Management of Patients With Gastric Varices

Fernando Calmet, MD,[1,2] Prasoon Mohan, MD,[3] Hamed Jalaeian, MD,[3] and Paul Martin, MD[4]

[1]Department of Medicine, Division of Gastroenterology, Newton-Wellesley Hospital, Newton, Massachusetts

[2]Department of Medicine, Division of Gastroenterology, Tufts University School of Medicine, Boston, Massachusetts

[3]Department of Interventional Radiology, Miller School of Medicine, University of Miami, Miami, Florida

[4]Department of Medicine, Division of Hepatology, Miller School of Medicine, University of Miami, Miami, Florida

Corresponding author:
Dr Fernando Calmet
2000 Washington Street, Suite 368
Newton, MA 02453
Tel: (617) 969-1227
E-mail: fcalme01@tufts.edu

Abstract: Management of patients with gastric varices represents a unique challenge for clinicians. The broad range of endoscopic and endovascular techniques currently available is in stark contrast with the limited evidence available to inform the optimal management of these patients. This article describes the classification, pathophysiology, and natural history of gastric varices; summarizes the available evidence regarding medical, endoscopic, and endovascular management of gastric varices; and provides recommendations on how to integrate these options. Management of these patients ultimately requires a multidisciplinary approach involving hepatologists, therapeutic endoscopists, and interventional radiologists, with consideration given to patient characteristics and local expertise.

Keywords
Gastric varices, variceal hemorrhage, gastrointestinal hemorrhage, portal hypertension, cirrhosis

Portal hypertension is associated with the development of gastric varices (GVs) in 20% of patients with cirrhosis. Variceal hemorrhage (VH) occurs in 9% to 78% of patients with GVs, depending upon the location of their GVs, and is associated with a mortality of 5% to 55%.[1-3]

Whereas the management of esophageal varices (EVs) is relatively straightforward and supported by a wealth of clinical studies, GVs pose a more nuanced clinical scenario with a relative scarcity of supporting evidence to guide best practices. Moreover, GVs require a multidisciplinary approach with close collaboration between a transplant hepatologist, a therapeutic endoscopist, and an interventional radiologist.[4] This article describes the classification, pathophysiology, and natural history of GVs; summarizes the available evidence regarding medical, endoscopic, and endovascular management of GVs; and provides recommendations on how to integrate these options.

Classification

Endoscopic Classification of Gastric Varices

The Sarin classification is the most widely used endoscopic classification system for GVs.[4] GVs are divided into gastroesophageal varices (GOVs), which extend from EVs, and isolated gastric varices (IGVs). GOVs are

further subdivided into GOV1s, which extend down the lesser curvature, and GOV2s, which extend up the cardia and fundus. GOV1s have a similar vascular supply as EVs, arising from the left gastric vein (LGV), whereas GOV2s have a distinct vascular supply, typically arising from the posterior gastric veins (PGVs) and short gastric veins (SGVs). IGVs are subdivided into IGV1s, located in the cardia and fundus, and IGV2s, located in the gastric body and antrum. IGV1s have a similar behavior to GOV2s, whereas IGV2s are more often associated with splenic vein thrombosis and noncirrhotic portal hypertension.[3-5]

GVs may also be classified as small (<5 mm), medium (5-10 mm), and large (>10 mm).[6] Risk factors for gastric VH include large GVs (>10 mm or >20 mm in different studies), presence of a red spot, coexisting portal hypertensive gastropathy, higher Child-Pugh score, and higher Model for End-Stage Liver Disease (MELD) score.[6-8] In a South Asian cohort of patients with GVs, bleeding risk was highest with IGV1s (78%), followed by GOV2s (55%), GOV1s (28%), and IGV2s (9%).[1] In this study, 47% of patients had noncirrhotic portal hypertension, so these findings may not extrapolate to other populations.

From a practical standpoint, GOV1s have a similar pathophysiology as EVs and are managed similarly, whereas cardiofundal varices (GOV2s and IGV1s) require more planning to understand their underlying vascular anatomy and often benefit from a combined endoscopic and endovascular approach.[4,9]

Vascular Classification of Gastric Varices

Over the past 2 decades, several classification systems have been proposed to describe the vascular anatomy of GVs. The Saad-Caldwell classification organizes GVs based on their afferent and efferent vasculature.[10]

Saad-Caldwell type 1 varices are located in the cardia and derive their blood supply from the LGV (so-called right-sided portal circulation) and correlate with GOV1s.[10] Type 2 varices are cardiofundal varices that derive their blood supply from the PGVs and SGVs (so-called left-sided portal circulation) and correlate with IGV1s or GOV2s. Type 3 varices are cardiofundal varices that derive their blood supply from the LGV as well as the PGVs and SGVs and correlate with GOV2s or IGV1s. Type 4 varices are similar to type 2 and 3 varices, but with the presence of splenic vein thrombosis. These groups are subdivided based on the absence of a draining gastrorenal shunt (GRS) (types 1a, 2a, 3a, 4a) or its presence (types 1b, 2b, 3b, 4b).

The Kiyosue classification is widely cited in the radiology literature and describes the afferent and efferent veins associated with the gastric variceal complex. It is important in guiding treatment during balloon-occluded retrograde transvenous obliteration (BRTO) or its variants, although the classification does not have significant applicability outside this procedure.[11-13]

Anatomy and Hemodynamics of Gastric Varices

The LGV (or coronary vein) runs along the lesser curvature of the stomach, which it drains before emptying into the distal splenic vein or proximal main portal vein. With development of portal hypertension, reversal of flow occurs, and instead portal venous blood travels into the LGV, which then supplies GOV1s and EVs. This comprises the right-sided component of spontaneous portosystemic shunting.[10,12,14]

A total of 3 to 5 SGVs and 1 or more PGVs drain the fundus and empty into the splenic vein. In portal hypertension, reversal of flow occurs, and instead portal venous blood travels through the splenic vein and supplies the SGVs and PGVs, which feed into GOV2s and IGV1s. This comprises the left-sided component of spontaneous portosystemic shunting.[10,12,14] It is important to note that variations in vascular anatomy can occur that do not fit the described patterns, so defining the underlying anatomy in each patient is essential for guiding management.

