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Biliary complications after paediatric liver transplantation: Birmingham's experience

Christophe Chardot
Daniel Candinas
Darius Mirza
Bridget Gunson
Suzanne Davison
M. Stephen Murphy
Deirdre Kelly
Philip John
Paul McMaster
David Mayer
John Buckels

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C. Chardot
Department of Pediatric Surgery,
Hôpital de Bicêtre,
78 Rue du Général Leclerc,
F-94275 Le Kremlin Bicêtre, France

D. Candinas
Department of Surgery,
University Hospital Zurich,
Rämistrasse 100,
CH-8091 Zurich, Switzerland

D. Mirza · B. Gunson · P. McMaster
D. Mayer · J. Buckels (✉)
Liver Unit,
Queen Elizabeth Medical Centre,
Edgbaston, Birmingham B15 2TH, UK
FAX: +44 21 414 1833

S. Davison · M. Stephen Murphy · D. Kelly
Liver Unit,
Birmingham's Children's Hospital,
Ladywood Middleway 16, Birmingham
B16 8ET, UK

P. John
Department of Paediatric Radiology,
Birmingham's Children's Hospital,
Ladywood Middleway 16, Birmingham
B16 8ET, UK

Abstract Between 1983 and 1992, 112 children underwent liver transplantation. Of 138 grafts, 60 (43.4 %) were whole livers, 77 (55.6 %) were reduced livers, and 1 (0.7 %) was a split liver. Biliary complications (BC) were defined as any abnormality, even minor, related to the biliary tract. Results were analysed with a minimum follow-up of 9 months. Some 36 grafts (26.1 %) in 34 patients (30.4 %) presented with BC: bile leaks (17 grafts), biliary obstructions or dilatations (16 grafts), and other complications (3 grafts). Management was mainly surgical with biliary reconstruction via a Roux-en-Y loop. Interventional radiology had an increasing role in recent years. BC were associated with a mortality of 1.8 % (2/112), a graft loss rate of 4.3 % (6/138), and significant morbidity. Among the various factors whose association with BC was studied, the date of transplantation, the use of reduced grafts and the use of gallbladder conduits appeared to be the main determining factors for BC. From multivariate analysis the use of reduced grafts emerged as the most important factor in reducing BC. We therefore conclude that BC are associated with significant morbidity, but general improvements in both surgical and medical management seem to account for better results in recent years.

Key words Liver transplantation, pediatric, biliary complications
Biliary complications, liver transplantation, pediatric · Pediatric liver transplantation, biliary complications

Introduction

Biliary complications are still a major concern after orthotopic liver transplantation (OLT) in children, leading to significant morbidity, graft loss and mortality [1, 6, 10–14, 18]. In addition to the factors involved in biliary complications in adults, such as surgical technique, ischaemia, preservation injury, chronic rejection and ABO incompatibility, some characteristics are more specific to paediatric liver transplantation, such as the tiny size of the bile ducts or the use of reduced or split grafts.

The purpose of this paper was to review biliary complications in Birmingham's paediatric liver transplantation programme, to analyse their features and to identify possible aetiological factors.

Table 1 Indications for primary liver transplantation

Cholestatic diseases: 55 patients (49.1 %):
- Biliary atresia (n = 52)
- Sclerosing cholangitis (n = 1)
- Alagille's syndrome (n = 1)
- Non-syndromic ductular hypoplasia (n = 1)

Inborn errors of metabolism: 24 patients (21.4 %):
- Alpha 1 antitrypsin deficiency (n = 10)
- Neonatal haemochromatosis (n = 1)
- Crigler-Najjar type 1 (n = 1)
- Propionic acidemia (n = 1)
- Tyrosinaemia type I (n = 6)
- Wilson's disease (n = 3)
- Oxalosis type I (n = 2)

Miscellaneous indications: 33 patients (29.5 %):
- Acute liver failure (n = 17)
- Cryptogenetic cirrhosis (n = 5)
- Post-hepatitic cirrhosis (n = 4):
  - Neonatal hepatitis (n = 2)
  - Hepatitis C (n = 1)
  - Autoimmune hepatitis (n = 1)
- Budd-Chiari syndrome (n = 2)
- Caroli's disease (n = 1)
- Primary liver tumors (n = 4):
  - Hepatoblastoma (n = 2)
  - Hepatocarcinoma (n = 1)
  - Haemangioendothelioma (n = 1)

Patients and methods

Between 29 December 1983 and 31 December 1992, 112 infants and children underwent OLT in Birmingham, receiving a total of 138 grafts. The median age at transplantation was 2.5 years (range 46 days to 14.8 years). The median weight at transplantation was 13 kg (range 4.7–55 kg).

