groups.

The first therapeutic measure was to open the T-tube in all patients in the T-tube group. This procedure was sufficient to resolve the bile leak in 2 cases (50%). The remaining patients, 2 (50%) in the T-tube group and 3 (100%) in the non–T-tube group, required percutaneous biliary drainage. Antibiotic treatment was administered in all cases.

Secondary Complications

In the entire series, 6 patients (3.2%) had secondary complications.

Choledocholithiasis was diagnosed in 3 patients (3.7%), all of them in the non–T-tube group. All were treated by endoscopic retrograde cholangiopancreatography and endoscopic sphincterotomy.

Two nonanastomotic biliary leaks (2.2%) occurred in the non–T-tube group and one of them required a retransplantation. A nonanastomotic stenosis (1.1%) was diagnosed in the non–T-tube group. No artery stenosis or thrombosis was diagnosed in the patients included in the final analysis.

T-tube–Inherent Complications

Fifty-seven patients with a latex T-tube and 43 patients with a rubber T-tube were randomized initially, although only 95 patients were finally included (53 with latex T-tube and 42 with rubber T-tube). Twenty-two (23%) of these patients had some type of T-tube–related complication.

Three patients (3%) had an intraperitoneal bile leak at the T-tube insertion site in the bile duct. These leaks were detected on x-ray cholangiography at postoperative day 7 and were resolved spontaneously by leaving the T-tube open for several days.

Thirteen patients (13.6%) were diagnosed with an intra-abdominal bile leak after T-tube removal at the third month after

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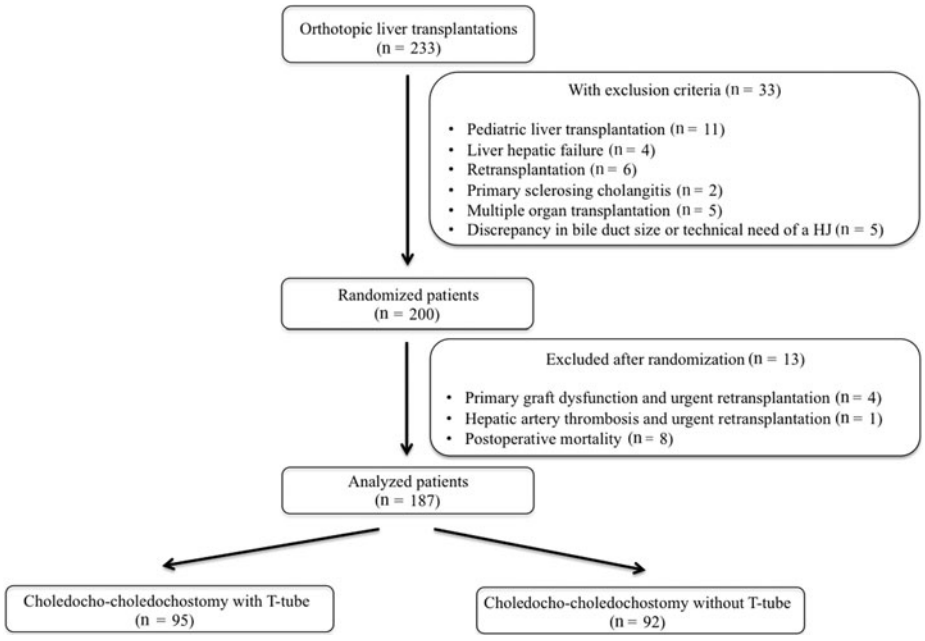

FIGURE 1. Flow of participants of the study.

TABLE 1. Comparison of Donor, Recipient, and Surgical Variables in the Study Groups