A less common pathway for portosystemic shunting may occur along the gastroepiploic veins. The left and right gastroepiploic veins run along the greater curvature of the stomach and drain the gastric antrum and body. These are rarely involved in portal hypertension owing to cirrhosis. However, in splenic vein thrombosis, blood flow from the spleen is diverted through the gastroepiploic veins, giving rise to IGV1s and, less commonly, IGV2s. The latter typically present as an arcade of linear varices along the greater curvature or posterior wall of the gastric body. This is often referred to as sinistral or segmental portal hypertension.[10,12,14]

Natural History of Gastric Varices

The behavior of GVs is closely tied to their underlying pathophysiology, with each subtype of GVs demonstrating a distinct natural history. As a group, GVs are less common than EVs and are present in 20% of patients with portal hypertension.[3] Unlike EVs, GVs are supported by gastric mucosa and are therefore less likely to bleed. However, bleeding from GVs is more severe than from EVs and is associated with a mortality rate of 45%.[3,4]

In a South Asian cohort in which 47% of patients had noncirrhotic portal hypertension, GOV1s were the most common varices; they represented 58% of GVs and were associated with bleeding in 12% of patients.[3] The prevalence of GOV1s is similar in patients with cirrhosis and noncirrhotic portal hypertension. GOV1s

Table 1. Nonselective β-Blockers for Primary Prophylaxis of Gastric Varices

β-Blocker	Starting Dose	Maximum Dose
Nadolol	20-40 mg daily	160 mg/day (patients without ascites) 80 mg/day (patients with ascites)
Propranolol	20-40 mg twice daily	320 mg/day (patients without ascites) 160 mg/day (patients with ascites)
Carvedilol	3.125 mg twice daily	6.25 mg twice daily

were usually associated with large EVs (92%). When EVs were obliterated, most GOV1s resolved (59%). However, bleeding occurred in up to 28% of EVs that persisted. GOV2s represented 21% of GVs. In contrast to GOV1s, GOV2s were more likely to bleed (55%) and were less often associated with large EVs (50%). GOV2s developed in 3.5% of patients after treatment of EVs.[3] IGV1s were the least common, representing 6% of GVs. However, they carried the highest risk of bleeding (78%) and a mortality rate of 29%. IGV2s represented 15% of GVs. In contrast to IGV1s, the bleeding risk of IGV2s was lower (9%), although IGV2s carried a mortality risk of 100%. These statistics may not be applicable to other parts of the world where similar data are currently unavailable.

Approach to Patients Without Prior Gastric Variceal Hemorrhage (Primary Prophylaxis)

There are limited data to guide the management of patients with incidentally found GVs. Current guidelines recommend the use of nonselective β-blockers (NSBBs), which are often indicated to treat concomitant EVs. However, this is based on data extrapolated from studies of EVs, and a definite benefit in GVs has not been established.[2,15] One randomized controlled trial (RCT) compared endoscopic cyanoacrylate injection (ECI) with NSBBs for primary prophylaxis in 89 patients with GOV2s or IGV1s deemed to be at higher risk of bleeding (GVs >10 mm).[8] After a median follow-up of 26 months, patients undergoing ECI had lower rebleeding rates (13%) than patients treated with NSBBs (28%; *P*=.039) and patients not receiving treatment (45%; *P*=.003). In a more recent retrospective study, patients with GOV1s, GOV2s, or IGV1s who had undergone ECI or BRTO were compared with similar patients undergoing observation only. Most patients in this study had large varices. After a median follow-up of 35 months, bleeding rates were lower in patients undergoing ECI (19.4%) and BRTO (7.3%) than patients undergoing observation alone (35.1%; *P*=.001).[16] Decreased bleeding rates in patients undergoing ECI and BRTO remained lower after exclusion of patients with GOV1s and patients receiving NSBBs. However, a direct comparison between ECI/BRTO and NSBBs was not possible. Additional prospective RCTs are needed to validate these findings.[17]

NSBBs used for primary prophylaxis include nadolol, propranolol, and carvedilol (Table 1). Only propranolol has been specifically studied in GVs, whereas the use of nadolol and carvedilol is based on indirect evidence. Nadolol and propranolol should be titrated every 2 to 3 days until a resting heart rate of 55 to 60 beats per minute is achieved. Carvedilol, an alternative NSBB with α-1–blocking properties, has a more profound effect on portal pressures, although it may lead to more systemic hypotension than other conventional NSBBs. Administration of carvedilol is easier, as dosing is not guided by heart rate. Instead, it is started at 3.125 mg twice daily and increased to the target dose of 6.25 mg after 3 days as tolerated. Increasing carvedilol beyond 12.5 mg/day does not appear to lead to further reductions in portal pressure. Patients should be monitored for the development of hypotension (systolic blood pressure <90 mm Hg), which may prompt drug discontinuation.[2,18]

Approach to Patients With Acute Gastric Variceal Hemorrhage

Initial Management of Variceal Hemorrhage

The initial management of gastric VH is identical to that of bleeding EVs. Initial resuscitation efforts are directed toward the patient's circulatory and respiratory status. Antibiotic prophylaxis and vasoactive agents are administered and early esophagogastroduodenoscopy (EGD) is performed within 12 to 24 hours after presentation.[2,15,19]

A restrictive packed red blood cell transfusion strategy aimed at maintaining a hemoglobin level of 7 to 9 g/dL is associated with decreased rebleeding and mortality rates.[20,21] Avoiding liberal transfusion strategies in patients with portal hypertension is important, as this may increase portal pressure or alter coagulation, increasing the risk of subsequent bleeding and mortality.[20] It is common practice to transfuse platelets to a target platelet count greater than 50 × 10^9/L and cryoprecipitate to a target fibrinogen level of 100 to 120 mg/dL, although these practices have not been formally evaluated. Prothrombin time and international normalized ratio are not reliable indicators

Table 2. Vasoactive Agents Used in Acute Variceal Hemorrhage

Vasoactive Agent	Regimen
Octreotide	50 μg IV bolus, followed by 50 μg/hour IV infusion A second 50 μg IV bolus may be given after 1 hour if bleeding is ongoing
Somatostatin	250 μg IV bolus, followed by 250-500 μg/hour IV infusion A second 250 μg IV bolus may be given after 1 hour if bleeding is ongoing
Terlipressin	2 mg IV every 4 hours for 48 hours or until bleeding cessation, followed by 1 mg IV every 4 hours

IV, intravenous.

of coagulopathy in cirrhosis, and the use of fresh frozen plasma to correct them is not recommended.[22]

Patients with VH are at risk of bacterial infections, and antibiotics have been shown to decrease the risk of infections, rebleeding, and death.[23] Ceftriaxone 1 g intravenous daily for 7 days is the drug of choice and was superior to norfloxacin in preventing bacterial infections in an RCT.[24] Patients discharged before day 7 may be switched to ciprofloxacin 500 mg orally twice daily to complete 7 days of antibiotics.