Indications for primary liver transplantation are detailed in Table 1. Twenty-six retransplantations were performed in 24 patients: 88 children received one graft, 22 children received two grafts, and 2 children received three grafts.

Of 138 grafts, 60 were whole livers (43.4 %), 77 were reduced livers (55.6 %), and 1 was a split liver (0.7 %). The use of reduced grafts started in 1987 (Fig. 1). Various anatomical types of reduced grafts were performed (Fig. 2); the most usual reduction was to utilise the left lobe (segments II + III). The only split liver in this series was a left lobe, the right liver being used for an adult.

The blood group match of the graft and the recipient was ABO-identical in 113 cases (81.9 %), ABO-compatible in 24 cases (17.4 %), and ABO-incompatible in 1 case (0.7 %).

Various types of biliary anastomoses were performed (Fig. 3), and the use of T tubes and biliary stents was abandoned in the last years of the study. Biliary anastomosis was usually performed with 5/0 PDS (Ethicon Laboratories) with interrupted and/or continuous suture. In the case of T tubes, a routine cholangiogram was performed on the 7th post-operative day and the tube was subsequently clamped. Three months later, the T tube was removed after another cholangiogram.

Immunosuppression was based on triple drug therapy including cyclosporin, azathioprine and steroids. CyA trough levels targeted (specific whole blood) were 200–250 ng/ml in the first 3 months post-OLT, 150–200 ng/ml between 3 and 12 months post-OLT, and 90–150 ng/ml after 1 year post-OLT. Azathioprine was started at 2 mg/kg per day IV, then switched to 1.5–2 mg/kg per day orally, and stopped after 1 year. The steroids regimen was started with

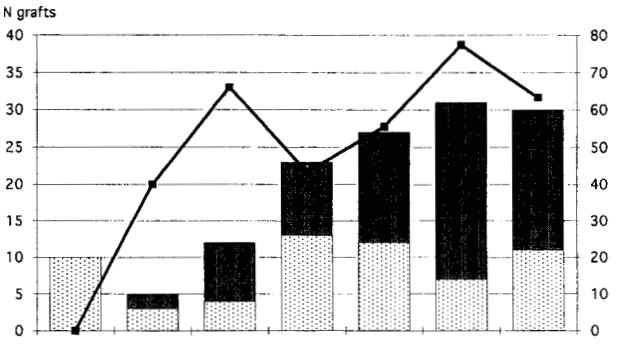
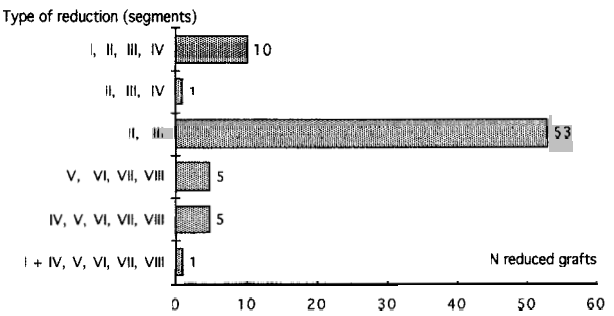


Fig. 1 Development of graft reduction and bipartition, 1983–1992. Total number of grafts = 138. ■ Reduced (n = 77) and split (n = 1) liver grafts, ⬚ whole liver grafts (n = 60), –■– % reduced + split grafts (56.5 %)



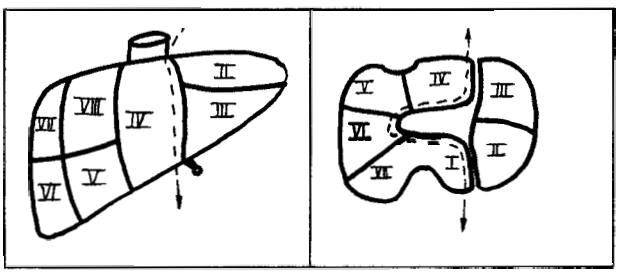


Fig. 2 Anatomical types of reduced grafts, according to Couinaud's segmentation of the liver [5]. *Top* Repartition of different reduced grafts in the Birmingham series. *Bottom* The most frequent type of reduction: segments II + III, according to Houssin et al. [8]

hydrocortisone, 50 mg/dose, IV two times a day if weight was below 10 kg, or 100 mg/dose IV two times a day if weight was above 10 kg; it was then switched to prednisolone, 1 mg/kg per dose orally two times a day, progressively decreased every 2 or 3 days, and completely stopped after 3 months.

