Progression of Noncirrhotic Portal Hypertension in a Pediatric Population

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Background/Objectives: The optimal management of children with noncirrhotic portal hypertension is controversial. Some groups suggest early and aggressive surgical intervention, while others report long-term success with conservative management. **Methods:** We conducted a retrospective study of 26 patients with noncirrhotic portal hypertension treated at our institution. We compared platelet counts, white blood cell (WBC) counts, spleen size, hospital admissions, gastrointestinal bleeds, and longitudinal trends of specific clinical parameters using standard univariate and time-trend analytic techniques. **Results:** Mean age at the time of diagnosis was 5.2 years. Portal vein thrombosis was found in 84.6% of patients ($n=22$). There was one mortality related to malignancy. There was not a progression of hypersplenism in patients that did not receive a shunt and conversely, we did not notice a significant decrease in spleen size following shunt surgery ($P=0.2$). Platelet and WBC counts trended downward among patients managed medically, while platelets increased and WBC counts remained stable in surgical patients. There was a significant decrease in hospital admissions for gastrointestinal bleeding following surgical intervention in the shunt group compared with nonshunt ($P=0.0009$). **Conclusion:** While our analysis was limited given small sample sizes and selection bias, it suggests that the majority of pediatric patients with noncirrhotic portal hypertension will do well long-term without surgical intervention. (J CLIN EXP HEPATOL 2011;1:169–176)

Portal hypertension is classically caused by cirrhotic liver disease. However, there are several etiologies of portal hypertension that do not coincide with liver failure. Noncirrhotic portal hypertension may manifest clinically by upper gastrointestinal (GI) bleeding from esophageal varices, leukopenia, and thrombocytopenia from splenomegaly.^{1,2} While studies have shown that certain liver functions are affected as a result of reduced portal venous flow, ascites and clinical encephalopathy are not common given the lack of intrinsic liver dysfunction.^{1–8} Noncirrhotic etiologies of portal hypertension are classified as prehepatic, hepatic, and posthepatic. Prehepatic causes are associated with thrombosis within the portal venous system. Hepatic causes include noncirrhotic portal fibrosis and schistosomiasis. Finally, Budd–Chiari syndrome, inferior vena cava (IVC) thrombosis/occlusion, and constrictive pericarditis are posthepatic etiologies of portal hypertension.

In pediatric patients, portal vein thrombosis (PVT), or extrahepatic portal vein obstruction (EHPVO), is the most common cause of noncirrhotic portal hypertension. The pathophysiology of PVT is poorly understood, although studies have identified several pre-disposing factors, including neonatal umbilical vein catheterization and hypercoagulable states.^{9,10} Indications for surgical intervention on these complex children are controversial, but include refractory variceal hemorrhage, severe thrombocytopenia, severe leukopenia, encephalopathy, and porto-pulmonary hypertension.² There are various surgical interventions available that attempt to improve the portal flow, including the meso-Rex bypass,¹¹ distal splenorenal shunt,^{12,13} splenectomy followed by proximal splenorenal shunt, and the mesocaval shunt.¹⁴ The aforementioned procedures are all significant operations and have a broad range of potential complications, including shunt thrombosis. Consideration of these risks is important, given that many patients have been reported to do well long-term without any surgical intervention.^{1,15}

While surgery is often recommended following a GI bleed requiring blood transfusion, specific indications for surgical intervention are unclear. Further, with the development of advanced endovascular techniques, clinical decision-making has become even more complex. We have recently established a pediatric portal hypertension program at our institution, which includes hepatologists, interventional radiologists, radiologists, and surgeons. As we develop our own protocols for the management of children with noncirrhotic portal hypertension, we have reviewed

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Abbreviations: CT: computed tomography; EHPVO: extrahepatic portal vein obstruction; GI: gastrointestinal; IVC: inferior vena cava; K=1000; MRI: magnetic resonance imaging; PVT: portal vein thrombosis; TIPS: transjugular intrahepatic portosystemic shunt; WBC: white blood cell
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our historical experience. Until recently, surgical cases were generally referred to another institution and many patients without strong indications for surgery received nonsurgical therapy. We hypothesize that the majority of patients with noncirrhotic portal hypertension will do well long-term without surgical interventions to reduce portal hypertension. With this work, we hope to better understand the natural history of noncirrhotic portal hypertension in order to improve the medical, interventional, and surgical management of these complex patients.