The use of vasoactive agents has been shown to decrease mortality and transfusion requirements. Commonly used agents include octreotide, terlipressin, and somatostatin, which are given as an initial bolus, followed by a continuous infusion for 2 to 5 days (Table 2). Vasopressin is not commonly used owing to increased systemic side effects compared with other vasoactive agents.[25-27]

Endoscopic Management of Bleeding Gastric Varices

Endoscopic variceal ligation (EVL) is effective in achieving hemostasis of GOV1s. EVL may also achieve initial hemostasis in small IGV1s and GOV2s, although additional therapies are required because of high rebleeding rates. Moreover, EVL may not be technically feasible for larger IGV1s and GOV2s. When available, ECI is recommended for initial hemostasis of IGV1s and GOV2s. However, in patients in whom bleeding has stopped spontaneously, ECI may be deferred until the underlying vascular anatomy has been elucidated such that a more definitive treatment may be provided.[2,4,15,28] Finally, balloon tamponade may be used for initial hemostasis until more definitive therapy is attempted.[29]

Approach to Patients With Prior Gastric Variceal Hemorrhage

In patients with gastric VH, an understanding of the underlying vascular anatomy is essential to inform the optimal endoscopic and/or endovascular approach (Table 3). Contrast-enhanced cross-sectional abdominal imaging is recommended in this setting.[4,10]

Saad-Caldwell type 1 varices are considered extensions of EVs and are treated similarly to EVs with EVL. Recurrent bleeding may be treated with a second attempt at EVL or with transjugular intrahepatic portosystemic shunt (TIPS). Balloon tamponade may be considered in refractory bleeding as a temporizing measure.[4,10]

The management of Saad-Caldwell type 2 varices (usually IGV1s or GOV2s by Sarin classification) depends largely on the presence or absence of a GRS. If a GRS is present (Saad-Caldwell type 2b), BRTO (or its variants) is favored, whereas if a GRS is not present (Saad-Caldwell type 2a), ECI may be performed instead. TIPS with trans-TIPS embolization of feeding portal vessels is an alternative when BRTO (or its variants) is not feasible (eg, in the setting of severe ascites or lack of a sizable shunt) or instead of ECI. Importantly, ECI after TIPS carries a higher risk of nontarget glue embolization through a patent TIPS and of portal vein thrombosis.[4,10]

The management of Saad-Caldwell type 3 varices (GOV2s by Sarin classification) also depends on the presence or absence of a GRS. If a GRS is present (Saad-Caldwell type 3b), BRTO (or its variants) may be performed, followed by EVL with or without subsequent TIPS. In absence of a GRS (Saad-Caldwell type 3a), TIPS is performed with simultaneous embolization of feeding portal vessels in combination with ECI.[4,10]

Antegrade transvenous obliteration (ATO) may be considered as an option for eradication of Saad-Caldwell type 2 or 3 varices when they are not amenable to alternatives such as ECI, TIPS, or retrograde transvenous obliteration (RTO).[4]

It should be acknowledged that the described treatment options are largely based on expert opinion and uncontrolled studies. The few RCTs that have been conducted in this area do not use the Sarin and Saad-Caldwell classifications.

Endoscopic Management of Gastric Varices

Endoscopic Variceal Ligation

EVL is an option for select patients who have GVs. In patients with actively bleeding GVs, EVL has been used to achieve initial hemostasis. However, rebleeding within 2 weeks of EVL occurs in 18.2% of patients and is most common in large GVs.[30] In patients with nonbleeding

Table 3. Vascular Anatomy, Endoscopic Correlation, and Management of Gastric Varices[4,10]

Saad-Caldwell Type	Feeding Vessels	Gastrorenal Shunt	Endoscopic Correlate	Treatment
Type 1a	LGV	Absent	GOV1s	EVL ± TIPS (with or without trans-TIPS embolization)[a]
Type 1b	LGV	Present	GOV1s	EVL ± TIPS (with or without trans-TIPS embolization)[a]
Type 2a	PGVs, SGVs	Absent	IGV1s > GOV2s	ECI, ATO
Type 2b	PGVs, SGVs	Present	IGV1s > GOV2s	RTO ± ATO
Type 3a	LGV, PGVs, SGVs	Absent	GOV2s > IGV1s	TIPS with embolization, ECI, ATO
Type 3b	LGV, PGVs, SGVs	Present	GOV2s > IGV1s	RTO ± ATO, EVL ± TIPS[a]

ATO, antegrade transvenous obliteration; ECI, endoscopic cyanoacrylate injection; EVL, endoscopic variceal ligation; GOVs, gastroesophageal varices; IGVs, isolated gastric varices; LGV, left gastric vein; PGVs, posterior gastric veins; RTO, retrograde transvenous obliteration; SGVs, short gastric veins; TIPS, transjugular intrahepatic portosystemic shunt.

[a]TIPS is recommended for GOV1s and GOV2s (arising from the LGV) refractory to EVL.