	T-tube (n = 95)	No T-tube (n = 92)
Donor variables		
Sex (male/female)	54/41	60/32
Age (mean ± SD)	55 ± 18.1	55 ± 16.3
Exitus etiology (%)		
Cerebrovascular	67.4	74
Trauma	22.1	16.1
Others	10.5	10
BMI (mean ± SD)	27 ± 4.1	27 ± 5.5
ICU, d (mean ± SD)	3.1 ± 4.6	3.49 ± 4.5
Cardiac arrest (%)	12	6
Na (mEq/L) (mean ± SD)	148.7 ± 10.9	149.5 ± 9.8
Hypotension episodes (%)	47	47
Recipient variables		
Sex (male/female)	75/20	66/26
Age (mean ± SD)	53.7 ± 7.68	53.2 ± 8.68
Disease etiology (%)		
HCV	47	45
Alcoholic	43	36
HCC	37	41
Child class (%)		
A/B/C/NA	21/36/42/1	23/39/38/0
Blood group (%)		
O/A/B/AB	45/48/5/2	41/47/9/3
MELD score (mean ± SD)	17.3 ± 7.8	15.3 ± 7.8
BMI (mean ± SD)	27 ± 4.3	27 ± 7.8
Surgical variables		
Piggyback hepatectomy (%)	100	100
Cold ischemia time (min)	316.4 ± 157.6	297.1 ± 143.8
Warm ischemia time (min)	39.3 ± 13.8	38.5 ± 14.1
Surgical procedure time (min)	252.6 ± 43.4	246.4 ± 47.1
Donor bile duct size (mm)	7.1 ± 2.1	6.8 ± 2.3
Recipient bile duct size (mm)	7.3 ± 2.7	7.3 ± 2.8
RBC transfusion (units)	2.6 ± 2.1	2.7 ± 2.5
Blood self-transfusion (ml)	679.4 ± 466.3	618.4 ± 367.8

BMI indicates body mass index; ICU, intensive unit care; HCC, hepatocellular carcinoma; HCV, hepatitis C virus; MELD, model for end stage liver disease; Na, sodium; NA, not applicable; RBC, red blood cells.

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TABLE 2. Complication Rates

	T-tube (n = 95)	No T-tube (n = 92)	*P*
Biliary complications (patients)	24 (25.3%)	18 (19.6%)	ns
Primary complications (events)			
Anastomotic bile leak	4 (4.2%)	3 (3.3%)	ns
Anastomotic stenosis	2 (2.1%)	13 (14.3%)	0.002
Secondary complications (events)			
Nonanastomotic bile leak	0	2 (2.2%)	ns
Nonanastomotic stenosis	0	1 (1.1%)	ns
Choledocholithiasis	0	3 (3.7%)	ns
T-tube inherent complications (events)	22 (23.2%)	—	
Bile leak after T-tube removal	13 (13.6%)	—	
Cholangitis	6 (6.3%)	—	
Bile leak in insertion of T-tube	3 (3.1%)	—	

ns indicates not significant.

TABLE 3. Classification of Complications According to Severity in the Study Groups

	Clavien-Dindo Classification						
	I	II	III a	III b	IV	V	Total
T-tube (n = 95)	4 (16.6%)	12 (50%)	6 (25%)	2 (8.3%)	0	0	24 (57.1%)
No T-tube (n = 92)	0	0	9 (50%)	8 (44.4%)	1 (5.6%)	0	18 (42.8%)
Total (n = 187)	4 (16.6%)	12 (28.6%)	15 (35.7%)	10 (23.8%)	1 (2.4%)	0	42 (100%)

TABLE 4. Cox Regression: Equation Variables

	Hazard Ratio	*P*	95% Confidence Interval
Use of T-tube	0.19	0.032	0.04–0.86
Bile duct diameter (donor or recipient)	0.72	0.045	0.52–0.99

TABLE 5. Logistic Regression: Equation Variables

	Odds Ratio	*P*	95% Confidence Interval
Use of T-tube	0.19	0.008	0.02–0.57
Bile duct diameter <7 mm (either donor or recipient)	3.96	0.025	1.18–13.25

transplantation. Twelve out of the 13 patients with bile leak after T-tube removal had latex T-tubes (12/53, 22.6%) and one patient had a rubber T-tube (1/42, 2.4%) ($P > 0.0001$). The initial therapeutic approach was conservative in all patients and included antibiotic and analgesic treatment. In 9 patients (69.3%), this approach was sufficient to resolve the complication, but 4 patients (30.7%) required percutaneous drainage and 1 underwent endoscopic sphincterotomy and insertion of a biliary prosthesis. None required a surgical procedure.

