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Reconstruction of choledochal wall defects with autogenous pediculated gallbladder

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Ethics Committee Approval
This experimental study was approved by the Ethics Committee of Erzurum Atatürk University (Approval date: 10 July 2020; Decision No: 0014).

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Abstract

Background/Aim: Biliary tract injuries with tissue loss remain challenging in hepatobiliary surgery. Primary repair, bilioenteric anastomosis, and various graft materials have been used; however, each approach has limitations, including stenosis, infection, and foreign-body reaction. This study aimed to evaluate the feasibility and effectiveness of an autogenous pediculated gallbladder flap for reconstructing choledochal wall defects in an experimental ovine model.

Methods: Fourteen Awassi sheep underwent surgical creation of a 2-3 mm full-thickness anterior choledochal wall defect located 1 cm distal to the cystic duct junction. The defect was repaired using an autogenous pediculated gallbladder flap without biliary stenting. Blood samples were obtained preoperatively and on postoperative days 7 and 14 to measure total bilirubin, AST, ALT, and ALP. Hepatobiliary scintigraphy with Tc-99m HIDA was performed on postoperative day 14. On day 30, surviving animals underwent relaparotomy and histopathological examination.

Results: Three animals died early postoperatively due to anesthesia-related cardiopulmonary complications and were excluded from the analysis. Eleven animals completed follow-up. Total bilirubin and ALP did not differ significantly across time points. AST and ALT increased on postoperative day 7 compared with baseline and returned to baseline by postoperative day 14. Scintigraphy showed normal bile transit without leakage, stenosis, or proximal dilatation. Macroscopic and histopathological evaluation confirmed flap viability and complete epithelialization.

Conclusion: Reconstruction of choledochal wall defects using an autogenous pediculated gallbladder flap appears safe and physiologically advantageous in this ovine model. Preserved mucosa, intact vascularity, and autogenous tissue characteristics support its potential as an alternative to synthetic materials or bilioenteric reconstruction.

Keywords: reconstruction, choledochal wall defect, autogenous pediculated gallbladder, biliary injury, experimental model

Introduction

Bile duct injuries remain a major source of morbidity after hepatobiliary procedures, particularly after cholecystectomy, and may require complex reconstruction when segmental tissue loss is present [1-3]. Current repair options include primary repair in selected cases, bilioenteric diversion, most commonly Roux-en-Y hepaticojejunostomy, and patch or tube graft reconstruction when native duct continuity cannot be maintained [4-6]. Although bilioenteric reconstruction is effective, it may be associated with long-term complications such as recurrent cholangitis and other reflux-related problems, including late biliary malignancy after longstanding biliary-enteric drainage for benign disease [7-9].

To overcome the limitations of diversion procedures and synthetic substitutes, several graft materials have been explored, including tissue-engineered constructs, bioabsorbable scaffolds, prosthetic vascular grafts, small intestinal submucosa, venous grafts, peritoneal tissue, and other autologous tissues [10-27]. However, synthetic materials may predispose patients to infection, foreign-body reaction, and stenosis, whereas autologous grafts can prolong operative time and cause donor-site morbidity. An ideal reconstructive material should be autogenous, well vascularized, easily accessible, resistant to bile exposure, and capable of epithelial regeneration.

The gallbladder is a potential candidate because it provides a mucosal surface compatible with biliary epithelium and can be fashioned as a pediculated flap with preserved arterial supply through the cystic artery. This study aimed to evaluate the feasibility and functional outcomes of reconstructing choledochal wall defects using an autogenous pediculated gallbladder flap in a sheep model.

Materials and methods

Experimental design and ethical approval

This experimental study was approved by the Ethics Committee of Erzurum Atatürk University (Approval date: 10 July 2020; Decision No: 0014). All procedures were conducted in accordance with applicable animal welfare principles. To minimize animal use while maintaining interpretability, the smallest feasible sample size was selected. Fourteen healthy Awassi sheep with a mean weight of 45 kg were included.

