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The role of surgical shunts in the treatment of pediatric portal hypertension

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ABSTRACT

Background: Portal diversion by surgical shunt plays a major role in the treatment of medically refractory portal hypertension. We evaluate our center's experience with surgical shunts for the treatment of pediatric portal hypertension.

Methods: All patients who underwent surgical shunt at a single institution from 2008 to 2017 were reviewed. The primary outcome was intervention-free shunt patency.

Results: In this study, 34 pediatric patients underwent portal shunt creation. The median age was 7.7 years (interquartile range 4.3–12.0). Twenty-nine patients (85%) had prehepatic portal hypertension and 5 patients (15%) had intrahepatic portal hypertension. The primary manifestations of portal hypertension were esophageal varices (97%) and gastrointestinal bleeding (77%). Eighteen patients (53%) underwent meso-Rex bypass, 10 patients (29%) underwent splenorenal shunt, and 6 patients (18%) underwent mesocaval shunt. Outcomes were notable for minimal wound complications (9%), rebleeding events (12%), and mortality (3%). In the postoperative setting, 10 patients (29%) experienced a shunt complication (occlusion or stenosis), 4 of which occurred in the early postoperative period and required urgent intervention. The 1-year and 5-year "primary patency" patency rates were 71% and 66%, respectively.

Conclusion: Children suffer significant morbidity from the sequelae of portal hypertension. Our experience reinforces the feasibility of surgical shunts as an effective treatment option associated with low rates of morbidity and mortality.

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Introduction

Pediatric portal hypertension (pHTN) can result from a variety of conditions, and if not adequately managed, the resulting sequelae may be associated with significant morbidity and mortality.[1,2] The most notable complication of pHTN is acute variceal bleeding. Although widespread use of endoscopic interventions for both the prevention and treatment of variceal bleeding have improved management of this problem,[3,4] shunt creation to bypass obstructed portal flow may be necessary for definitive treatment.[5] However, with continued success in pediatric liver transplantation[6] and the emergence of transjugular intrahepatic portosystemic shunt (TIPS) in children,[7,8] the utility of surgical shunts in the treatment of pediatric pHTN has been challenged.

Similar to adults with end-stage liver disease, children with intrahepatic pHTN can be treated with portosystemic shunts (PSS), with liver transplantation as the definitive treatment. However, there is a high prevalence of prehepatic pHTN among pediatric patients due to extrahepatic portal vein thrombosis (EPVT) with cavernous transformation, for which the meso-Rex bypass (MRB) has emerged as the recommended approach.[9] The MRB is a shunt between a mesenteric vessel and the intrahepatic left portal vein at the Rex recess of the liver. As a result, both shunt types are potential interventions for pediatric patients with pHTN. Herein, we evaluate our center's experience with surgical shunts for the treatment of pediatric pHTN.

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Methods

Patient selection

A retrospective review of all pediatric patients who underwent creation of a surgical shunt for pHTN from January 2008 to December 2017 at a single, freestanding pediatric hospital was performed. Patients who underwent TIPS ($n = 5$ from 1992–2017) were not included in this study. Patient demographics, operative details, and postoperative outcomes were collected. Short-term outcomes included events occurring during the index hospitalization and long-term outcomes included events within 60 days of discharge or at most recent follow-up. All operations were performed by 5 surgeons who are fellowship trained in both pediatric and transplant surgery. This study was approved by the institutional review board at Cincinnati Children's Hospital Medical Center.

Definitions

Operations were categorized as emergent (within 48 hours of admission), urgent (>48 hours after admission), or elective. Shunt complications include both shunt occlusion and stenosis. Short-term complications were defined as occurring during the index hospitalization and included duration of stay, need for transfusion, wound complication, and reoperation. Wound complications included wound infections and skin dehiscence. Other complications included any deviation from an expected postoperative course. Early shunt thrombosis was defined as shunt complication within 30 days. Long-term outcomes included 60-day recurrent gastrointestinal bleed, 60-day readmission, and 60-day mortality. As a measure of postoperative growth development, patient height and length percentiles were calculated based on measurements at most recent follow-up using Center for Disease Control growth charts, and appropriate growth development was defined as having a height or length greater than the fifth percentile, as recommended for pediatric patients aged 2 to 19 years old.[10] Although formal cognitive assessments were not performed for this patient cohort, clinical assessment of cognitive development was used as a surrogate marker. During clinic follow-up appointments, all patients were screened by nursing staff for normal cognitive development (yes or no), and the response at the patient's most recent follow-up was recorded. Shunt patency, and details of interventions performed if a shunt complication occurred, were evaluated up to the most recent follow-up.