GVs, EVL is effective in the prevention of rebleeding of GOV1s.[31] However, rebleeding rates were high and eradication rates low with GOV2s and IGV1s.[31,32]

Endoscopic Cyanoacrylate Injection

Several cyanoacrylate formulations are available and differ in their polymerization times. N-butyl-2-cyanoacrylate is available in North America, Europe, and Asia and polymerizes quickly within 5 to 10 seconds of contact with blood or saline, which can rarely lead to premature solidification within the injection needle or entrapment of the needle within a varix.[14,33] N-butyl-2-cyanoacrylate was typically mixed with ethiodized oil (Lipiodol, Guerbet) to slow polymerization time and determine radiographic success after ECI, although this is no longer recommended, given an increased risk of distant embolization.[4,34] 2-octyl-cyanoacrylate is available in North America and has a slower polymerization time.[33]

ECI may be performed with a regular gastroscope or an echoendoscope. Silicone gel or olive oil is instilled into the working channel to prevent glue adherence within the endoscope. An injector needle is then passed through the endoscope and primed with cyanoacrylate. The needle is inserted into the gastric varix, at least 3 to 5 cm away from the endoscope to prevent cyanoacrylate from splashing back onto the endoscope. The varix is injected with cyanoacrylate over a period of 4 to 5 seconds (when N-butyl-2-cyanoacrylate is used) or at a rate of 1 to 2 mL/minute (when 2-octyl-cyanoacrylate is used). This is quickly followed by injection of 2 mL of distilled water while removing the needle from the varix. This helps prevent impaction of the needle within the solidified glue inside the gastric varix. Saline should not be used, as it may precipitate cyanoacrylate solidification within the needle. After injection and with the needle retracted, the varix is palpated with the blunt catheter tip to confirm its hardness from glue obliteration. If the varix is still soft, additional injections are performed.[4,14,33-35] After successful obturation of GVs, EGD is repeated every 2 to 4 weeks for retreatment until eradication, followed by reassessment at 3 to 6 months and yearly thereafter.[4]

Complications are overall uncommon with ECI.[36] Extrusion of the glue cast typically occurs after 1 to 3 months and can lead to bleeding owing to mucosal oozing in 4.4% of patients. Sepsis occurs in up to 1.3% and is sometimes delayed, with infection arising at the site of glue extrusion. Distant embolization is rare (0.7%) and may be prevented with avoidance of ethiodized oil use.

Endoscopic Thrombin Injection

Thrombin injection is an alternative technique to ECI for the management of bleeding GVs. An average of 1500 to 2500 units of reconstituted human thrombin is injected into the bleeding gastric varix in order to induce thrombosis and achieve hemostasis. Repeat injections are performed as needed for ongoing bleeding. Bovine thrombin has previously been used but has fallen out of favor because of concerns of prion transmission.[14,37] In one meta-analysis, thrombin injection led to low early (within 5 days) and late (after 5 days) rebleeding rates of 9.3% and 13.8%, respectively.[37] No serious adverse events were reported.

Comparative studies of thrombin and ECI are lacking. One small RCT found similar hemostasis and rebleeding rates.[38] Injection site gastric ulcers were seen only in patients undergoing ECI and in 2 cases were associated with ulcer bleeding. Additional studies are needed before thrombin injection can be universally recommended.

Endoscopic Ultrasound–Guided Treatment of Gastric Varices

Endoscopic ultrasound (EUS)-guided therapies have more recently emerged for the treatment of GVs, including EUS-guided cyanoacrylate injection, coil embolization, and combined cyanoacrylate/coil delivery. When compared with ECI, EUS-guided therapies are associated with greater obliteration of GVs (84.4% vs 62.6%; *P*=.02) and a trend toward decreased recurrence of GVs (9.1% vs 18%; *P*=.06).[39] However, a beneficial effect on rebleeding has not been demonstrated. When comparing EUS-guided therapies, combined cyanoacrylate/coil delivery was associated with greater technical and clinical success than either modality alone. Combination therapy was also associated with a lower rate of adverse effects than EUS-guided cyanoacrylate injection.[40] More RCTs comparing direct ECI with EUS-guided therapies in better-defined populations are needed. Additionally, local expertise may limit the availability of EUS-guided therapies.

Balloon Tamponade of Gastric Varices

Balloon tamponade is used as a temporizing measure for hemostasis in severe or refractory gastric VH until more definitive therapy is attempted.[41,42] The Sengstaken-Blakemore tube is most commonly deployed and contains a 250 mL gastric balloon, an esophageal balloon, and a gastric port. The Minnesota tube is similar to the Sengstaken-Blakemore tube but with an additional esophageal suction port, whereas the Linton-Nachlas tube has a single 600 mL gastric balloon. When available, the Linton-Nachlas tube is preferred, owing to a larger gastric balloon.[29]

The tube is first advanced through the nose or mouth into the esophagus and stomach. Adequate positioning can be confirmed by epigastric auscultation with air insufflation into the gastric port or with a radiograph. Once appropriate positioning of the tube is confirmed, the gastric balloon is inflated with air and continuous tension is applied with a 500 to 1000 mL intravenous bag in order to tamponade lesser curvature and cardiofundal varices.

In 1 report, balloon tamponade with a Linton-Nachlas tube achieved initial hemostasis in 50% of patients, whereas the Sengstaken-Blakemore tube failed in all cases.[29] Complications are common and include esophageal perforation, aspiration, and balloon migration.[29,42]

Endovascular Management of Gastric Varices

There are 2 distinct management strategies for endovascular treatment of VH, both of which were developed in relative isolation in different parts of the world.[43] The first of these focuses on shunting by insertion of a TIPS. The aim of TIPS is to shunt or bypass the portal blood back into the systemic circulation to decrease the hepatic venous pressure gradient (HVPG) and thus indirectly control VH. The second management strategy focuses on the direct occlusion or obliteration of the varices to stop bleeding. BRTO and its variants and ATO belong to this category. Such treatments evolved in Asia and have been popular in that part of the world for many decades.[43] Increasingly, both treatment modalities are viewed as complementary and can be combined.[44] Clinicians managing gastric variceal bleeding should have a thorough understanding of the indications, contraindications, and complications of these procedures and the specific clinical scenarios in which they may be best suited. The following sections discuss each endovascular treatment option and its appropriate use.