Biliary complications were suspected either on clinical signs (peritonitis, cholangitis, sepsis, jaundice) or on biochemical abnormalities (deranged liver function tests with evidence of cholestasis and/or biochemical signs of sepsis). Investigations generally included an ultrasound scan of the liver. Hepatobiliary scintigraphy (DISIDA scan), cholangiograms (percutaneous, T tube or endoscopic cholangiogram) and/or liver biopsies were considered according to the clinical situation.

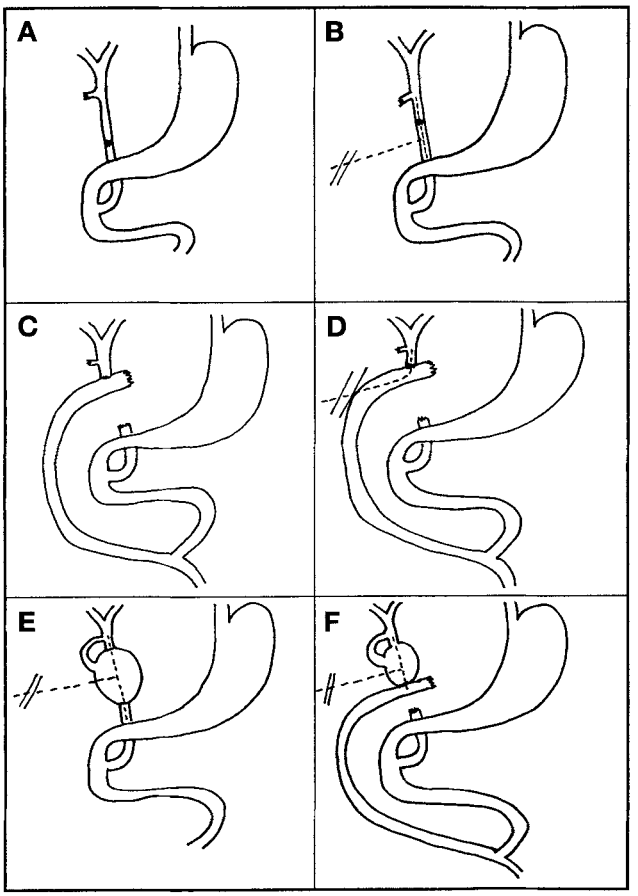


Fig. 3 A–F Types of biliary anastomosis: **A** duct-to-duct, no tube ($n = 12$, 8.7 %); **B** duct-to-duct, with tube ($n = 33$, 23.9 %); **C** duct to Roux-en-Y loop, no tube ($n = 46$, 33.3 %); **D** duct to Roux-en-Y loop, with tube ($n = 36$, 26.1 %); **E** gallbladder conduit-to-duct, with tube ($n = 6$, 4.3 %); **F** gallbladder conduit to Roux-en-Y loop, with tube ($n = 5$, 3.6 %)

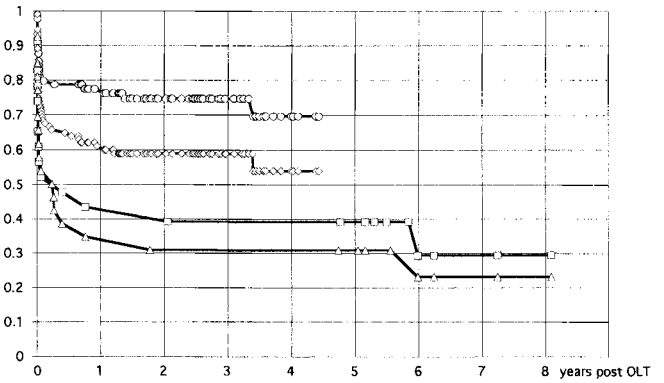


Fig. 4 Actuarial patient and graft survival after paediatric liver transplantation. –○– 1989–1992 ($n = 89$ patients), –◇– 1989–1992 ($n = 111$ grafts), –□– 1983–1988 ($n = 23$ patients, –△– 1983–1988 ($n = 27$ grafts)