METHODS

Patient Selection

Pediatric patients with a diagnosis of portal hypertension that was not due to cirrhotic liver disease treated at our institution were identified using three rounds of subsequent selection. First, electronic medical records for patients seen at our pediatric gastroenterology clinic from 2002 to 2010 were searched using a natural language search program called the Electronic Medical Record Search Engine (EMERSE). A search criterion was built to identify patients diagnosed with portal hypertension or a disease that could lead to it as a sequelae. The search selected records that contained 'thrombosis of portal vein' or 'endovenotomy' or 'portal vein thrombectomy' or 'congenital vascular anomalies' or 'noncirrhotic portal hypertension' or 'portal vein hypertension' or 'Abernathy's disease' or 'splenic vein thrombosis' or 'mesenteric vein thrombosis' or 'PVT' or 'schistosomiasis.' A second round EMERSE search using 'cirrhosis' or 'cirrhotic' eliminated patients with forms of cirrhotic liver disease. All EMERSE searches accepted standard abbreviations and eliminated negative precursor statements (e.g. 'evaluate for' or 'rule out'). The third round consisted of an individual review of the medical record for each patient selected from round two, performed by two independent reviewers. Those that did not meet our inclusion criteria were eliminated. Final inclusion criteria included children with noncirrhotic portal hypertension.

Data Collection

We reviewed each patient's medical record to log-selected clinical parameters. Prior to the onset of data extraction, both investigators reviewed a subset of 5 patients to identify the weaknesses in the data collection protocol and enhance reproducibility and reliability. Demographic factors collected included date of birth, date of death, cause of death, gender, and race. Date of portal hypertension diagnosis was considered the first time it was documented by a gastroenterologist; the etiology of disease was recorded if it was known.

Spleen size was trended by collecting all documented measurements by computed tomography (CT), ultrasound, or magnetic resonance imaging (MRI). Splenectomy, splenic vein rupture, and associated activity were noted. All white

blood cells (WBC) and platelet counts were recorded with the date of blood draw. The patient was considered to have ascites if this was documented on physical examination by a gastroenterologist; imaging diagnosis of ascites was not included. The PVT was considered a thrombus in the portal vein, splenic vein, or mesenteric vein as documented by CT, ultrasound, or MRI. It was noted if the patient had a source of a hypercoagulable state.

All inpatient hospital admissions were included along with the date of admission, date of discharge, and discharge diagnosis. Inpatient and outpatient procedures with their respective date were noted. Portal hypertension interventions included shunt or transjugular intrahepatic portosystemic shunt (TIPS). The dates of intervention, description of complications, and subsequent interventions or modifications were recorded.

Statistical Analysis

Decompensation due to portal hypertension was defined as WBC <2.5 , platelets <50 , hospital admission for GI bleeding, and death. Patients that had co-morbidities or a procedure that would confound the analysis of the response to intervention were excluded from the statistical analysis, but included in the descriptive tables.

Continuous variables were summarized by mean and standard deviation and compared using a student's *t* test. Fisher's exact test was used for the categorical variables. A filtered level plot was created using SAS9.2 PROC UCM procedure, which analyzes univariate time series data by using an unobserved component model (UCM) for WBC count, platelet count, and spleen size.¹⁶ The filtered series represents an estimate based on an observed time series by removing the estimated measurement noise. All analyses used SAS v9.2 (SAS Institute).