Transjugular Intrahepatic Portosystemic Shunt

As the name implies, the TIPS procedure involves creation of an intrahepatic shunt between the portal vein and hepatic veins via transjugular access. A catheter is advanced via the jugular vein to the hepatic veins after which the liver parenchyma is punctured in order to cannulate the portal vein. Once this is achieved, the intrahepatic tract is dilated and an expanded polytetrafluoroethylene–covered stent is deployed. Further stent dilation may be performed to achieve the target HVPG depending on the indication.[45-47]

Technically, the most challenging step in TIPS placement is accessing the portal vein using sharp puncture of the liver parenchyma. Conventionally, this puncture has been guided by CO_2 (or contrast) portal venography and/or fluoroscopic landmarks. More recently, intravascular ultrasound guidance has been used to target the portal vein. TIPS placement with intravascular ultrasound has shown to decrease extrahepatic punctures, procedural time, and radiation exposure, and improve the overall safety of the procedure.[48,49]

Although historic databases have lumped bleeding EVs or GVs into a single category, data suggest that EVs and GVs respond differently to currently available treatment strategies.[50] It is important to highlight that EVs bleed almost exclusively at HVPGs greater than 12 mm Hg, whereas gastric variceal bleeding may occur at lower portal pressures.[51-53] Further, rebleeding of GVs occurs in 15% to 50% of patients after successful TIPS placement.[47,54] Rebleeding rates according to gastric varix subtype remain unknown. There are several explanations for why TIPS placement may not necessarily be effective in controlling bleeding GVs. Given that GVs are larger in caliber and anatomically not close to TIPS, they may not decompress after TIPS placement (proximity theory). In

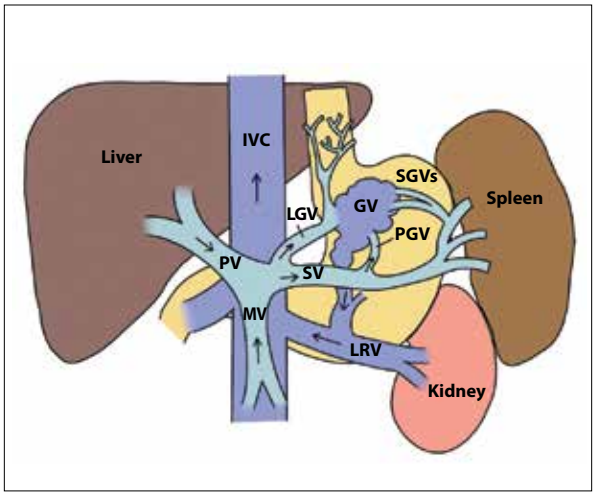

Figure 1. Vascular anatomy of GVs.

GVs, gastric varices; IVC, inferior vena cava; LGV, left gastric vein; LRV, left renal vein; MV, mesenteric vein; PGV, posterior gastric vein; PV, portal vein; SGVs, short gastric veins; SV, splenic vein.

addition, large outflow gastrorenal or splenorenal shunts may have significant throughput with TIPS. TIPS placement may not be effective in decompressing GVs in the presence of these competing shunts (throughput theory). Alternatively, some researchers advocate treating GVs as an arteriovenous malformation, in which additional collateral veins may develop even in the presence of TIPS if the nidus is not specifically treated (recruitment theory).[50]

Lesser curvature varices (GOV1s) may likely have lower rebleeding rates after TIPS, similar to those reported for EVs. Cardiofundal varices (GOV2s and IGV1s) bleed at lower pressures, which likely accounts for the higher rebleeding rates of GVs. When TIPS is performed for gastric VH, TIPS is often recommended in combination with endovascular embolization of the GV feeders. This may be an alternative to BRTO (and its variants) in patients with EVs and ascites.[4,47]

Contraindications to TIPS creation include heart failure, asymptomatic severe or symptomatic valvular heart disease, moderate-to-severe pulmonary hypertension, uncontrolled sepsis, refractory overt hepatic encephalopathy, unrelieved biliary obstruction, severe uncorrected coagulopathy, and anatomic barriers to shunt creation (eg, polycystic liver disease, extensive hepatic malignancy).[45,47,55]

Patients undergoing elective TIPS typically receive contrast-enhanced cross-sectional abdominal imaging for preprocedural planning and a comprehensive echocardiogram. However, this may not be feasible in patients requiring emergency TIPS, in which case it is suggested that patients undergo at least a liver ultrasound with Doppler to assess portal vein patency. A limited echocardiogram to assess left ventricular ejection fraction and right ventricular systolic pressure may also be considered, although it may be inaccurate during VH and should not delay an otherwise potentially life-saving therapy.[46,47]

One month after TIPS for cardiofundal varices, endoscopic examination is recommended to reassess the GVs. For enlarging GVs, ATO (percutaneously or through a patent TIPS) or BRTO (or its variants) may be offered, depending on the absence or presence of a GRS, respectively. Alternatively, ECI may be performed, although it carries a risk of glue embolization.[4]

Some operators suggest use of smaller diameter TIPS in patients who are at risk of hepatic encephalopathy and/or accelerated liver failure, such as patients with prior episodes of hepatic encephalopathy, age over 65 years, high Child-Pugh or MELD score, and comorbidities.[56] Passive expansion of the legacy VIATORR TIPS stent grafts (Gore) has been demonstrated within the first 30 days of TIPS creation and continued over 180 days on serial imaging and has been attributed to intrinsic properties of the stent.[57] Placement of novel VIATORR Controlled Expansion stent grafts (Gore) provides the operator the chance to dilate between 8 and 10 mm. VIATORR Controlled Expansion stent grafts underdilated to 8 mm do not passively expand and have been reported to reduce hospital readmissions precipitated by hepatic encephalopathy, uncontrolled ascites, and heart failure, and improve 1-year survival compared with underdilated VIATORR TIPS stent grafts.[58]

Anatomic Considerations Relevant to Retrograde Transvenous Obliteration

A working knowledge of the anatomy and drainage patterns of varices is essential for understanding endovascular treatment options. The 3 main feeding veins to EVs, GOVs, and IGVs are the LGV, PGVs, and SGVs (Figure 1). Gaba and colleagues have shown that the most common filling pattern for EVs is from the LGV alone (63%) followed by a combination of the LGV and PGVs (25%).[59] For GOVs, the inflow is from the LGV and PGVs (43%) or the LGV alone (33%). The most frequent pattern of IGV supply is from the LGV, PGVs, and SGVs (37%), followed by the LGV and PGVs (18%) or the LGV and SGVs (18%).