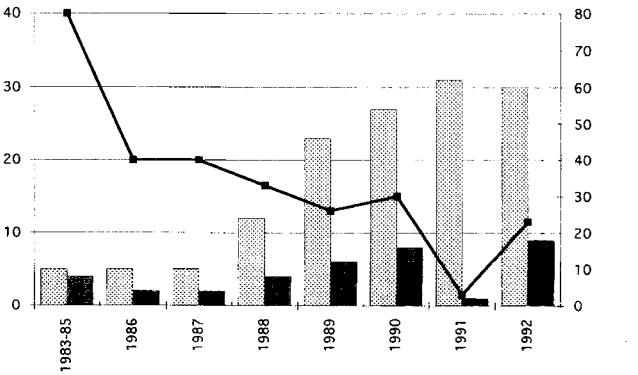


Fig. 5 Biliary complications according to the date of transplantation, 1983–1992. ⁘ Total number of grafts = 138, ■ number of grafts with biliary complications ($n = 36$), –■– % of grafts with biliary complications (26.1 %)

Results were analysed with a minimum follow-up of 9 months after transplantation (median follow-up 3.1 years). Data were collected retrospectively from the patients' charts, operative notes, and the liver Unit database. Due to the retrospective analysis, a few data sets could not be identified completely (e.g. CMV status) and, therefore, some figures given in this paper do not add up to 100 %, as indicated.

Biliary complications were defined as any abnormality, even minor, related to the biliary tract. They were divided into three groups: bile leaks (possibly associated with biliary obstruction), biliary obstructions or dilatations, and other biliary complications.

As for the statistical analysis, data are expressed as median values with range. Proportions were compared using Fischer's exact test and continuous data using nonparametric methods (Mann-Whitney U-test). Survival analysis was performed using the Kaplan-Meier method and survival times were compared using the log-rank test. For multivariate analysis, stepwise logistic regression was used. Two-tailed P-values below 0.05 were considered to indicate statistical significance.

Results

Overall results

Actuarial patient and graft survival was 70.4 % and 56.1 %, respectively, 1 year post-OLT and 64.0 % and 50.6 %, respectively, 5 years post-OLT for the entire period 1983–1992. Actuarial 1-year patient and graft survival was 43.5 % and 34.7 % over the period 1983–1988 and 77.5 % and 61.1 % over the period 1989–1992 (Fig. 4). Thus actuarial patient ($P = 0.001$) and graft ($P = 0.027$) survival was significantly higher after 1989.

Actual patient survival 3 months after OLT was 74.1 % for the entire period 1983–1992; it increased from 52.2 % over the period 1983–1988 to 79.8 % over the period 1989–1992 ($P = 0.009$).

A total of 36/138 grafts (26.1 %) in 34/112 patients (30.4 %) presented with biliary complications, as previously defined. The incidence of biliary complications has decreased over time (Fig. 5).

Table 2 Bile leaks: main characteristics (17 grafts in 16 patients)

Presentation
Clinical (n = 13)
Biochemical (n = 3)
Median date of presentation 10 days (range 2–49 days)
Radiology
Ultrasound scans: various abnormalities (n = 12); normal (n = 1)
Cholangiograms: (n = 5) via the biliary tube (n = 4) or endoscopically (n = 1); diagnosis of the leak made in each case
Site of the leak
Determined by cholangiogram and/or peroperatively
Anastomotic (n = 7)
Non-anastomotic (n = 7):
from the cystic duct of the donor (n = 1)
around the entry site of the biliary tube in the bile duct (n = 2)
from the cut surface of a reduced liver graft (+ stricture of the biliary anastomosis; n = 1)
from a necrotic area in the liver (due to compression; n = 1)
following complete bile duct necrosis (hepatic artery thrombosis; n = 1)
from a perforated gallbladder conduit (ischaemic gallbladder; n = 1)
Treatment
Apart from antibiotic therapy and non-specific resuscitation measures:
Surgery (n = 9): biliary reconstruction by means of a duct to Roux-en-Y anastomosis (n = 7), other (n = 2)
Interventional radiology (n = 2)
Surgery + interventional radiology (n = 2)
Conservative treatment (n = 3)
Post-mortem diagnosis (n = 1)
Outcome
Patients alive and well with satisfactory liver function and no problems related to the biliary tract (n = 11)
Patients alive with problems related to the biliary tract (n = 1)
Death (n = 4); related to the biliary complications (n = 2; multiple organ failure secondary to peritonitis in one case, post-mortem diagnosis in another case); not related (n = 2)
Graft loss (n = 7); graft loss related to the death of the patient in four cases, two of which are secondary to the bile leak; graft loss related to ischemia resulting in bile leak in two cases (hepatic artery thrombosis, n = 1, necrosis due to compression, n = 1) and not related to the bile leak in one case

Bile leaks

Seventeen grafts (12.3 %) in 16 patients (14.3 %) were complicated by a bile leak. Characteristics of presentation, radiology, site of the leak, treatment, patient and graft outcome are indicated in Table 2.