Cholangitis was diagnosed in 6 patients after x-ray cholangiography through the T-tube. Antibiotic treatment was sufficient to resolve the complication in all cases.

Patient and Graft Survival

The cumulative 1-, 2-, and 3-year patient survival rates were 90%, 88%, and 72% in the T-tube group and 85%, 82%, and 82% in the non–T-tube group (log-rank test = 0.19; Fig. 2). No mortality was directly related to biliary complications or T-tube use.

Actuarial 1-, 2-, and 3-year graft survival rates were 89%, 87%, and 87% in the T-tube group and 84%, 80%, and 80% in the non–T-tube group (log-rank test = 0.16; Fig. 3).

Biliary Complication–Free Survival

The most severe complication in each patient was considered in calculating biliary complication–free survival rates.

The cumulative 1-, 3-, 6-, and 12-month biliary complication–free survival rates were 92%, 89%, 75%, and 75% in the T-tube group and 96%, 88%, 85%, and 81% in the non–T-tube group (log-rank test = 0.36; Fig. 4).

Biliary complications occurred in the first 6 months after LT in the T-tube group, whereas they appeared within the first 12 months after LT in the non–T-tube group. No postoperative mortality was attributable to biliary complications.

DISCUSSION

Biliary complications, once considered the technical Achilles' heel of OLT, remain a common source of morbidity and mortality. Early studies by Starzl et al[15] and Calne et al[16] reported morbidity rates of 34% to 50% and mortality rates of 25% to 30%. With improvements in organ selection, retrieval, preservation, immunosuppression, and implantation techniques, such complications have been reduced dramatically. However, biliary complications still occur in 5% to 30%

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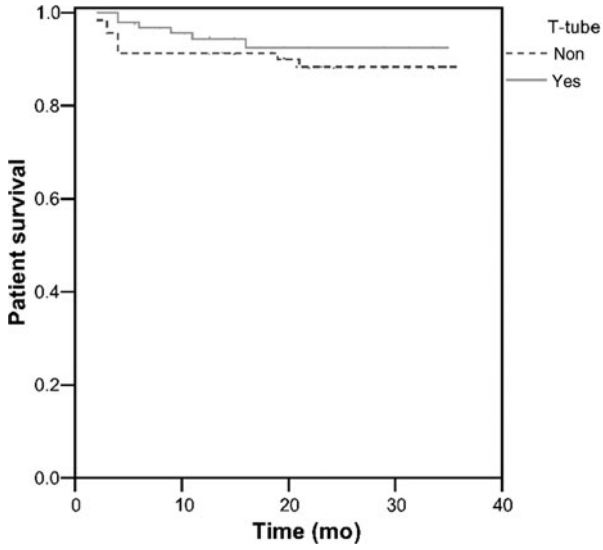

FIGURE 2. Patient survival in the study groups.

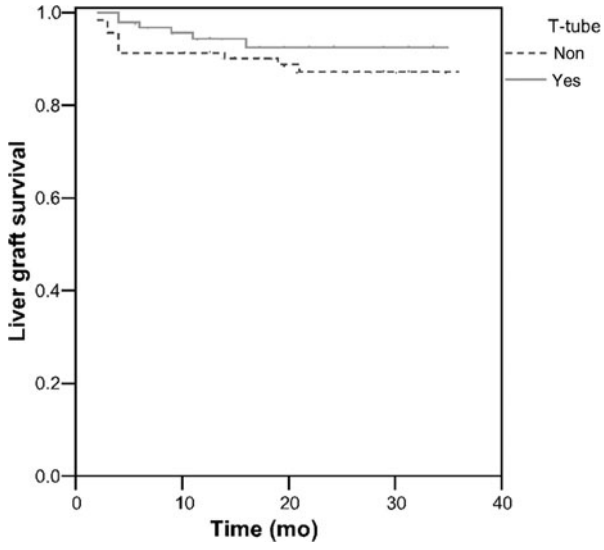

FIGURE 3. Liver graft survival in the study groups.