Operative details

The indication for surgical shunt was pHTN with attention to worsening hypersplenism, thrombocytopenia, gastroesophageal varices, or recurrent variceal bleeding. Before surgery, patients underwent evaluation of mesenteric and hepatic vasculature by computed tomography angiography or magnetic resonance angiography and percutaneous hepatic venogram to assess the presence and patency of potential inflow and outflow vessels. All patients underwent open shunt creation via a midline or transverse laparotomy, depending on patient age and size. The operative intent for prehepatic pHTN patients was MRB, depending on the presence of a candidate mesenteric inflow vessel and an identifiable target left portal vein in the Rex recess of the liver; PSS were reserved for patients with intrahepatic pHTN or unfavorable MRB anatomy.

Surgical shunts were of 3 varieties: MRB, mesocaval shunt, and distal splenorenal shunt (DSRS). MRB was created by anastomosis of a named mesenteric vessels (superior mesenteric vein [SMV], inferior mesenteric vein [IMV], or left gastric vein) or use of a prominent hilar varix to the distal left portal vein at the Rex recess as was originally described and thereafter modified.[9,11–14] DSRS was performed in the standard fashion as described by Warren et al with anastomosis of the distal splenic vein to the left renal vein[15] or in a modified fashion with anastomosis of the splenic vein to the left adrenal vein.[16] One patient underwent a central splenorenal shunt secondary to aberrant mesenteric anatomy. Mesocaval shunts were performed using the internal jugular vein (IJV) or a polytetrafluoroethylene graft as a conduit between the mesenteric and caval systems.

Before and after portal shunting, all patients had measurement of portal pressures by 1 of 2 methods based on surgeon preference. Most commonly, a terminal mesenteric vein in the small bowel mesentery was cannulated via a 5 French feeding tube and connected to intravenous tubing and manometry via which portal pressure was measured in centimeters of water (cmH_2O). Less commonly, a large bore angiocatheter was placed into the splenic pulp and similarly connected to intravenous tubing and manometry with portal pressure measured in cmH_2O. In this study, we report data for the patients who had mesenteric pressures taken ($n = 26$). Pressures were converted from cmH_2O to millimeters of mercury (mm Hg) using the formula mm Hg value = cmH_2O value $\times$ 0.07356 and Δ pressure was calculated as the difference between the pre- and postshunt portal pressures. Postoperatively, MRB patients received systemic anticoagulation with continuous heparin followed by transition to 6 weeks of therapeutic enoxaparin therapy. PSS patients received either systemic anticoagulation with continuous heparin followed by transition to 6 weeks of therapeutic enoxaparin therapy or aspirin antiplatelet therapy alone, depending on provider preference, type of conduit used, or inability to tolerate systemic anticoagulation. All patients underwent evaluation for shunt patency between 2 and 4 weeks by ultrasound duplex or computed tomography-angiography, unless clinical concern warranted sooner.

Statistical analysis

Continuous data are reported as median and interquartile range (IQR) and compared by surgical shunt type using Kruskal-Wallis test. Categorical data are reported as total (n) and percentage (%), with Fisher exact tests used to evaluate across shunt types. Intervention-free shunt patency was calculated using Kaplan-Meier survival analysis with differences between groups estimated by a log-rank test. All statistical analyses were performed using JMP Pro (SAS Institute, Cary, NC, version 14.0).