Systemic drainage from EVs and GVs is either into the azygos/hemiazygos system or via the inferior phrenic vein into the left renal vein. The veins around the esophagus form the esophageal venous plexus, which anastomoses with the LGV. EVs and GOVs drain via this anastomosis into the azygos/hemiazygos system and then into the superior vena cava. The second drainage pathway involves the gastrophrenic venous system. The gastric veins in and around the posterosuperior part of the gastric

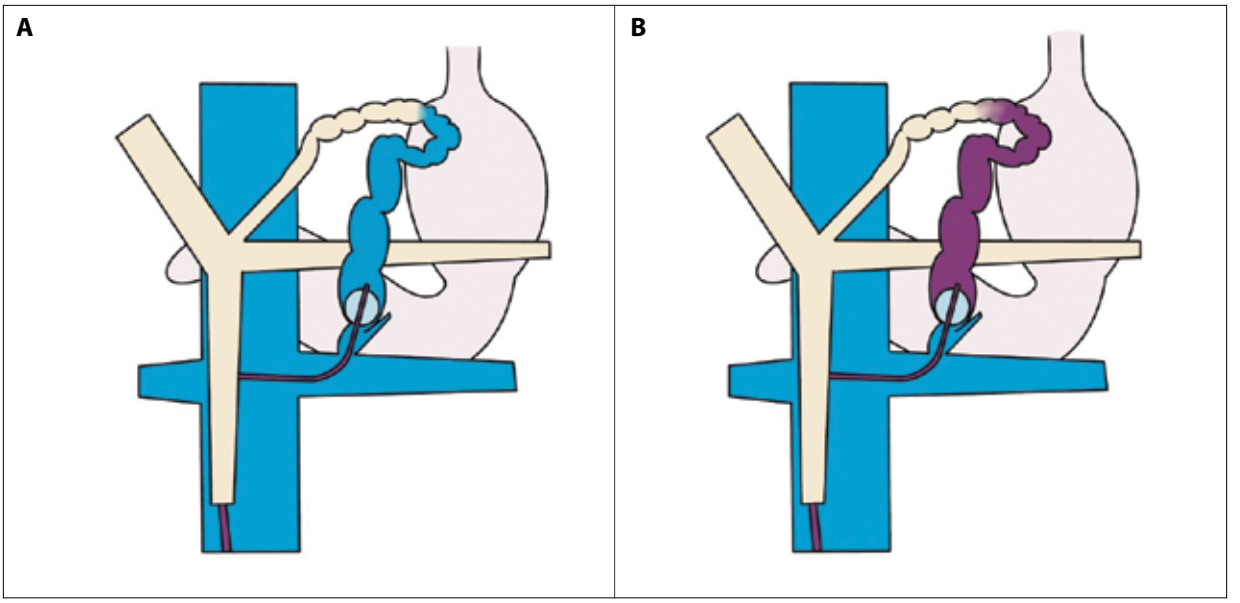

Figure 2. Balloon-occluded retrograde transvenous obliteration. **A:** A catheter is advanced through the inferior vena cava and left renal vein and into the gastrorenal shunt, draining the gastric varices where a balloon is inflated to occlude outflow. **B:** A variceal venogram is obtained to identify systemic collaterals requiring embolization before gastric variceal obliteration is performed.

wall anastomose with the inferior phrenic vein, which drains into the left renal vein. Cardiofundal varices drain via this anastomosis into the left renal vein.

Balloon-Occluded Retrograde Transvenous Obliteration

Kanagawa and colleagues developed the concept and technique of BRTO in Japan in 1996.[60] Over the past decade, BRTO has been increasingly used in Europe and the United States.[50] BRTO may be used as primary prophylaxis or for prevention of recurrent GV bleeding and can be performed in the setting of a GRS, which is present in 85% of GV cases.[61]

Indications and Contraindications Per current guidelines, BRTO is indicated for the prevention of recurrent gastric variceal bleeding along with TIPS.[2] BRTO can also be used for refractory hepatic encephalopathy arising from portosystemic shunting from GVs. BRTO is particularly suitable for patients with VH who have a relative contraindication to TIPS such as a high MELD score (>18), hepatic encephalopathy, or right-sided heart failure.

Major contraindications include portal or splenic vein thrombosis, as occlusion of the GRS may result in venous infarction of the mesenteric organs. Uncontrolled bleeding from EVs is a contraindication because BRTO will worsen such bleeding.[62] Lack of an appropriate GRS is another relative technical contraindication.[50]

Preprocedural Evaluation Preprocedural evaluation should include endoscopic evaluation, which is necessary for confirming GVs as the cause of bleeding and for evaluating the presence of EVs. Cross-sectional imaging with contrast-enhanced computed tomography or magnetic resonance imaging is essential to confirm the presence of a GRS accessible by catheter, confirmation of the GV and its feeders, patency of portal and splenic veins, presence of additional systemic collaterals, and evaluation of ascites.[50]

Technique The overall aim of the RTO procedure is to fill the GV with a sclerosing agent or embolic material in a retrograde fashion via the GRS while preventing the systemic outflow of the sclerosant by blocking the GRS using a balloon, plug, or coils (Figure 2). The GRS can be catheterized from the femoral or internal jugular access. In conventional BRTO, after the GRS is catheterized, an appropriately sized occlusion balloon is inflated in the shunt to occlude flow. With the occlusion balloon inflated, contrast is injected and a gastric variceal venogram is obtained (Figure 3). If significant systemic collaterals are visualized, they are embolized with coils or other agents. Next, a microcatheter is introduced coaxially through the balloon catheter and advanced deep into the GV. The sclerosant is then injected into the varices through the microcatheter under fluoroscopic guidance. Typically, in the United States, sodium tetradecyl sulfate is used as the sclerosant, which is mixed with contrast and air to make a foam. After the entire GV is filled and