RESULTS

Study Population

We searched an initial list of 3117 pediatric patients from our gastroenterology clinic and ultimately identified 26 patients that carried a confirmed diagnosis of noncirrhotic portal hypertension. Patients were divided into 2 groups, 'shunt' and 'nonshunt,' the former being those that underwent surgical intervention.

Patient Characteristics

Individual characteristics of study patients are described in Table 1. Etiologies of portal hypertension included PVT from a prior umbilical vein catheter ($n=7$), idiopathic ($n=6$), hypercoagulable state ($n=6$), congenital hepatic fibrosis ($n=2$), chemotherapy-associated PVT ($n=2$), agenesis of a vessel within the portal system ($n=2$), and Budd-Chiari secondary to polycythemia vera ($n=1$). The PVT was found in 84.6% of patients ($n=22$). Patient 18 was

found to have an isolated splenic vein thrombosis that resolved (presumably recanalized) 1 year later. He was included in the study.

Collective characteristics of the study population are displayed in Table 2. Mean age at the time of diagnosis was 5.2 years. The mean follow-up time was 5.8 and 5.2 years for the nonshunt and shunt group, respectively. There was

a slight female predominance (58%) and the majority of the study population was Caucasian (92%). Inpatient hospital admission for GI bleeding was common, occurring once in 46% of patients and at least 2 times in 24% of patients. Decompensation defined by WBC or platelet counts occurred in 62% and 48% of patients, respectively. There was 1 patient death that was determined to be secondary

Table 1 Individual characteristics of noncirrhotic portal hypertension patients.

Patient	Portal hypertension etiology	Gender	Age at diagnosis (yr)	Death	PVT ¹	Splenectomy	Intervention	Ascites ²	GI bleeds ³
1	Agenesis of PV	F	2.75	No	Yes	Yes	Shunt	No	5
2	Agenesis of suprarenal cava and PV	F	14.5	No	Yes	Yes	Shunt	No	0
3	Budd–Chiari syndrome from polycythemia vera	F	2.25	No	Yes	No	No	Yes	0
4	Chemotherapy-associated PVT	M	9.75	No	No	No	No	Yes	0
5	Chemotherapy-associated PVT	M	15	No	No	Yes	No	No	1
6	Congenital hepatic fibrosis	F	6.5	No	No	No	TIPS	No	1
7	Congenital hepatic fibrosis	M	2.75	Yes	No	No	No	Yes	0
8	Hypercoagulable; MTHFR homozygous	F	0.5	No	Yes	No	Shunt	Yes	3
9	Hypercoagulable; MTHFR homozygous	M	0.75	No	Yes	Yes	No	Yes	19
10	Hypercoagulable; MTHFR heterozygote/protein C deficiency	F	7.25	No	Yes	No	No	Yes	1
11	Hypercoagulable; MTHFR homozygous	F	1.75	No	Yes	No	No	No	1
12	Hypercoagulable; protein C deficiency	M	11.75	No	Yes	No	No	Yes	0
13	Hypercoagulable; protein C deficiency	F	6.75	No	Yes	No	Shunt	Yes	2
14	Idiopathic PVT	F	3.25	No	Yes	No	No	No	1
15	Idiopathic PVT	F	3	No	Yes	No	No	No	1
16	Idiopathic PVT	F	1	No	Yes	No	Shunt	No	1
17	Idiopathic PVT	M	3	No	Yes	No	No	Yes	1
18	Idiopathic PVT	M	4	No	Yes	No	No	No	1
19	Idiopathic PVT	M	14.25	No	Yes	No	No	No	1
20	Umbilical vein catheter PVT	M	14	No	Yes	No	No	Yes	2
21	Umbilical vein catheter PVT	M	3	No	Yes	No	No	No	0
22	Umbilical vein catheter PVT	F	2	No	Yes	No	Shunt	No	2
23	Umbilical vein catheter PVT	F	2.75	No	Yes	No	Shunt	No	1
24	Umbilical vein catheter PVT	F	3	No	Yes	No	No	No	0
25	Umbilical vein catheter PVT	F	0.25	No	Yes	No	No	No	1
26	Umbilical vein catheter PVT; factor V Leiden	M	0.25	No	Yes	No	No	No	0

PVT: portal vein thrombosis; GI: gastrointestinal; PV: portal vein; TIPS: transjugular intrahepatic portosystemic shunt; MTHFR: methylenetetrahydrofolate reductase.