Results

Demographics and outcomes for patients undergoing surgical shunt

During the 10-year study period, 34 patients underwent creation of a surgical shunt. The demographics for all patients are reported in Table I. The median age was 7.7 years (IQR 4.3–12.0). Twenty-eight patients (82.4%) had prehepatic pHTN resulting from EPVT with cavernous transformation, 1 patient (2.9%) with prehepatic pHTN secondary to an aberrant splenic vein that drained into the left coronary vein, and 5 patients (14.7%) had intrahepatic pHTN secondary to hepatic fibrosis of varying causes. Nearly all shunts ($n = 28$, 82.4%) were performed in the elective setting, with the remainder ($n = 6$, 17.7%) done urgently during a pHTN-related admission; no shunts were performed emergently. The primary manifestations of pHTN were esophageal varices ($n = 33$, 97.1%) and gastrointestinal bleeding ($n = 26$, 76.5%). Four patients (11.8%) were prior liver transplant recipients who subsequently developed EPVT

Table I
Demographics and baseline characteristics for patients with pHTN undergoing surgical shunt

	All patients (n = 34) n (%) median (IQR)	Meso-rex (n = 18) n (%) median (IQR)	Splenorenal (n = 10) n (%) median (IQR)	Mesocaval (n = 6) n (%) median (IQR)	*P* value[†]
Male	20 (58.8)	11 (61.1)	5 (50.0)	4 (66.7)	.81
Race					.45
White	26 (76.5)	13 (72.2)	8 (80.0)	5 (83.3)	
Black	3 (8.8)	1 (5.6)	2 (20.0)	0	
Hispanic	3 (8.8)	3 (16.7)	0	0	
Asian	2 (5.9)	1 (5.6)	0	1 (16.7)	
Age at time of surgery, y	7.7 (4.3–12.0)	6.9 (4.3–8.7)	8.1 (4.6–12.3)	10.4 (4.4–16.9)	.67
ASA classification					.04[*]
Class I	0	0	0	0	
Class II	3 (8.8)	2 (5.9)	0	1 (16.7)	
Class III	27 (79.4)	16 (94.1)	7 (70.0)	4 (66.7)	
Class IV	4 (11.8)	0	3 (30.0)	1 (16.7)	
Timing of operation					.60
Emergent	0	0	0	0	
Urgent	6 (17.7)	3 (16.7)	1 (10.0)	2 (33.3)	
Elective	28 (82.4)	15 (83.3)	9 (90.0)	4 (66.7)	
Prior liver transplant	4 (11.8)	2 (11.1)	1 (10.0)	1 (16.7)	1.00
Cause of pHTN					<.01[*]
EPVT	28 (82.4)	18 (100.0)	4 (40.0)	6 (100)	
CLD	5 (14.7)	0	5 (50.0)	0	
Other	1 (2.9)	0	1 (10.0)	0	
Type of pHTN					<.01[*]
Prehepatic	29 (85.3)	18 (100.0)	5 (50.0)	6 (10.0)	
Intrahepatic	5 (14.7)	0	5 (50.0)	0	
Posthepatic	0	0	0	0	
Preoperative symptoms of pHTN					
Esophageal varices	33 (97.1)	17 (94.4)	10 (100.0)	6 (10.0)	1.00
GI bleeding	26 (76.5)	12 (66.7)	8 (80.0)	6 (10.0)	.31
Refractory ascites	2 (5.9)	0	2 (20.0)	0	.11
Hepatopulmonary syndrome	2 (5.9)	1 (5.6)	1 (10.0)	0	1.00
Hepatorenal syndrome	0	0	0	0	—
Hepatic encephalopathy	0	0	0	0	—

ASA, American Society of Anesthesiologists; *CLD*, chronic liver disease; *GI*, gastrointestinal.
[*] $P < .05$.
[†] *P* value comparing shunt subgroups by Kruskal-Wallis or Fisher exact tests.

and pHTN. The median time from liver transplantation to portal shunt among these patients was 10.7 years (IQR 3.3–17.8).

Outcomes after shunt creation are reported in Table II. Short-term outcomes were notable for few wound complications ($n = 3$, 8.8%). Other complications occurred in 7 patients and included acute respiratory failure ($n = 3$), acute kidney injury ($n = 2$), pancreatitis ($n = 1$), decompensated right heart failure in a patient with pre-existing cardiomyopathy ($n = 1$), seizure ($n = 1$), and an iatrogenic bowel injury that required reoperation ($n = 1$). The 60-day readmission rate was 11.8%, none of which were for reoccurrence of pHTN, and rebleeding within 60 days occurred in 4 patients (11.8%). The 60-day mortality rate was 2.9% ($n = 1$); this was the only mortality of the cohort at any point and occurred in a patient with a thrombosed shunt performed for palliative management of an unresectable hepatocellular carcinoma who elected to discharge to hospice. The median follow-up was 34.1 months (IQR 13.1–79.4) and the majority of patients had appropriate growth, duration, and cognitive development at the time of last follow-up.