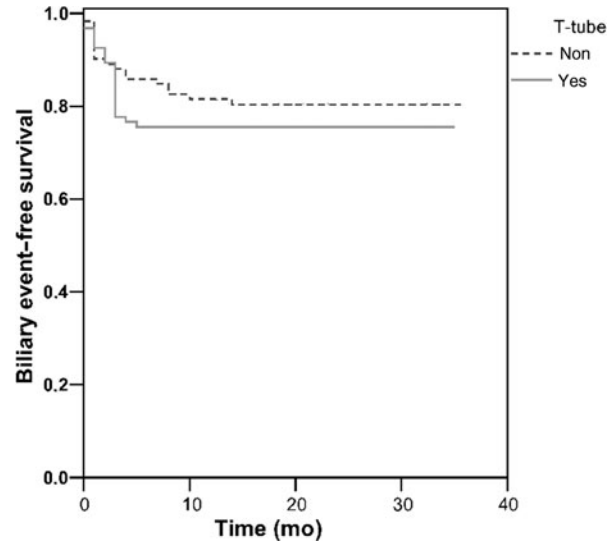

FIGURE 4. Biliary complication–free survival in the study groups.

of patients after whole-organ OLT, resulting in mortality rates of up to 10%.[1–3] The type of biliary anastomosis is a key factor affecting the risk of developing biliary complications. The technique can be chosen on the basis of several factors, including the basal disease that led to the transplant procedure, the sizes of the donor and recipient biliary ducts, retransplantation, prior surgery on the biliary duct, and surgeon preference. No consensus exists for the best approach to biliary reconstruction.[12] Many biliary reconstruction techniques have been described, including choledochoduodenostomy, end-to-end CCS, side-to-side CCS, and Roux-en-Y HJ, associated with or without the use of stents or a T-tube (Kehr drain). The end-to-end CCS technique is the most commonly adopted approach in patients with a healthy biliary duct and symmetric calibers, and it is the technique of choice in our surgical team. The advantage of this technique is the preservation of the natural sphincter mechanism, which acts as a barrier against intestinal secretions and bacteria, facilitating future endoscopic therapy when required.[17]

Nevertheless, the value of T-tube use has been questioned. A T-tube drainage has traditionally been used for patients undergoing OLT to provide easy access to the biliary tree and lower the pressure in the biliary system, which may be elevated in the case of stenosis at the anastomotic site or because of dysfunction of the Oddi sphincter.[18,19] In addition, a T-tube helps monitor the quality and output of bile and may reduce the incidence of late anastomotic biliary strictures and the need for surgical repair.[4,8,9,19] However, some practitioners argue that the use of a T-tube lengthens surgery time, leads to patient discomfort, increases the risk for a fistula in the drain orifice, and can cause cholangitis after cholangiography. A risk also exists for T-tube displacement and possible biliary obstruction and peritonitis due to the delayed formation of a fibrous trajectory to allow safe removal as a result of immunosuppression.[8,20,21] The incidence of biliary drain–related complications is 10% to 22%, with bile leaks occurring in 5% to 15% of patients after bile drain removal.[8,22–24] Systematic use of a T-tube has not ceased to be a controversial issue because it is associated with inherent complications. For this reason, many groups have abandoned its systematic use, and several retrospective studies published in the 1990s suggested that biliary reconstruction by means of a CCS with no T-tube led to excellent results due to the avoidance of inherent T-tube complications.[6,20,21,25–27]

In the beginning of our LT program in 1991, biliary reconstruction was systematically performed by means of a CCS with a latex T-tube. Because of the morbidity inherent in its use and with the support of good results for biliary reconstruction with no T-tube reported in retrospective studies, together with the shortage of prospective randomized studies and meta-analyses comparing the benefits and drawbacks of systematic T-tube use,[7,8,10,28] we decided to design a prospective study after more than 1500 liver transplants were performed at our institution. The goals of this study were to determine the total number of biliary complications for both types of anastomosis, to grade their severity, and to assess the way in which they were resolved. Data collected during the period after transplantation, when complications are diagnosed and patient and graft survival can be assessed according to the type of anastomosis, are also important to describe the advantages and disadvantages of T-tube use.

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The biliary reconstruction technique we used was an end-to-end CCS, which we perform systematically. The added value of this study consists of its randomized, prospective, single-center design, with a sufficiently large number of cases to obtain statistically significant conclusions. The study was also quite uniform, as only 4 surgeons performed all anastomoses with the same technique.