Biliary obstructions or dilatations

Sixteen grafts (11.6 %) in 16 patients (14.3 %) were complicated by biliary obstruction and/or duct dilatation. Their features are summarised in Table 3.

Table 3 Biliary obstructions or dilatations: main characteristics (16 grafts in 16 patients)

Presentation
Clinical (n = 12)
Biochemical (n = 2)
Incidental ultrasound discovery of bile duct dilatation (n = 2)
Median date of presentation 32.5 days (range 5–360 days)
Radiology
Ultrasound scans: various abnormalities (n = 10); normal (n = 5)
Cholangiograms: percutaneous cholangiograms (n = 7); tube cholangiogram (n = 4); 11/11 abnormal
DISIDA scans: delayed excretion (n = 3); normal (n = 1)
Cause of obstruction or duct dilatation
Determined by cholangiogram and/or peroperatively
Anastomotic strictures (n = 4)
Non-anastomotic strictures (n = 6):
Bifurcation of segmental bile ducts in reduced graft to segments II + III (n = 1)
Diffuse bile duct damage due to ischemia (hepatic artery thrombosis; n = 1)
Diffuse bile duct damage due to chronic rejection (n = 2)
Oedematous bile duct (n = 2)
Obstruction not due to stenosis (n = 3):
Obstructive biliary tube (n = 1)
Sludge (n = 1)
Gallstones in gallbladder conduit (n = 1)
Unknown (n = 3):
Minor and/or transient bile duct dilatation, no cholangiogram or surgery
Treatment
Apart from the medical treatment of cholangitis:
Surgery (n = 9): biliary reconstruction (n = 5); biliary reconstruction + retransplantation (n =2); retransplantation (n = 2); biliary reconstruction by means of a Roux-en-Y loop in all cases
Interventional radiology (n = 2): percutaneous balloon dilatation + biliary drain
medical (n = 2): removal of obstructive tube (n = 1), ursodeoxycholic acid (n = 1)
No specific treatment (n = 3)
Outcome
Patients and well with satisfactory liver function and no problems related to the biliary tract (n = 6) patients
Patients alive with problems related to the biliary tract (n = 6); secondary biliary cirrhosis (two patients, one of them with compensated cirrhosis and the other awaiting retransplantation), recurrent cholangitis, low-grade cholestasis and mild bile duct dilatation (n = 1), asymptomatic biochemical cholestasis (n = 1), asymptomatic mild bile duct dilatation (n = 2)
Death: (n = 3) none of them related to the biliary complication
Insufficient follow-up: one patient whose biliary stricture has just been percutaneously dilated
graft loss (n = 5): patient's death (n = 1); ischemia and/or chronic rejection, with subsequent biliary damage (n = 3); secondary biliary cirrhosis (n = 1)

Other biliary complications

Infectious complications related to the T tube presenting as cholangitis occurred in three other grafts, without evidence of bile leak or biliary obstruction. In the