Demographics and outcomes by shunt type

Eighteen patients (52.9%) underwent MRB, 10 patients (29.4%) underwent splenorenal shunt, and 6 patients (17.7%) underwent mesocaval shunt. Comparing patients by shunt type, the demographics of each cohort are reported in Table I. As expected, there were differences in the cause and type of pHTN ($P < .05$ for each). All patients in the MRB group had prehepatic pHTN and all 5 of the patients with intrahepatic pHTN underwent splenorenal. Of the remaining 11 patients (all with prehepatic pHTN who did not undergo MRB), 5 underwent splenorenal shunt, and 6 underwent mesocaval shunt. Compared with MRB patients, the splenorenal and mesocaval shunt patients had slightly worse American Society of Anesthesiologists scores ($P = .04$). There were otherwise no differences between groups.

Intraoperative, short-term, and long-term outcomes were similar between the cohorts, as reported in Table II. Although not statistically significant, larger decrements in portal pressures were noted after portosystemic shunt compared with MRB. MRB had a median decrease of 2.2 mm Hg (pre 24.3 mm Hg, post 20.6 mm Hg) compared to 5.1 mm Hg (pre 28.7 mm Hg, post 22.8 mm Hg) with splenorenal shunts and 7.7 mm Hg (pre 26.5 mm Hg, post 20.6 mm Hg) with mesocaval shunts ($P = .10$). Rebleeding occurred in 1 patient in the MRB group, 1 patient in the splenorenal group, and 2 patients in the mesocaval group. Moreover, shunt complication occurred in 27.8% ($n = 5$) of the MRB group, 20.0% ($n = 2$) of the splenorenal group, and 50.0% ($n = 3$) of the mesocaval group.

Postoperative shunt complications and long-term patency

Among all patients, 10 (29.4%) experienced a shunt complication, 4 of which occurred in the early postoperative setting and required urgent intervention. Two patients underwent reoperation and shunt revision, while the other 2 were managed percutaneously by interventional radiology. Two patients (5.9%) had more than 1 shunt complication, and of all 10 complications, only 2 patients (5.9%) were unable to achieve shunt salvage yielding an overall secondary patency rate of 94%. The details of the patients experiencing shunt complications are reported in Table III. Compared by group, early shunt thrombosis did not occur in the