Only 4 published prospective and randomized trials[4,7–9] have examined the advantages and disadvantages of T-tube use in end-to-end CCS, and they have presented an incoherent scenario with different results and conclusions.

The first conclusion we can get in our study is that the number of patients with biliary complications is quite similar in both groups (25.3% vs 19.6%, P = ns), but in a deep analysis of the kind of complications, we found some differences. Anastomotic stenosis rate is clearly higher in the no T-tube group (n = 13, 14.3%) than in 2 patients (2.1%) in the T-tube group. Our results are similar to those of these prospective studies of Nuño et al[9] and Vougas et al.[4]

We firmly believe that the types of complication differ qualitatively according to T-tube use. More anastomotic stenosis occurred when no T-tube was used. A difference in biliary leakages can also be observed between both groups, but it is worth noting that although the rate of bile leak after T-tube removal is 13.6% in the group of T-tube patients, and logically 0 in the no T-tube group, the rate of anastomotic bile leaks is similar in both groups (4.2% vs 3,3%, P = ns).

A French multicenter study by Scatton et al,[8] showed a greater impact on the controversial nature of systematic T-tube use during biliary reconstruction. That study showed higher morbidity with T-tube use. Complications were not categorized according to severity, but 60% of all biliary complications were directly related to the T-tube and the most frequent complication was cholangitis. In our study, a rate of 23.2% of complications was inherent to the use of a T-tube and 6.3% of patients developed cholangitis, even with the systematic use of antibiotic prophylaxis before the procedure. In the multicenter study by Scatton,[8] the number of surgeons performing the anastomoses was not reported. On the contrary, only 4 surgeons with a standardized biliary anastomosis technique and with a great amount of personal cases performed the anastomosis in our study. All the patients allocated to T-tube group succeeded in receiving it and no malposition of the T-tubes was recorded. This fact highlights the importance of the experience of the surgeon in the surgical technique to obtain better results.

An important aspect to consider in the design of our study was that we evaluated the efficacy of the T-tube not only by analyzing the total number of complications but also by stratifying the complications according to their severity and the type of therapeutic approach. The Clavien-Dindo classification, used for general postoperative complications, synthesizes all these aspects; thus, we used it to stratify complications in the groups.[14]

Although the complication rate was higher in the T-tube group of the French study,[8] the number of reoperations was similar in both groups (7.7% in T-tube group vs 8.8% in non–T-tube group). Our results differed from these findings but were similar to those of other prospective studies,[4,9] as we recorded a higher number of surgical reoperations and complex treatments in the non–T-tube group (all complications were included in Clavien-Dindo types III and IV) than in the T-tube group (66.6% of complications were Clavien-Dindo types I and II).

Therefore, not only the rate of different types of biliary complications but also their severity are important to be described to clarify whether T-tube must be recommended.

The complexity of complications seemed to differ between the 2 groups of patients, as patients with no T-tube required more invasive therapeutic procedures to resolve the complications.

The more frequent complication inherent to T-tube is bile leak after T-tube removal. Reported incidences of biliary drain–related biliary complications range from 10% to 22%, with a bile leak occurring after bile drain removal in 5% to 15% of patients.[8,22–24] This complication could be due to the inadequate development of a fibrous fistulous tract along the course of the drain as a result of impaired fibrogenesis under immunosuppression caused by steroids.[29] Several measures have been proposed to reduce the incidence of biliary leaks after bile drain removal. Experimental evidence has demonstrated that the material used for T-tube manufacture affects the quality of the fibrous fistula formed.[30,31] This finding is supported by clinical evidence that polyvinyl chloride or hypoallergenic latex T-tubes (such as those coated with silicon) increase rates of biliary peritonitis after T-tube removal compared with red rubber or normal latex T-tubes, as the former increase the time required to form a mature tract.[32] In OLT, the use of rubber T-tubes instead of silicone T-tubes has been proposed to reduce such complications.[18]

In this study, 2 types of T-tube materials were used. In the beginning, latex T-tube was used (the one that traditionally we had been using in our unit) and in the middle of the series, a preliminary analysis of the results showed us a high rate of biliary leakage after T-tube removal (12/53); so, we decided to change the T-tube material and used a rubber T-tube sequentially in the following patients allocated to T-tube group.