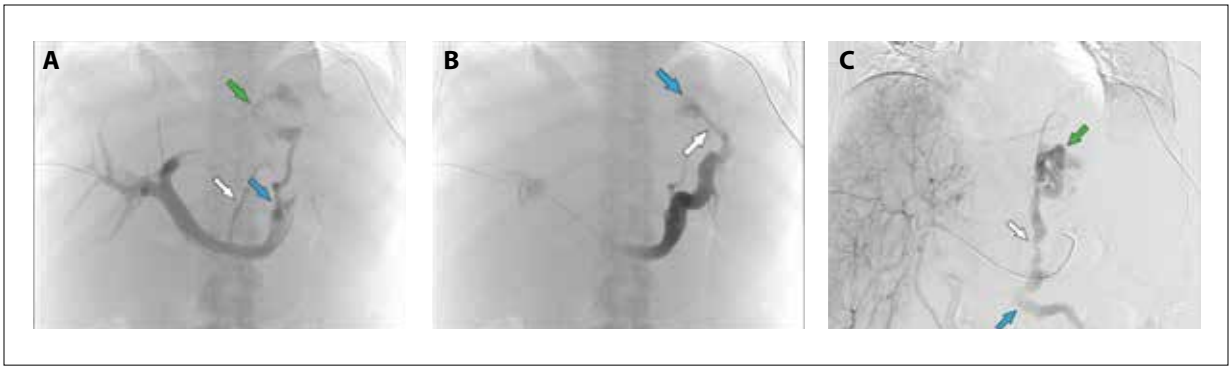

Figure 3. Images obtained during balloon-occluded antegrade transvenous obliteration showing gastric variceal anatomy. **A:** Portal venogram showing the left gastric vein (white arrow) and a posterior gastric vein (blue arrow) contributing to the gastric varices (green arrow). **B:** Subsequent image of the same venogram showing a short gastric branch (white arrow) contributing to the gastric varices (blue arrow). **C:** Further subsequent image from the same venogram showing a gastrorenal shunt (white arrow) draining the gastric varices (blue arrow) into the left renal vein (green arrow).

portal inflow vessels are identified, the sclerosant injection is stopped. The microcatheter is removed and the balloon catheter is kept inflated for at least 4 hours to ensure the dwelling time for the sclerosant. Following the dwelling period, the balloon catheter is deflated and removed under fluoroscopic guidance.

Complications and Outcomes A meta-analysis that included 24 studies on 1016 patients undergoing BRTO showed an overall technical success rate of 96.4%, clinical success rate of 97.3%, and a major complication rate of 2.6%.[63] Complications included pulmonary emboli (4 patients), splenic vein thrombosis (11 patients), renal vein thrombosis (3 patients), extravasation of sclerosant (5 patients), and death (2 patients). Further, BRTO increases portal venous pressure and thus can worsen existing EVs and ascites, both of which need to be monitored. In a meta-analysis of 9 studies on 797 patients, Wang and colleagues compared the outcomes of TIPS with those of BRTO for the management of GVs. TIPS and BRTO did not demonstrate significant differences in technical success rate, immediate hemostasis rate, or procedure-related complications.[64] However, patients who received TIPS for GVs had a lower overall survival rate (relative risk [RR], 0.81; 95% CI, 0.66-0.98; *P*=.03), higher rebleeding rate (RR, 2.61; 95% CI, 1.75-3.90; *P*<.00001), and a higher incidence of hepatic encephalopathy (RR, 16.11; 95% CI, 7.13-36.37; *P*<.00001). A recent RCT compared BRTO with ECI in patients with GOV2s and IGV1s.[65] Rebleeding was more frequent in patients undergoing ECI than BRTO (34.4% vs 15.6%; *P*=.005). Rebleeding in patients in the ECI group was most frequently from GVs or GV-related ulcers followed by EVs, whereas rebleeding in the BRTO group occurred solely from EVs.

Cross-sectional imaging or EUS is recommended to confirm complete obliteration of GVs within 48 hours of any type of RTO. EGD is recommended within 2 weeks (for high-risk EVs) and within 4 to 6 weeks (for low-risk EVs) to assess for worsening EVs that may require EVL.[4]

Modifications of Balloon-Occluded Retrograde Transvenous Obliteration Conventional BRTO requires that the retrograde balloon catheter be left in place with the balloon inflated for at least 4 hours. This poses logistical challenges in busy interventional radiology departments. Other risks include balloon rupture and reflux of the sclerosant into the systemic circulation.[66] Several modifications of BRTO have been developed to address some of these issues.

Plug-Assisted Retrograde Transvenous Obliteration Plug-assisted retrograde transvenous obliteration (PARTO) is a modification of BRTO in which a permanent vascular plug is used to occlude the GRS instead of the indwelling balloon (Figure 4). PARTO reduces procedure time and other complications associated with an indwelling balloon. In this procedure, an appropriately sized vascular sheath is inserted into the GRS and a microcatheter is advanced deep into the GVs. Next, a vascular plug is introduced through the same sheath by the side of the microcatheter and the plug is deployed in the GRS. The GVs are then filled with absorbable gelatin powder (Gelfoam, Pfizer) slurry mixed with contrast. Sodium tetradecyl sulfate can also be combined with this mixture. After the GVs are filled, the catheter and the sheath are removed. The largest series by Gwon and colleagues included 73 patients who underwent PARTO with 100% technical success and 99% clinical success.[67]

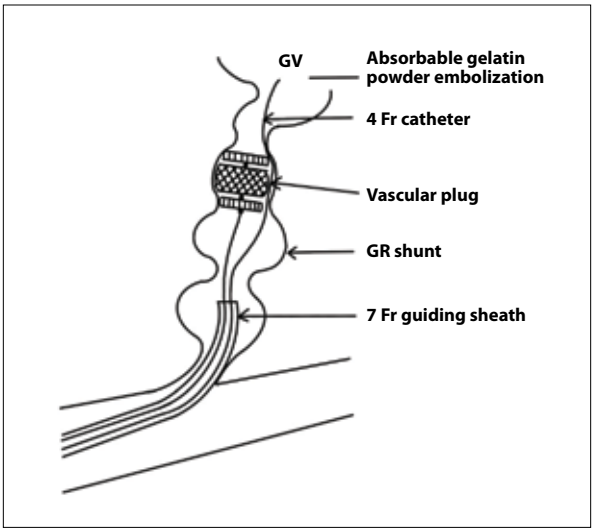

Figure 4. Plug-assisted retrograde transvenous obliteration.
Fr, French; GR, gastrorenal; GV, gastric varices.