Table II
Outcomes for patients with pHTN undergoing surgical shunt

	All patients (n = 34) n (%) median (IQR)	Meso-rex (n = 18) n (%) median (IQR)	Splenorenal (n = 10) n (%) median (IQR)	Mesocaval (n = 6) n (%) median (IQR)	*P* value[†]
Operative time, min	455 (361–617)	422 (400–578)	390.5 (331–545)	553.5 (455–705)	.52
Estimated blood loss, mL	200 (100–350)	200 (100–300)	125 (100–200)	450 (150–1000)	.26
Intraoperative resuscitation					
Crystalloid, L	1.9 (1.2–2.9)	1.7 (1.2–2.5)	2.1 (1.0–3.2)	2.1 (1.5-3.0)	.53
Albumin, mL	451 (203–912)	280 (205–740)	500 (120–823)	625 (451–1,000)	.40
Required pRBC	14 (4.1)	7 (38.9)	4 (40.0)	3 (5.0)	.90
Required FFP	1 (2.9)	0	1 (10.0)	0	.47
Required platelets	5 (14.7)	2 (11.1)	2 (20.0)	1 (16.7)	.82
Required cryoprecipitate	2 (5.8)	0	1 (10.0)	1 (16.7)	.21
Portocaval gradient, mm Hg[‡]					
Pre-shunt mesenteric pressure	25.0 (22.1–29.3)	24.3 (22.1–25.7)	28.7 (25.0–35.3)	26.5 (21.7-3.2)	.36
Post-shunt mesenteric pressure	21.0 (18.8–23.0)	20.6 (19.9–25.0)	22.8 (16.9–22.8)	2.6 (16.2-22.8)	.82
Δ Mesenteric pressure	2.9 (0–5.5)	2.2 (0–4.0)	5.1 (2.9–8.8)	7.7 (2.2-12.1)	.10
Short-term outcomes					
Duration of stay, d	9.5 (7.0–16.3)	9.0 (7.0–13.5)	9.5 (7.8–13.3)	18.0 (9.0-37.5)	.21
Postoperative RBC transfusion	9 (27.3)	4 (23.5)	3 (30.0)	2 (33.3)	.94
Wound complication	3 (8.8)	1 (5.6)	0	2 (33.3)	.14
Early shunt thrombosis	4 (11.8)	0	2 (20.0)	2 (33.3)	.03*
Unplanned reoperation	4 (11.8)	1 (5.6)	1 (10.0)	2 (33.3)	.20
Other complications	7 (20.6)	2 (11.1)	2 (20.0)	3 (5.0)	.13
Long-term outcomes					
60-day recurrent GI bleeding	4 (11.8)	1 (5.6)	1 (10.0)	2 (33.3)	.20
60-day readmission	4 (11.8)	1 (5.6)	3 (30.0)	0	.19
60-day mortality	1 (2.9)	0	0	1 (16.7)	.18
Appropriate growth development, length[§]	28 (82.4)	16 (88.9)	7 (70.0)	5 (83.3)	.51
Appropriate growth development, weight[§]	29 (85.3)	17 (94.4)	7 (70.0)	5 (83.3)	.22
Appropriate cognitive development[§]	27 (79.4)	15 (83.3)	9 (90.0)	3 (5.0)	.16
Shunt complication (at any point)	10 (29.4)	5 (27.8)	2 (20.0)	3 (5.0)	.46
Postshunt liver transplantation	4 (11.8)	0	3 (30.0)	1 (16.7)	.07
Median follow-up, mo	34.1 (13.1–79.4)	35.1 (15.4–77.9)	14.0 (6.1–93.5)	37.0 (14.3–85.0)	.58

FFP, fresh frozen plasma; *GI*, gastrointestinal; *pRBC*, packed red blood cells.
* $P < .05$.
† *P* value comparing shunt subgroups by Kruskal-Wallis or Fisher exact tests.
‡ Among patients who had intraoperative portal pressures measured ($n = 17, 6, 5$, respectively).
§ Defined as growth greater than the fifth percentile or normal cognitive assessment at most recent follow-up.

MRB group but was observed more frequently in the splenorenal and mesocaval shunt groups ($n = 2$, 20.0% and $n = 2$, 33.3%, respectively, $P = .03$).

Finally, the overall 1-year and 5-year intervention-free shunt patency rates were 71% and 66%, respectively (Fig 1, *A*). Although there was no significant difference in intervention-free shunt patency by shunt type ($P = .28$), mesocaval shunts seemed to have worse rates of primary patency. The 1-year and 5-year intervention-free shunt patency rates were 77% and 68% for MRB, 80% and 80% for splenorenal, and 40% and 40% for mesocaval shunts (Fig 1, *B*).

Discussion

In this study, we report our center's experience with mesentericoportal and portosystemic shunts for the treatment of pediatric pHTN in the modern era. Consistent with existing