¹PVT included a thrombus in portal, splenic, and mesenteric veins.

²Ascites as determined by portal hypertension clinic physical examination; did not consider based on imaging.

³GI bleeds considered if they required inpatient admission.

to an underlying malignancy. Surgical intervention was completed in 31% of patients by shunt ($n=7$) or by TIPS ($n=1$). Splenectomy was performed in 4 patients (15%) and patients receive prophylactic immunizations and penicillin for 1 year following surgery. There were no diagnoses

Table 2 Characteristics of noncirrhotic portal hypertension patients.

Characteristic	(Total $n=26$) (%)
Age at diagnosis (mean $\pm$ SD)	5.2 $\pm$ 4.8
Years follow-up time (mean $\pm$ SD)	
Shunt	5.2 $\pm$ 2.8
Nonshunt	5.8 $\pm$ 4.8
Hospital admissions (mean $\pm$ SD)	
Total	4.9 $\pm$ 7.6
GI bleeding	1.8 $\pm$ 3.8
0	8 (31%)
1	12 (46%)
>2	6 (24%)
Gender	
Female	15 (58%)
Race	
Asian	1 (4%)
African American	1 (4%)
Caucasian	24 (92%)
Decompensations	
Platelets <50	16 (62%)
WBC <2.5	15 (58%)
Death	1 (4%)
Intervention	
Shunt	7 (27%)
TIPS	1 (4%)
Splenectomy	4 (15%)

GI: gastrointestinal; WBC: white blood cells; TIPS: transjugular intrahepatic portosystemic shunt.

of clinically relevant porto-biliopathy or encephalopathy in either group, though specific neuro-cognitive testing was not completed.

Progression of Disease in Surgical and Nonsurgical Intervention Groups

Patients 1, 2, 5, and 9 received a splenectomy and patient 3 had an underlying diagnosis of polycythemia vera. They were excluded from the statistical analysis as these factors would confound alternative treatment responses (i.e., cytopenias). Patient 6 was recommended to have a shunt, but the family chose to have a TIPS performed to avoid surgery. This patient was the only TIPS recipient and was excluded from the shunt group statistical analysis.

Splenomegaly

Splenomegaly was assessed using a time series filter plot of spleen measurements in both shunt and nonshunt groups. The shunt group showed a decrease in the spleen size from 10.9 cm prior to surgical intervention, to 9.8 cm following ($P=0.2$) (Figure 1). The nonshunt group spleen size showed a slight increase with time and had an overall mean of 15.0 cm. Univariate analysis comparing the 2 groups demonstrated that both the shunt group pre-intervention ($P=0.0001$) and post-intervention ($P=0.0009$) spleen sizes were significantly lower compared with the overall nonshunt group (Table 3).

Thrombocytopenia

Thrombocytopenia was assessed by comparing the platelet counts using the analyses previously described. The shunt group remained thrombocytopenic, but increased

Figure 1 Spleen size plotted in relation to the date of surgical intervention or diagnosis in the shunt and nonshunt groups, respectively. Data series was filtered to remove background noise and outliers. Shaded area represents 95% confidence interval. There was no significant difference in the spleen size in the shunt group following surgical intervention ($P=0.237$).

Table 3A Univariate analysis comparing clinical parameters between the shunt group prior to surgical intervention and all nonshunt group values.