Table 4 Investigation of actiological factors of biliary complications

	Whole series	Bile leaks	*P* values[a]	Biliary obstructions or dilatations	*P* values[a]
Number of patients	112	16 (14.2 %)		16 (14.2 %)	
Number of grafts	138	17 (12.3 %)		16 (11.6 %)	
Age at OLT (range)	Median 2.5 years (46 days to 14.8 years)	Median 2.1 years (5.7 months to 14.8 years)	NS	Median 4.1 years (9.5 months to 11.9 years)	NS
Weight at OLT (range)	Median 13 kg (4.7–55 kg)	Median 12.6 kg (6.2–49.9 kg)	NS	Median 17.2 kg (6.3–38 kg)	NS
First graft/ retransplantation		All biliary complications, 1983–1992			NS
	112		30 (26.8 %)		
	26		6 (23 %)		
Biliary atresia/ other indications (re-OLT excluded)	52	3 (5.8 %)	NS	5 (9.6 %)	NS
	60	9 (15 %)		11 (18.3 %)	
Warm ischemia[b] (range)	Median 40 min (10–122 min)	Median 40 min (20–80 min)	NS	Median 40.5 min (27–87 min)	NS
Cold ischemia[b] (range)	Median 8.8 h (3.4–18.9 h)	Median 7.6 h (3.8–18.9 h)	NS	Median 10.8 h (3.4–18.1 h)	NS
Total ischemia[b] (range)	Median 9.4 h (4.1–19.6 h)	Median 7.3 h (4.7–19.6 h)	NS	Median 11.6 h (4.1–18.8 h)	NS
Whole grafts/ reduced + split livers (1983–1992)		All biliary complications, 1983–1992			0.006
	60		23 (38.3 %)		
	78		13 (16.6 %)		
Whole grafts/ reduced + split livers (1989–1992)		All biliary complications, 1989–1992			0.019
	43		15 (34.9 %)		
	68		10 (14.7 %)		
Biliary anastomosis:		All biliary complications, 1983–1992			0.035
Duct-to-duct	45		10 (22.2 %)		
Duct-to-Roux	82		20 (24.4 %)		
Gallbladder conduit	11		6 (54.5 %)		
Biliary tube	80	11 (13.8 %)	NS	8 (10 %)	NS
No biliary tube	58	6 (13.3 %)		8 (13.8 %)	
Hepatic artery thrombosis (HAT)	16	1 (6.3 %)	NS	2 (12.5 %)	NS
No HAT	122	16 (13.1 %)		14 (11.5 %)	
Chronic rejection	14	1 (7.1 %)	NS	4 (28.6 %)	NS
No chronic rejection	124	16 (12.9 %)		12 (9.7 %)	
CMV[b]:					
Seroconversion or reactivation	27	0	0.017	5 (18.5 %)	NS
No seroconversion no reactivation	68	12 (17.6 %)		9 (13.2 %)	
Unknown	43	5 (11.6 %)		2 (4.7 %)	
ABO – incompatible graft	1	0		0	
Date of OLT:			All biliary complications:		
1983–1988	27		11 (40.7 %)		0.048
1989–1992	111		25 (22.5 %)		

[a] Derived from comparison between group with event versus group without respective event
[b] Incomplete data sets

three cases, infection was controlled with antibiotic therapy and did not affect the outcome of transplantation.

Mortality and morbidity

Biliary complications were associated with a mortality of 1.8 % (2/112), a graft loss rate of 4.3 % (6/138), and significant morbidity.

Aetiological factors

Several features such as indications, techniques and associated complications were studied in order to identify factors related to biliary complications (Table 4). None of the following features was significantly associated with biliary leak or biliary obstruction: age at transplantation, weight at transplantation, biliary atresia versus other indications, ischaemic time of the graft (cold, warm and total), use or not of a biliary tube, hepatic artery thrombosis or chronic rejection. Only one patient in the whole series received an ABO-incompatible graft and did not have any biliary complications. First grafts and retransplantations did not have significantly different rates of biliary complications.

Absence of CMV seroconversion or reactivation was associated with bile leaks. This finding needs to be interpreted cautiously, however, because of the high rate of grafts with bile leaks and unknown CMV status. Moreover, most of the bile leaks (69.2 %) occurred in the first 3 weeks after transplantation, before the period at risk for CMV, and therefore a role of CMV status in bile leaks seems unlikely.

The date of transplantation before 1989 proved to be statistically related to a higher rate of biliary complications. Innovative techniques (reduced + split livers) resulted in significantly fewer biliary complications than whole grafts. Gallbladder conduits had significantly more biliary complications than other types of biliary reconstruction.

In order to assess their relative contributions to biliary complications, the parameters timing of transplantation, type of biliary anastomisis, and use of reduced grafts were analysed by stepwise logistic regression. In this regression model only the use of reduced grafts showed a significant influence on biliary complications ($P = 0.007$, odds ratio 2.98, 95 % confidence interval 1.35–6.56).

Discussion

Since the early days of liver transplantation, biliary complications have been a major concern and biliary reconstruction has been considered the technical "Achilles heel" of the procedure [3]. In reports of paediatric series, the rate of biliary complications ranges from 5 % to 38.3 % [1, 6, 10–14, 18]. However, comparisons between these series are inappropriate for several reasons. Firstly, no common definition of biliary complications is used, some authors considering only the patients in whom surgery or interventional radiology is needed. In this series, any abnormality, even minor, in relation to the biliary tract has been taken into account. If a definition including only complications leading to death, surgery or interventional radiology is used, the rate of biliary complications in the Birmingham's series falls from 26.1 % to 18.1 %. Secondly, the length of the follow-up is important to consider: some biliary strictures may be discovered several months after transplantation, and lack of follow-up tends to underestimate them. In this series, the minimum follow-up was 9 months after transplantation (median 3.1 years).