Table III
Details for patients who experienced postoperative shunt complications

Patient	Sex, age (y)	Cause of pHTN	Type of pHTN	ASA classification	Type of shunt	Timing of shunt	Time to shunt complication[†] (mo)	Shunt complication details
1	M, 12	EPVT	Prehepatic	3	DSRS	Elective	0.1	Occlusion requiring surgical thrombectomy
2	F, 1	EPVT	Prehepatic	2	Mesocaval	Elective	0.3	Occlusion requiring IR administration of tPA into SMV
3*	M, 21	EPVT	Prehepatic	3	Mesocaval	Elective	0.5	Occlusion requiring surgical revision; subsequent occlusion POD 3 after revision, not amendable to surgical revision; managed medically thereafter
4	M, 1	EPVT	Prehepatic	3	DSRS	Elective	0.8	Stenosis requiring IR balloon angioplasty
5	M, 2	EPVT	Prehepatic	3	Meso-Rex	Urgent	1.6	Occlusion requiring surgical revision with DSRS
6	F, 6	EPVT	Prehepatic	3	Meso-Rex	Elective	4.2	Occlusion not amenable to surgical revision, managed symptomatically with EGD banding as needed
7*	M, 8	EPVT	Prehepatic	2	Meso-Rex	Elective	5.6	Stenosis requiring IR angioplasty; stenosis 5 months after procedure requiring repeat IR angioplasty
8	M, 11	EPVT	Prehepatic	3	Meso-Rex	Elective	6.2	Occlusion requiring surgical revision with DSRS
9	M, 4	EPVT	Prehepatic	3	Mesocaval	Urgent	7.5	Occlusion requiring surgical revision with CSRS
10	F, 4	EPVT	Prehepatic	3	Meso-Rex	Elective	30.6	Stenosis with no intervention required

ASA, American Society of Anesthesiologists; *CSRS*, central splenorenal shunt; *EGD*, esophagogastroduodenoscopy; *IR*, interventional radiology; *POD*, postoperative day; *TPA*, tissue plasminogen activator.
* Patient experienced >1 shunt complication event.
† If multiple occlusions or stenoses, refers to timing of first complication.