Surgical procedure

After a 12-hour fast, anesthesia was induced using thiopental sodium (10 mg/kg) and pancuronium bromide (0.15 mg/kg). Maintenance was achieved with O2/N2O (0.5/0.5) and 1%-2% halothane. A right subcostal incision was performed to expose the extrahepatic bile duct. A 2-3 mm full-thickness anterior defect was created in the choledochal wall, 1 cm distal to the cystic duct junction.

The cystic duct was ligated and divided while preserving the cystic artery. A pediculated gallbladder flap was fashioned and tailored to cover the defect. The flap was sutured with fine absorbable sutures, positioning the mucosal surface toward the bile duct lumen. No biliary stent or external drain was placed.

Biochemical analysis

Blood samples were obtained preoperatively and on postoperative days 7 and 14 from surviving animals. Total bilirubin, AST, ALT, and ALP were measured. Biochemical trends were interpreted together with the other hepatobiliary markers to assess postoperative biliary function.

Scintigraphic evaluation

On postoperative day 14, Tc-99m HIDA hepatobiliary scintigraphy was performed after intravenous administration of the radiotracer. Dynamic and static images were acquired to evaluate bile transit, leakage, obstruction, and ductal dilatation.

Histopathological examination

On postoperative day 30, surviving animals underwent relaparotomy. The reconstruction segment was excised en bloc. Specimens were processed using standard techniques and stained for microscopic evaluation.

Statistical analysis

Continuous variables are presented as mean (SD). Comparisons across time points were performed using repeated -measures ANOVA followed by Bonferroni-adjusted pairwise comparisons. Exact *P*-values are reported, with values <0.001 expressed as $P < 0.001$.

Results

Three animals died in the early postoperative period on days 3, 5, and 7 due to anesthesia-related cardiopulmonary complications and were excluded from the analysis. Eleven animals completed follow-up. No clinical evidence of bile leakage, wound infection, or other postoperative complications was observed among survivors.

The individual biochemical values and comparative statistics are presented in Tables 1 and 2.

Total bilirubin values did not differ significantly between the preoperative measurement and postoperative day 7 or day 14 ($P = 0.089$ and $P = 0.796$, respectively). Similarly, ALP values showed no significant differences versus baseline on postoperative day 7 or day 14 ($P = 0.117$ and $P = 0.989$, respectively).

AST increased from 19.55 (3.08) U/L preoperatively to 30.00 (5.78) U/L on postoperative day 7 ($P < 0.001$) and returned to 19.36 (1.50) U/L by postoperative day 14 ($P = 0.848$). ALT increased from 17.00 (2.24) U/L preoperatively to 25.45 (8.58) U/L on postoperative day 7 ($P = 0.005$) and decreased to 17.91 (3.62) U/L by postoperative day 14 ($P = 0.250$).

HIDA scintigraphy demonstrated normal hepatobiliary function and physiologic bile passage into the intestine without leakage, stenosis, or proximal ductal dilatation. At relaparotomy on day 30, the gallbladder flap appeared viable and well integrated, with no macroscopic evidence of narrowing. Histopathological examination confirmed complete epithelial coverage over the reconstructed area, with mild subepithelial fibrosis and neovascularization.

Table 1. Total bilirubin (T.BIL), AST, ALT, and ALP values at preoperative, postoperative day 7, and postoperative day 14

No	Preoperative T.BIL	Preoperative AST	Preoperative ALT	Preoperative ALP	Day 7 T.BIL	Day 7 AST	Day 7 ALT	Day 7 ALP	Day 14 T.BIL	Day 14 AST	Day 14 ALT	Day 14 ALP
1	0.8	18	15	158	0.9	40	22	133	0.7	17	17	140
2	0.6	16	15	129	0.7	32	20	141	0.7	20	18	172
3	0.7	20	16	172	0.9	28	25	180	0.6	19	15	140
4	0.7	19	14	132	0.8	23	15	182	0.8	20	15	160
5	0.8	23	19	155	0.8	25	16	165	0.9	21	16	145
6	0.7	26	21	142	0.9	32	29	149	0.8	19	27	141
7	0.9	22	20	171	0.8	39	37	190	0.7	21	20	174
8	0.8	17	16	151	0.8	22	18	162	0.8	20	15	132
9	0.8	16	18	161	0.8	29	26	162	0.7	18	20	158
10	0.7	19	17	188	0.9	29	42	186	0.8	17	19	183
11	0.8	19	16	113	0.7	31	30	123	0.7	21	15	128

ALP: alkaline phosphatase, ALT: alanine aminotransferase, AST: aspartate aminotransferase, T.BIL: total bilirubin.