Pre-intervention parameters	Shunt	Nonshunt	P value
	Mean±standard deviation		
Annual admissions	4.4±3.5	3.1±5.9	0.6418
Annual admissions for GI bleed	1.8±0.8	0.7±0.6	0.0043
Spleen size (cm)	10.9±2.3	15.3±5.3	0.0001
Death	0	1	1.00
WBC (K/mm ³)	4.8±2.9	6.1±5.3	<0.0001
WBC <2.5	3 (60%)	6	0.6169
Platelets (K/mm ³)	122.1±53.9	111.6±62.1	0.0490
Platelets <50	5 (100%)	6 (40%)	0.0379

GI: gastrointestinal; WBC: white blood cells; K=1000.

significantly from 122 K/mm³ to 174 K/mm³ following surgical intervention ($P<0.0001$) (Figure 2). The nonshunt group demonstrated a modest decrease over the observation period with an overall mean of 112 K/mm³ (Figure 2).

Direct comparison by univariate analysis showed the shunt group pre-surgical ($P=0.0490$) and postsurgical ($P<0.0001$) platelet counts to be significantly increased compared with the nonshunt group (Table 3). While 100% of shunt patients experienced a thrombocytopenic decompensation prior to surgery, there were no decompensations following shunt placement.

Leukopenia

Leukopenia was assessed by comparing WBC using the analyses that were previously described. The plot in the shunt group remained stable and did not change significantly from 4.8 K (1000)/mm³ to 4.6 K/mm³ following shunt ($P=0.6656$) (Figure 2). The nonshunt group showed a downward trend in leukocytes with an overall mean of 5.7 K/mm³. Univariate analysis showed the overall number of leukocytes in the nonshunt group to be significantly elevated compared with the pre-surgical ($P<0.0001$) and postsurgical ($P<0.0001$) shunt group values.

Hospital Admissions

Hospital admissions were normalized by the length of time the patient was followed. There was no significant difference in the number of overall hospitalizations between the groups at any time. However, hospitalizations for GI bleeding were significantly increased in the shunt group prior to surgery compared with the nonshunt group (1.8±0.8 vs 0.7±0.6, $P=0.0043$) (Table 3). Following intervention, there were no further admissions for GI bleeding in the shunt group, which was lower than that in the

Table 3B Univariate analysis comparing clinical parameters between the shunt group following surgical intervention and all nonshunt group values.

Post-intervention parameters	Shunt	Nonshunt	P value
	Mean±standard deviation		
Annual admissions	1.2±2.7	3.1±5.9	0.1395
Annual admissions for GI bleed	0	0.7±0.6	0.0009
Spleen size (cm)	9.8±2.3	15.3±5.3	<0.0001
Death	0	1 (7%)	1.00
WBC (K/mm ³)	4.6±1.7	6.1±5.3	<0.0001
WBC <2.5	2 (40%)	2 (40%)	1.00
Platelets (K/mm ³)	173.9±57.7	111.6±62.1	<0.0001
Platelets <50	0 (0%)	6 (40%)	0.2604

GI: gastrointestinal; WBC: white blood cells; K=1000.

nonshunt group (0±0 vs 0.7±0.5, $P=0.0009$) (Table 3). While the majority of hospital admissions were for GI bleeding, other common discharge diagnoses that were not related specifically to another chronic disease included observation following a liver biopsy ($n=4$), viral illness ($n=3$), bacteremia/sepsis ($n=3$), neutropenia ($n=2$), pneumonia ($n=2$), gastroenteritis ($n=2$), splenectomy ($n=2$), observation following endoscopy ($n=2$), complication of shunt/TIPS ($n=2$), and *Clostridium difficile* colitis ($n=2$) (data not shown).