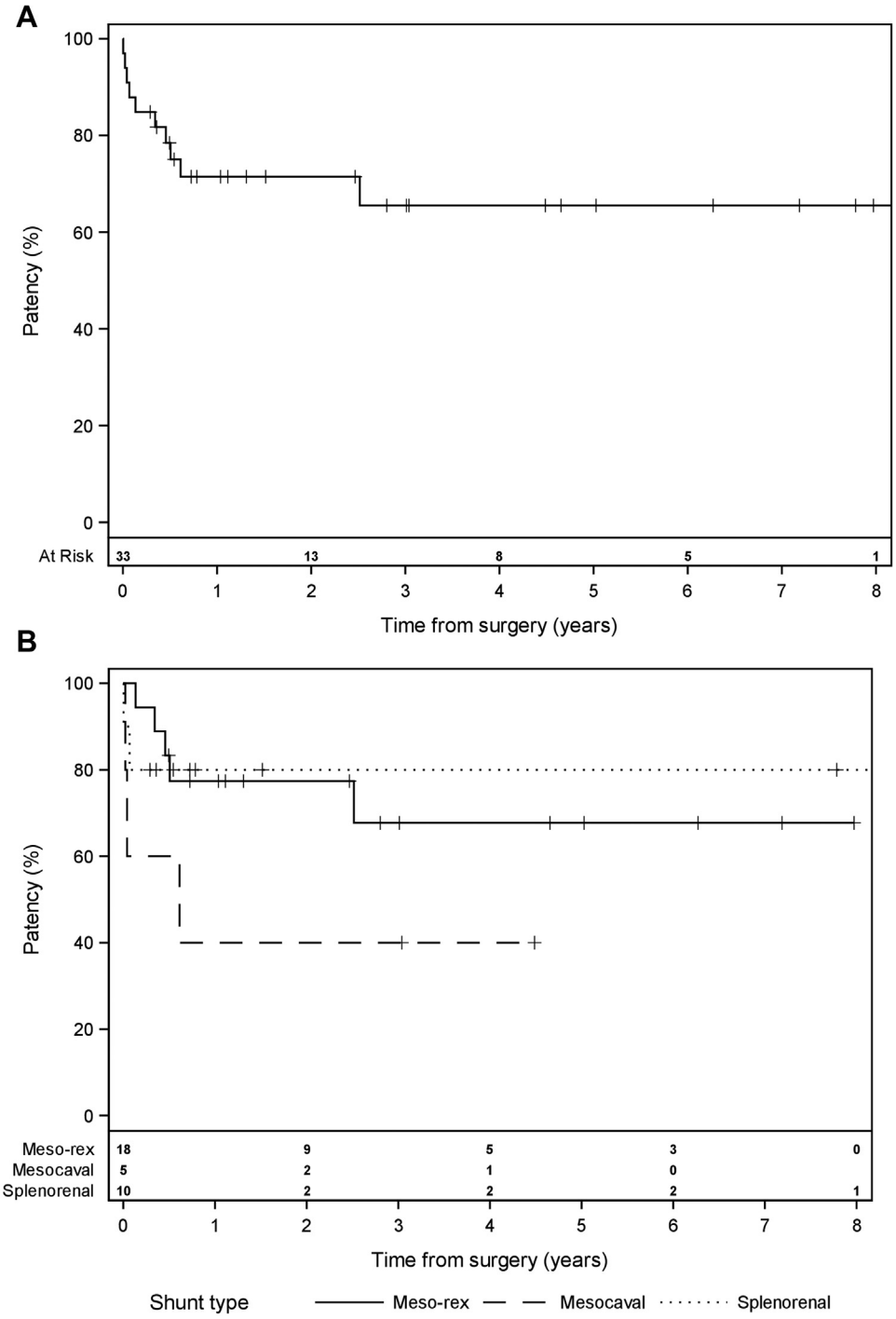

Fig 1. Intervention-free shunt patency following surgical shunt creation in pediatric patients with portal hypertension. (*A*) Overall intervention-free shunt patency for entire cohort. (*B*) Intervention-free shunt patency by shunt type.

literature, both the MRB and PSS were effective at treating the underlying pathophysiology of pHTN and accompanied by low rates of postoperative morbidity and mortality. Our outcomes were notable for a low rate of rebleeding ($n = 4$, 11.8%), and despite 10 patients experiencing a shunt complication, only 2 (5.9%) were unable to be salvaged. Our experience supports the approach of attempting MRB as the preferred first-line technique, reserving the splenorenal and mesocaval shunts for when MRB is unable to be performed.

Pediatric portal diversion was originally achieved by PSS nearly 40 years ago and has been established as an effective treatment option in children.[17,18] Since these early reports the management of pHTN has evolved. More recently, the use of TIPS in carefully selected pediatric patients has emerged.[7,8] TIPS has been successfully performed among patients with various forms of pHTN, including prehepatic pHTN due to EPVT with cavernous transformation.[19] It is important to note, however, that the majority of existing literature supporting TIPS in children are case series and

data addressing appropriate patient selection and long-term outcomes are lacking.[20–22] Although direct comparison of surgical shunt to TIPS in the pediatric population has not been performed, data from the adult population suggests that PSS are associated with improved survival and shunt patency compared with TIPS.[23] A recently published single-center experience on long-term outcomes of TIPS in children sheds light on this topic. The authors report that although TIPS was able to be performed in 95% of patients, 9 (45%) required revision and 10 (48%) developed hepatic encephalopathy within the first year after TIPS placement.[24] This highlights that TIPS should be viewed as a temporizing measure, rather than definitive intervention. Consequently, if TIPS is undertaken, knowledge and experience with surgical shunts remains important for the eventual TIPS failure.[25]

Once the decision is made to intervene surgically, there are a variety of operative techniques that can be implemented. Although various forms of PSS have been used to divert portal flow for all types of pHTN, the MRB has emerged as a unique option to reestablish proper portal circulation to the liver and alleviate prehepatic pHTN subsequent to portal obstruction.[9] In 2013, Lautz et al provided the first study directly comparing MRB to PSS in children and provided evidence that MRB is superior to PSS.[26] Although the majority of outcomes did not differ by shunt type in our analysis, we did observe that the MRB was less likely to have early shunt occlusion compared with PSS shunts. The MRB was originally described by de Ville de Goyet et al as an interposition graft from the SMV to Rex recess.[9] The MRB has since been modified by manipulation of the afferent vessel, with modifications including use of the IMV,[11] left gastric (coronary) vein,[12] splenic vein,[13] or a dilated portal vessel (when cavernous transformation has occurred)[14] for shunt inflow. Among the 18 MRB anastomoses performed in this study, 8 involved a hilar varix shunted using an autologous IJV conduit, 5 were from the SMV or IMV with an IJV conduit, 4 were direct end-to-side anastomosis of the left gastric vein, and 1 spleno-Rex bypass using an IJV conduit. Our small cohort size unfortunately precludes comparison by Rex modifications or conduit type. However, recent work suggests that use of an autologous vein graft is superior to a synthetic graft and that shunting between a hilar varix or portal vessel and the Rex recess may be the optimal modification.[27,28]