General management of paediatric liver transplantation has changed during the 9-year period studied in this paper. From 1983 until 1988, liver transplantation in children was part of the general liver transplantation programme in Birmingham. In 1989 a specific paediatric approach to liver transplantation was started, with the creation of a paediatric liver unit with a paediatric team specially trained in the management of children with liver disease. The importance of this specific paediatric approach is emphasised by many other paediatric liver transplantation centres [12, 19]. Increasing surgical experience and refined general management of the patients accounts for the improvement in the results in this series over recent years.

Regarding initial surgery and its implications for the biliary tract, three main surgical changes occurred during the period of the study. Firstly, gallbladder conduits, which were used in the early days of the programme, were abandoned in 1988. Their complication rate is significantly higher than other techniques in this series, confirming a previous study done mainly in adults [7]. Secondly, graft reduction has been developed since 1987, and one split liver was performed in 1992. Innovative techniques (reduced and split livers) were associated with a lower rate of biliary complications in our series, and in the multivariate analysis this was even found to be the main contributing factor in reducing these complications. This tendency was also reported by other centres [8, 12]. It is not explained in our series by the exclusive use of whole grafts in the early years of the programme: if only the period 1989–1992 is considered, the rate of biliary complications is 15/43 (34.8 %) for whole grafts and 10/68 (14.7 %) for reduction techniques ($P = 0.019$). Therefore, we hypothesise that the larger diameter of the bile duct and its supplying artery in reduced grafts is the crucial factor contributing to a lower rate of biliary complications. The third evolution was the progressive abandonment of biliary tubes (T tube or other biliary stents). The incidence of bile leaks and of biliary obstructions or dilatations is not altered by omitting the biliary tube as reported by others [15–20]. With the development of interventional radiology, if biliary drainage is needed for the management of biliary complications, it can nowadays be performed percutaneously. Freedom from any prosthesis as early as possible seems to be an important advantage for small children.

Regarding the diagnosis of biliary complications, our experience has led to a more systematic investigation of

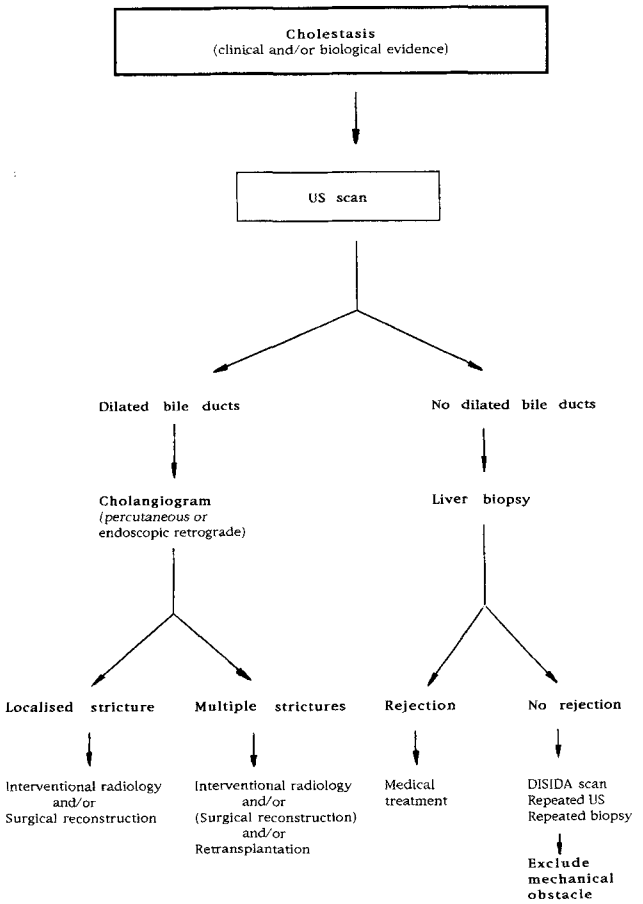


Fig. 6 Management of cholestasis after paediatric liver transplantation

every cholestasis in order to exclude a surgical origin. Two patients in this series had prolonged cholestasis, and the diagnosis of biliary stricture was made several months later when cholangitis finally occurred. One of these children subsequently had hepatic candidiasis requiring 6 months of antifungal therapy, and this child now has established secondary biliary cirrhosis (compensated). Sonography is known to produce false-negatives [21], the rate in our series being 6/28 (21.4 %). Consequently, repeated ultrasound scans and/or other examinations like hepatobiliary scintigraphy [2] are performed to identify a surgical cause of cholestasis.