Table 2. Comparison of biochemical parameters at preoperative, postoperative day 7, and postoperative day 14

Parameter	Preoperative mean (SD)	Postoperative day 7 mean (SD)	Postoperative day 14 mean (SD)	*P*-value (preop vs day 7)	*P*-value (preop vs day 14)
Total bilirubin (mg/dL)	0.75 (0.08)	0.82 (0.08)	0.75 (0.08)	0.089	0.796
AST (U/L)	19.55 (3.08)	30.00 (5.78)	19.36 (1.50)	<0.001	0.848
ALT (U/L)	17.00 (2.24)	25.45 (8.58)	17.91 (3.62)	0.005	0.250
ALP (U/L)	152.00 (21.76)	161.18 (22.49)	152.09 (18.38)	0.117	0.989

ALP: alkaline phosphatase, ALT: alanine aminotransferase, AST: aspartate aminotransferase, SD: standard deviation.

Discussion

Major bile duct injuries with segmental tissue loss remain among the most demanding complications in hepatobiliary surgery. Roux-en-Y hepaticojejunostomy is widely used for complex injuries but disrupts physiologic bile flow and bypasses the natural antireflux mechanism of the duodenal papilla. Long-term outcomes after bilioenteric drainage may include recurrent retrograde cholangitis, and some reports have suggested an association with bile duct malignancy after longstanding biliary-enteric diversion for benign disease. Therefore, reconstructive approaches that preserve native biliary continuity while maintaining patency are conceptually attractive.

A broad range of materials has been evaluated for choledochal reconstruction. Prosthetic grafts have demonstrated experimental technical feasibility but have been limited by infection, foreign-body reaction, and late stenosis. Tissue-engineered and bioabsorbable constructs have shown epithelial regeneration in experimental settings and may reduce some prosthesis-related issues; however, they remain artificial substitutes and may not fully replicate native bile duct structure and function. Other approaches, including biodegradable stented venous interposition, arterial grafts, serosal onlay patches, skin grafts, ureteral grafts, and amniotic grafts, have also been investigated experimentally [29-35].

In the present ovine model, a pediculated gallbladder flap provided immediate access to autogenous tissue within the operative field, retained vascular supply through the cystic artery, and offered a mucosal surface compatible with biliary epithelium. The short-term functional findings were favorable: scintigraphy showed intact bile flow without leakage or obstruction, and histology demonstrated complete epithelialization of the reconstructed segment. The transient postoperative elevation in liver enzymes on day 7, with recovery by day 14, is consistent with a reversible perioperative response rather than persistent biliary compromise.

This study has limitations. It was an animal experiment with a modest sample size, and follow-up was limited to 30 days; therefore, late stricture formation, long-term mucosal remodeling, and durability beyond the early healing phase could not be assessed. Larger studies with longer follow-up and, ultimately, well-designed clinical investigations are needed to determine long-term safety, patency, and generalizability.

Overall, autogenous pediculated gallbladder flap repair may represent a physiologically preserving alternative for localized choledochal wall defects when the cystic artery can be maintained and adequate tissue can be mobilized.

Conclusion

Biliary tract injuries and strictures remain significant surgical challenges, particularly when segmental tissue loss is present. Multiple reconstructive approaches have been described, including synthetic prostheses, bioabsorbable scaffolds, and autologous tissue grafts; however, each strategy has important limitations related to infection, foreign-body reaction, donor-site morbidity, or disruption of physiologic bile flow. In this experimental ovine study, reconstruction of choledochal wall defects using an autogenous pediculated gallbladder flap demonstrated favorable short-term outcomes, including preserved bile passage, flap viability, and complete epithelialization. Although these findings support feasibility and potential physiologic advantages, long-term experimental studies and carefully designed clinical investigations are required before routine clinical adoption.

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