Current guidelines recommend preferential use of the MRB when anatomically feasible.[29] Although all patients undergo preoperative imaging to assess anatomic feasibility, such workup is nuanced by a high false negative rate. At our institution, all patients undergo multimodal imaging to assess mesenteric vasculature. In this series, the positive predictive value of MRB feasibility by preoperative workup was 94%, whereas the negative predictive value was 43%. As such, we recommend that all patients undergo intraoperative exploration for MRB despite unfavorable anatomy on preoperative imaging. When an MRB is not achieved in a patient with prehepatic pHTN, it is important to note why. In our study, 29 patients had prehepatic pHTN, of whom 11 did not receive an MRB. Of these 11 patients, the operative intent in 5 was PSS from the onset due to anatomic or physiologic reasons, and 3 patients had unfavorable anatomy on preoperative workup, which was confirmed upon intraoperative exploration. The remaining 3 patients had preoperative imaging suggestive of favorable anatomy, but an MRB was not successfully performed. Finally, when an MRB is not possible, our preference is the splenorenal shunt unless a mesocaval shunt is necessary. Of the 6 patients who underwent mesocaval shunt, reasons included prior surgery precluding a DSRS (ie, splenectomy, $n = 1$; Nissen fundoplication, $n = 1$), need to decompress bleeding varices in the Roux limb of a prior biliary reconstruction ($n = 1$), and palliative decompression in a patient with unresectable hepatocellular carcinoma. The remaining 2 mesocaval shunts occurred in patients in whom an MRB was attempted but intraoperative shunt complications resulted in conversion to a mesocaval shunt.

Taken together, our data, in conjunction with existing literature, support the use of portal diversion by surgical shunt in the management of pediatric pHTN. Moving forward, discussions now center on the role of preemptive portal diversion for prehepatic pHTN before the development of any sequelae of pHTN. Current leaders in the field have argued for such approach to EPVT, suggesting that in patients with favorable anatomy, MRB should be considered early in the disease course.[30] In fact, consideration of surgical shunting as a primary treatment for prehepatic pHTN is consistent with expert consensus for the management of pediatric pHTN based on the group's application of the Baveno V statements to children.[1] Although questions remain as to when and how to achieve portal diversion in the management of pHTN, it is clear that surgical shunt creation remains an important tool in the modern era.

There are several limitations to this study. First, it is retrospective in nature and as such is limited in comparing outcomes among the groups compared with a prospective, randomized study design. Second, the small cohort lacks sufficient power to detect small or modest effect sizes between shunt type; as such, we interpret the data with care. Third, our postoperative antiplatelet or anticoagulation regimens differ by shunt type, which may affect primary shunt patency rates. To our knowledge, however, no consensus guidelines exist on the optimal regimen by shunt type, but this question cannot be addressed by our data. Our approach has been developed in collaboration with hematologist at our institution with the notion that patients should be anticoagulated while the conduit, if used, has time to endothelialize. Fourth, our postoperative outcomes of morbidity, including ascites and hepatic encephalopathy, are limited to 60 days postoperatively. Therefore, we cannot account for potential episodes of morbidity beyond this time point except for shunt complications. Finally, our institution serves a large referral population and some acute events may be managed at outside hospitals; however, given our center's expertise in pediatric hepatopancreatobiliary surgery, most patients follow-up at our center during which time comprehensive review of patients' course is conducted.

In conclusion, we report our center's modern experience with mesentericoportal and portosystemic shunts for the treatment of pediatric pHTN. Consistent with existing literature, both the MRB and PSS were effective at treating the underlying pathophysiology of pHTN with low rates of postoperative morbidity and mortality. Patients who underwent portal diversion had low rates of rebleeding and limited occlusion events, of which the majority were able to be salvaged. Given the efficacy of surgical shunts and their long-term patency, careful consideration should be given to shunt creation during interdisciplinary management of pHTN in the pediatric population.

Disclosure

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