Our results support that proposal, as we found a great difference in the rates of bile leakage after T-tube removal depending on T-tube material (22.6% with latex vs 2.4% with rubber). The superiority of latex and rubber material on T-tubes over silicon had been demonstrated,[32] but we recommend only rubber T-tubes after having analyzed our results.

More recently, Weiss et al[28] reported a randomized trial to side-to-side CCS with or without a T-tube. Patients in the T-tube group received a 2.5-mm rubber T-tube, which was removed after 6 weeks. The authors reported no bile leak after T-tube removal. Although the rates of biliary leakage and stricture did not differ between the 2 groups, the number of overall biliary complications was significantly higher in the non–T-tube group. These authors recommended the systematic use of T-tubes.

Amador et al[7] published a rate of 37.7% of T-tube–related complications. Ten patients (20%) developed biliary leakage after T-tube removal, 6 required reoperation, and 8 developed cholangitis after T-tube removal. The cost of therapeutic procedures was €28.232 in the T-tube group versus €16.088 in the non–T-tube group (P < 0.05). The analysis of therapeutic procedure costs makes that study interesting, but we consider that their rate of surgical procedures to treat bile leaks after T-tube removal was too high (60%). This is an important issue because each center has its own action protocol to treat biliary complications. In our series, no patient required a surgical procedure, and conservative, endoscopic, or radiological treatment usually resolved biliary complications. In the study by Amador et al[7], treatment costs were higher in the T-tube group and were influenced by these complications considering that, excluding those patients with bile leakage after T-tube removal, a surgical procedure was performed 1 one patient in the T-tube group and in 4 patients in the non–T-tube group. We have never treated patients with biliary leakage after T-tube removal by a surgical reoperation. Percutaneous drain guided by ultrasound has always been adequate to treat such complication. Of course, this approach decreases the severity and the costs of the complication because the treatment is much less invasive for patients.

Two recent meta-analyses reviewed the usefulness of the T-tube for CCS in OLT. Sotiropoulos et al[10] concluded that outcomes were equivalent in the 2 groups with respect to anastomotic bile leaks or fistulas, choledochojejunostomy revisions, dilatation and stenting, and mortality due to biliary complications. The non–T-tube group had

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better outcomes when considering cholangitis and peritonitis, and the T-tube group showed superior results for anastomotic strictures and a favorable trend for the number of overall biliary complications. Similar results were reported by Rieddiger et al,[11] who found no significant difference between groups in the number of overall biliary complications. Conversely, biliary strictures were significantly more common in the group of patients who underwent reconstruction with no T-tube. Thus, although reconstruction of the biliary tree with a T-tube prevents the occurrence of biliary strictures and may reduce long-term morbidity with respect to late strictures, no clear evidence favors the use of a T-tube during OLT.

If we could reduce the complications inherent to T-tube use, it might become routine due to its potential protective effect against anastomotic stenosis. In our experience, we consider that the protective effect of the T-tube on the development of stenosis is clinically relevant. By using the T-tube in 8 patients (number needed to treat), one anastomotic stenosis might be avoided and so, the therapeutic effort to obtain a benefit does not seem to be very high. An analysis of the relative risk value shows a 15% value, which means that in patients with T-tube, we could get to diagnose only 15% of strictures that we would diagnose without using a T-tube, and this is a relevant result from the clinical point of view. Moreover, as shown in Table 4, the use of T-tube has an influence in the prevention of anastomotic stenosis.

Other benefits of T-tube use may lead to its development into an excellent tool, such as the ability to monitor bile excretion to control hepatic function in the first 7 posttransplantation days, to decrease the pressure in the biliary tree, and to easily and cheaply access the bile duct.

As mentioned earlier, to reduce intra-abdominal bile leakage after T-tube removal (main inherent T-tube complication), published results and our own experience recommend the use of a rubber T-tube but not a silicone or latex T-tube.[18,30–32]

Cholangitis is another important complication inherent to T-tube use. Antibiotic prophylaxis seems insufficient to reduce the rate of cholangitis.[8,20] We agree with that statement because the systematic use of antibiotic before the procedure could avoid the diagnosis of 6 cholangitis episodes in our series. The only effective measure is to minimize T-tube manipulation and the number of cholangiographies performed.