Evolutions also occurred in the treatment of biliary complications. First of all, we learned that a conservative approach is not appropriate when a biliary complication has been identified: one patient with known biliary stricture and debris had a failed attempt at choleretics, resulting in delayed effective treatment and secondary biliary cirrhosis. This child is currently awaiting retransplantation. The second evolution in the treatment of biliary complications has been the wider use of interventional radiology [13]. In bile leaks, the role of interventional radiology was mainly to aspirate or drain a collection. In biliary strictures, balloon dilatation was always considered before reconstructive surgery in the past few years. When successful, such an approach may avoid major surgery, especially in reduced grafts of segments II + III, where surgical access to the biliary tract requires remobilisation of the whole graft. An algorhithm for management of cholestasis after paediatric liver transplantation is proposed in Fig. 6.

In our experience, bile leaks are life-threatening in the 1st weeks post-transplantation, whereas biliary obstructions are graft-threatening in the following months. Two deaths were related to bile leaks. Two additional grafts with bile leak were lost, but the primary cause of graft loss was ischaemia in both cases. No death was directly related to biliary obstruction, but delayed treatment of anastomotic strictures (due to delayed diagnosis in one case and a failed attempt at conservative management in the other case) resulted in secondary biliary cirrhosis in two patients, one of whom is now awaiting retransplantation. In addition, two patients kept presenting with low-grade cholestasis, one of them (with previous hepatic artery thrombosis) suffering from recurrent episodes of cholangitis. Three other grafts with biliary obstruction were lost, in all cases due to hepatic artery thrombosis and/or chronic rejection.

Two main aetiological factors seem to be related to bile leaks: technical failure and ischaemia. Technical failure is very likely when the leakage occurs in the very early days post-transplantation, as in one of our patients on day 2. On the other hand, ischaemia is the obvious determining factor in cases of hepatic artery thrombosis with necrosis of the biliary tract. In between are the anastomotic leaks occurring at the end of the first post-operative week or later on. These leaks may be related to local ischaemia, which may be induced by the surgical technique itself. Two leaks were directely related to the use of a biliary tube; the patients recovered with minimal intervention.

The group "biliary obstructions or dilatations" may be divided into four subgroups: anastomotic strictures, non-anastomotic strictures, other causes of obstruction, and dilatation of the bile duct without obstruction. Three patients fell into this latter category, with subsequent complete or nearly complete disappearance of bile duct dilatation, good clinical outcome and no biochemical evidence of cholestasis, as previously reported in adults [4]. Aetiologies of biliary obstruction depend on the type. Anastomotic strictures may be due to technical failure or local ischaemia and, in that aspect, resemble bile leaks. Obstruction was not due to a stricture in three patients but rather to sludge ($n = 1$), gallstones in a gallbladder conduit ($n = 1$) and obstructive biliary tube ($n = 1$). In the group of non-anastomotic strictures, presumed aetiologies were ischaemic dam-

age to the biliary tract secondary to arterial thrombosis ($n = 1$), chronic rejection ($n = 2$), or oedema of bile duct ($n = 2$). A stricture at the bifurcation of segmental ducts occurred in a reduced graft of segments II + III. An ischaemic origin seems likely in that case, although great attention is paid not to damage the blood supply of the bile duct during the preparation of reduced grafts. None of the non-anastomotic strictures were related to ABO incompatibility or prolonged ischaemic time of the graft [9, 16, 17].

We conclude that with an overall rate of 26.1 % (36/138) of grafts, biliary complications have represented a major concern after paediatric liver transplantation in Birmingham. Biliary complications were related to a mortality rate of 1.8 % (2/112), a graft loss rate of 4.3 % (6/138) and significant morbidity.

The main determining factors of biliary complications proved to be the date of transplantation, the use of whole or reduced grafts and the type of biliary anastomosis. The continuous improvement in results with time probably reflects the increasing experience of the team. Better surgical techniques (standardised and simplified), improved general management of the patients with a specific paediatric approach, earlier diagnosis and more effective management of biliary complications seem to account for this improvement.

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