Surgical Interventions and Complications

A description of the surgical interventions and complications of all patients receiving a shunt or TIPS is provided in Table 4. Initial shunts included Rex ($n=4$) and splenorenal ($n=3$). Two of the initial Rex shunts and one splenorenal shunt failed due to thrombosis. Replacement shunt types included mesocaval and meso-ovarian shunts. Patients 8 and 13 had an underlying coagulopathy requiring warfarin. The 2 patients that had both a shunt and a splenectomy showed a more robust increase in both WBC and platelets. One patient with congenital hepatic fibrosis received TIPS and showed worsening spleen size and very little change in WBC and platelets.

DISCUSSION

With this work, we described the natural history of non-cirrhotic portal hypertension in 26 children. Overall, we noted that most of these children did quite well; there was only one mortality, which was related to malignancy. Surprisingly, patients that did not receive a surgical shunt had a relatively stable spleen size over the observation period. Thrombocytopenia and leukopenia are the markers of disease progression and surgical intervention

Figure 2 Platelet and leukocyte counts plotted in relation to the date of surgical intervention or diagnosis in the shunt and nonshunt groups, respectively. Data series was filtered to remove background noise and outliers. Shaded area represents 95% confidence interval. Platelet count increased significantly in the shunt group following surgical intervention ($P < 0.0001$). There was no significant change in white blood cells following surgical intervention ($P = 0.6656$).

WBC: white blood cells; K=1000.

Table 4 Qualitative description of interventions, complications, anti-coagulation treatment, and change in clinical parameters of 8 pediatric patients that had a surgical intervention for noncirrhotic portal hypertension.

Patient #	Intervention	Complication	Pre-/post-intervention parameters			
			Spleen (cm)	WBC (K/mm ³)	Platelets (K/mm ³)	Anti-coagulation
1	Splenorenal shunt	Thrombosis	Splenectomy	3.1/6.7	62/331	Aspirin
	Meso-ovarian shunt	Patent				
2	Rex shunt	Thrombosis	Splenectomy	2.2/6.0	37/249	No
8	Rex shunt	Thrombosis	7.5/7.3	4.0/5.6	140/210	Warfarin
	Mesocaval shunt	Thrombosis				
	Mesocaval shunt	Patent				
13	Rex shunt	Patent	13.8/12.5	3.3/5.5	77/134	Warfarin
16	Splenorenal shunt	None	13.8/12	–	–	No
22	Splenorenal shunt	Patent	11.7/12.0	4.3/3.0	86/115	No
23	Rex shunt	Patent	10.2/9.5	8.3/7	147/184	No
6	TIPS	Patent	17.4/20.3	1.7/2.2	38/40	No

WBC: white blood cells; K=1000; TIPS: transjugular intrahepatic portosystemic shunt.

is sometimes considered for platelet counts $<20\text{ K/mm}^3$ and WBC $<1\text{ K/mm}^3$. Trends with respect to platelet count and WBC count were more difficult to interpret than spleen size. Shunt surgery did seem effective for preventing GI bleeding and subsequent hospital admission. This work supports our hypothesis that the majority of patients with noncirrhotic portal hypertension do not develop significant complications without surgical intervention.

There remains significant controversy in the optimal management of patients with noncirrhotic portal hypertension. With the development of novel surgical techniques, such as the meso-Rex bypass, some groups have suggested an aggressive surgical approach to patients with extrahepatic PVT.^{11,14,17} Conversely, numerous series have suggested that the vast majority of these pediatric patients do well long-term without surgery, even when they develop complications including bleeding from both esophageal and gastric varices.^{18–20} In all, our work supports the contention that a rather conservative approach to the management of noncirrhotic portal hypertension is warranted. Unlike previous work, we did not see clear trends toward decreasing platelet and WBC count and increasing spleen size in patients managed conservatively for noncirrhotic portal hypertension.¹⁵ This may have been related to our small sample size. It is also important to note that previous work suggests that $>90\%$ patency can be achieved with meso-Rex shunt operations.¹⁴ The patients from our institution did not fare this well, requiring numerous reoperations and long-term anti-coagulation for shunt thrombosis. These operations were not done at our institution, but were referred to a center that does a high volume of pediatric portal hypertension surgery. These outcomes will be carefully considered as we develop our own treatment protocols.