After analyzing the advantages and disadvantages of T-tube use and seeking to determine how to minimize the morbidity inherent in its use, we wondered about the real impact of anastomotic stenosis. In a meta-analysis of 639 patients by Riediger et al,[11] stenosis was described in 31 (9.7%) patients in the non–T-tube group and 14 (4.3%) patients in the T-tube group; thus, 17 (2.7%) patients benefited from receiving a T-tube in terms of stenosis development. In our study, greater differences were observed between the 2 groups; an anastomotic stenosis developed in 2 (2.1%) patients in the T-tube group and 13 (14.1%) patients in the non–T-tube group.

It would also be desirable to identify patients in whom the T-tube plays no protective role in terms of stenosis development, and for whom it would be better not to use because we could avoid the inherent T-tube morbidity.

Our results show that the diameters of bile ducts, both in donors and recipients, are overall smaller in the group of patients with stenosis (median donor bile duct size 5.6 $\pm$ 2.6 mm and median recipient bile duct size 5.8 $\pm$ 2 mm) than in the group of patients without it (median donor bile duct size 7 $\pm$ 2.6 mm and median recipient bile duct size 7.4 $\pm$ 2.8 mm), and differences are significant statistically ($P = 0.036$).

A better scenario would be to select patients in whom the probability of biliary stricture development is sufficiently high to firmly recommend T-tube use, while taking into account the morbidity that can be caused by its placement. Our results show that the wider the bile duct diameter, the lower number of anastomotic stenosis.

In our series, T-tube use and donor and/or recipient bile duct diameters, measured at the time of transplant surgical procedure, had a significant influence on anastomotic biliary stricture development. The group of patients with either the donor bile duct diameter or the recipient bile duct diameter or both diameters smaller than 7 mm are significantly associated with a higher number of anastomotic stenosis. In an independent way, the 2 variables that enhance the number of stenosis are the smaller diameter of bile duct and the performance of bile duct anastomoses without T-tubes (Table 4).

A small percentage of patients in our series had stenosis due to ischemic bile type, with no associated arterial problem. Although the follow-up period of our series (22 months) was longer than that of other series, the diagnosis of this late complication usually requires an even longer follow-up period.

Biliary complications occurred in the first 2 months after OLT in the T-tube group versus 111 days in the non–T-tube group. Our study found a similar difference between groups in the length of the complication-free period. Complications in patients with no T-tube occurred later, indicating the importance of studies with a follow-up period of sufficient length to allow the inclusion of most complications.

As we have demonstrated, the treatment of complications in patients with T-tube could be resolved more readily with less intervention, so we also think that when in doubt or when risky anastomoses, it would be better to perform the anastomosis with a T-tube. The groups of patients that would benefit of a T-tube are suboptimal grafts, to quantify the quality and quantity of bile in the immediate posttransplant period; split grafts and retransplantations because of the quality and size of the bile ducts and when a significant difference between donor and recipient bile duct size or when technical intraoperative setbacks occur. Those cases are not included in the population of this study, but the percentage of bile duct complications is higher and the use of T-tube can reduce them and moreover facilitate their treatment.

It is important to consider surgeon experience and preference, the usefulness of the T-tube in patient follow-up, and the availability of therapeutic procedures for secondary complications. So, whether it is convenient to place a T-tube in all patients to prevent biliary strictures must be decided by each transplant team, based on the clinical evidence, on its own diagnose and treatment algorithms, and on its own results. But according to our experience in this large, prospective, randomized, and single-center trial, complications after CCS in OLT are more severe in patients with no T-tube with the need to more invasive treatment techniques. Moreover, we have demonstrated that the use of a T-tube prevents and reduces the number of anastomosis stenosis that leads to reoperations and invasive procedures. The need of postoperative diagnostic and therapeutic measures and their inherent risks, to treat biliary complications, are reduced with the use of a rubber T-tube in the CCS. We strongly recommend the use of a rubber t-tube when either donor bile duct diameter or recipient bile duct diameter is less than 7 mm.

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