The conclusions of this manuscript must be considered within the context of its significant limitations. However, there is little previous work highlighting the course of patients who are medically managed and clinically stable with noncirrhotic portal hypertension. This is a retrospective cohort study from a single institution with a small sample size. While shunt/TIPS is usually recommended following a GI bleed requiring a blood transfusion, specific indications could not be determined due to the retrospective nature of the study and that care was provided by a variety of surgeons outside of our institution. Similarly, indications for the patients who received a splenectomy were unable to be determined. Robust statistical analyses were not possible, given both the small sample size and the complexity of these patients. More importantly, though we make specific comparisons between the shunt and the nonshunt groups, such comparisons are inherently flawed by selection bias. Specifically, the patients were only referred for shunt surgery after significant portal hypertensive complications, confounding

comparisons with the nonshunt group. Similarly, there is significant diversity among this patient group, ranging from patients with hepatic fibrosis to patients with hypercoagulable states and complex mesenteric veno-occlusive disease. Efforts to grade the severity of portal hypertension were limited by the retrospective nature of this study. Finally, previous work has suggested that the restoration of portal flow has a number of beneficial effects, including improvement in neuro-cognitive ability, synthetic liver function, and growth. None of these assessments were performed in our study cohort.

This work suggests that the majority of patients with noncirrhotic portal hypertension do well long-term without surgical shunt placement. Certainly, a subset of patients will develop clear indications for shunt surgery, including refractory or recurrent GI bleeds, profound hypersplenism, and thrombocytopenia. For patients with a relatively focal extrahepatic PVT, with adequate intrahepatic portal venous outflow and mesenteric venous inflow, endovascular portal vein recanalization is a potential option. This is a relatively low-risk procedure, is noninvasive, and if it fails it does not eliminate future surgical options.^{21,22} Given the low risk and potentially high yield of these procedures, they can be considered in children without clear indications for surgical intervention that have a favorable anatomy. If this procedure fails, then continued observation seems appropriate for the majority of patients, unless they develop significant complications of portal hypertension.

In summary, controversy will remain regarding the optimal management of pediatric patients with noncirrhotic portal hypertension. Review of these cases and their diagnostic studies by a multidisciplinary group of pediatric subspecialists, including interventional radiologists, surgeons, and hepatologists, is critical for developing an optimal management plan. Currently, this patient population is screened for varices by endoscopy every 6–12 months with subsequent banding if indicated. Endoscopic screening and management may be adequate for the majority of these patients. Therefore, the pediatric hepatologist is critical in determining the indications for surgical intervention. With the rapid development of novel endovascular technologies, a collaboration between surgeons and interventional radiologists is of increased importance. Additional multicenter prospective studies are needed to better understand and manage these complex children.

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CONFLICTS OF INTEREST

All authors have none to declare.

REFERENCES

1. Sarin SK, Kumar A, Chawla YK, et al. Noncirrhotic portal fibrosis/idiopathic portal hypertension: APASL recommendations for diagnosis and treatment. *Hepatol Int* 2007;1:398–413.
2. Superina RA, Alonso EM. Medical and surgical management of portal hypertension in children. *Curr Treat Options Gastroenterol* 2006;9:432–43.
3. Chaudhary A, Dhar P, Sarin SK, et al. Bile duct obstruction due to portal biliopathy in extrahepatic portal hypertension: surgical management. *Br J Surg* 1998;85:326–9.
4. Chiu B, Superina R. Extrahepatic portal vein thrombosis is associated with an increased incidence of cholelithiasis. *J Pediatr Surg* 2004;39:1059–61.
5. Mack CL, Superina RA, Whittington PF. Surgical restoration of portal flow corrects procoagulant and anticoagulant deficiencies associated with extrahepatic portal vein thrombosis. *J Pediatr* 2003;142:197–9.
6. Mack CL, Zelko FA, Lokar J, et al. Surgically restoring portal blood flow to the liver in children with primary extrahepatic portal vein thrombosis improves fluid neurocognitive ability. *Pediatrics* 2006;117:405–12.
7. Sarin SK, Guptan RC, Malhotra S. Increased frequency of gallstones in cirrhotic and non-cirrhotic portal hypertension. *J Assoc Physicians India* 2002;50:518–22.
8. Rangari M, Gupta R, Jain M, Malhotra V, Sarin SK. Hepatic dysfunction in patients with extrahepatic portal venous obstruction. *Liver Int* 2003;23:434–9.
9. Gauthier F. Recent concepts regarding extra-hepatic portal hypertension. *Semin Pediatr Surg* 2005;14:216–25.
10. Pietrobattista A, Luciani M, Abalde JG, et al. Extrahepatic portal vein thrombosis in children and adolescents: influence of genetic thrombophilic disorders. *World J Gastroenterol* 2010;16:6123–7.
11. de Ville de Goyet J, Alberti D, Clapuyt P, et al. Direct bypassing of extrahepatic portal venous obstruction in children: a new technique for combined hepatic portal revascularization and treatment of extrahepatic portal hypertension. *J Pediatr Surg* 1998;33:597–601.
12. Shilyansky J, Roberts EA, Superina RA. Distal splenorenal shunts for the treatment of severe thrombocytopenia from portal hypertension in children. *J Gastrointest Surg* 1999;3:167–72.
13. Warren WD, Zeppa R, Fomon JJ. Selective trans-splenic decompression of gastroesophageal varices by distal splenorenal shunt. *Ann Surg* 1967;166:437–55.
14. Superina R, Shneider B, Emre S, Sarin S, de Ville de Goyet J. Surgical guidelines for the management of extra-hepatic portal vein obstruction. *Pediatr Transplant* 2006;10:908–13.
15. Maksoud-Filho JG, Goncalves ME, Cardoso SR, Gibelli NE, Tannuri U. Long-term follow-up of children with extrahepatic portal vein obstruction: impact of an endoscopic sclerotherapy program on bleeding episodes, hepatic function, hypersplenism, and mortality. *J Pediatr Surg* 2009;44:1877–83.
16. Kalman RE. A new approach to linear filtering and prediction problems. *Trans ASME—J Basic Eng* 1960;82:35–45.
17. Dasgupta R, Roberts E, Superina RA, Kim PC. Effectiveness of Rex shunt in the treatment of portal hypertension. *J Pediatr Surg* 2006;41:108–12.
18. Poddar U, Thapa BR, Singh K. Frequency of gastropathy and gastric varices in children with extrahepatic portal venous obstruction treated with sclerotherapy. *J Gastroenterol Hepatol* 2004;19:1253–6.
19. Poddar U, Thapa BR, Singh K. Endoscopic sclerotherapy in children: experience with 257 cases of extrahepatic portal venous obstruction. *Gastrointest Endosc* 2003;57:683–6.
20. Goncalves ME, Cardoso SR, Maksoud JG. Prophylactic sclerotherapy in children with esophageal varices: long-term results of a controlled prospective randomized trial. *J Pediatr Surg* 2000;35:401–5.
21. Semiz-Oysu A, Keussen I, Cwikiel W. Interventional radiological management of prehepatic obstruction of [corrected] the splanchnic venous system. *Cardiovasc Intervent Radiol* 2007;30:688–95.
22. Cwikiel W, Keussen I, Larsson L, Solvig J, Kullendorff CM. Interventional treatment of children with portal hypertension secondary to portal vein occlusion. *Eur J Pediatr Surg* 2003;13:312–8.