Coil-Assisted Retrograde Transvenous Obliteration

Coil-assisted retrograde transvenous obliteration is another modification of BRTO in which coils are used to occlude the GRS instead of a balloon or plug.[68] Similar to PARTO, a vascular sheath is placed into the GRS and a microcatheter is advanced deep into the GVs. Another microcatheter is advanced into the narrowest portion of the shunt and coil embolization is performed. The varices are then embolized with absorbable gelatin powder slurry mixed with contrast through the deeper microcatheter in the varices. The catheter and sheath are removed after the gastric varix is appropriately filled. A small case series has confirmed the safety and efficacy of this procedure.[68]

Antegrade Transvenous Obliteration

ATO can be performed via image-guided direct access into the portal vein (percutaneous transhepatic obliteration) or through a preexisting TIPS access. The main inflow branches of the portal or splenic veins that supply GVs are catheterized individually, and embolization of the perigastric inflow veins and obliteration of GVs are performed. Once embolization is completed, the percutaneous transhepatic access tract should be embolized.

ATO may be considered in the acute management of bleeding GVs, in secondary prophylaxis of recently bleeding GVs, or as an adjunct to RTO. A specific scenario in which ATO may be considered is in a patient with bleeding GVs when a high MELD score or overt encephalopathy precludes TIPS placement and RTO is not possible because of the lack of a GRS.

It is important to be aware that embolization of the proximal inflow veins (without complete eradication of the nidus of GVs) has been associated with a high rebleeding rate.[69-72] The goal of the embolization should be proximal embolization of the perigastric inflow varices as well as complete eradication of the GVs. This may be technically challenging but can be performed by combining placement of balloon catheters or coils in the outflow vessels with injection of liquid embolic material or sclerosants into the nidus of GVs.[69] The technical success ranges from 44% to 100%.[73] Cumulative rebleeding rates are 3.7% to 36.7% and 21.6% to 53.6% at 12 and 24 months after ATO, respectively.[74-77]

The main complications reported following ATO are fever, abdominal pain, new or worsening ascites and/or hydrothorax, and worsening EVs. Fever, abdominal pain, and worsening ascites and hydrothorax are usually transient and respond to expectant management or medical treatment. The cumulative aggravation rates of EVs are 4.2%, 16.1%, 28.1%, and 28.1%, at 1, 2, 3, and 5 years, respectively.[74]

Combined Approaches

Few studies have evaluated the combination of RTO/ATO with TIPS. From a hemodynamic perspective, RTO and TIPS have opposing goals: occluding a portosystemic shunt in RTO, with a consequential increase in portal hypertension, and creating a portosystemic shunt in TIPS to decompress the portal system.[44] However, RTO with TIPS may temper the aggravated portal hypertension that is commonly encountered after RTO. In a retrospective study of 39 patients undergoing BRTO, the presence of prior TIPS was associated with decreased recurrent bleeding up to 24 months later (21% vs 0%; P=.03) and was protective against post-BRTO ascites and hepatic hydrothorax.[78] Overall survival at 1 year was similar between both groups.

Summary

GVs represent a complex challenge that requires a multidisciplinary approach. NSBBs may be considered for primary prophylaxis of GV bleeding, although additional data specific to GVs are needed. Further studies are also required to determine the role of endoscopic and endovascular interventions. GV bleeding is a medical emergency that requires initial resuscitation attempts followed by prompt EGD. Lesser curvature varices are treated with EVL, whereas bleeding cardiofundal varices are best managed with ECI. Balloon tamponade serves as a temporizing measure in refractory bleeding. Patients with prior GV bleeding should undergo cross-sectional imaging to define their underlying vascular anatomy. Multiple treatment options are available, including endoscopic and endovascular approaches, which will ultimately depend

on the underlying vascular anatomy, endoscopic findings, and local expertise.

Disclosures

The authors have no relevant conflicts of interest to disclose.

References

1. Angeli P, Bernardi M, Villanueva C, et al; European Association for the Study of the Liver. EASL Clinical Practice Guidelines for the management of patients with decompensated cirrhosis. *J Hepatol*. 2018;69(2):406-460.
2. Garcia-Tsao G, Abraldes JG, Berzigotti A, Bosch J. Portal hypertensive bleeding in cirrhosis: risk stratification, diagnosis, and management: 2016 practice guidance by the American Association for the Study of Liver Diseases. *Hepatology*. 2017;65(1):310-335.
3. Sarin SK, Lahoti D, Saxena SP, Murthy NS, Makwana UK. Prevalence, classification and natural history of gastric varices: a long-term follow-up study in 568 portal hypertension patients. *Hepatology*. 1992;16(6):1343-1349.
4. Henry Z, Patel K, Patton H, Saad W. AGA clinical practice update on management of bleeding gastric varices: expert review. *Clin Gastroenterol Hepatol*. 2021;19(6):1098-1107.e1.
5. Sarin SK, Kumar A. Gastric varices: profile, classification, and management. *Am J Gastroenterol*. 1989;84(10):1244-1249.
6. Kim T, Shijo H, Kokawa H, et al. Risk factors for hemorrhage from gastric fundal varices. *Hepatology*. 1997;25(2):307-312.
7. Hashizume M, Kitano S, Yamaga H, Koyanagi N, Sugimachi K. Endoscopic classification of gastric varices. *Gastrointest Endosc*. 1990;36(3):276-280.
8. Mishra SR, Sharma BC, Kumar A, Sarin SK. Primary prophylaxis of gastric variceal bleeding comparing cyanoacrylate injection and beta-blockers: a randomized controlled trial. *J Hepatol*. 2011;54(6):1161-1167.
9. Maydeo A, Patil G. How to approach a patient with gastric varices. *Gastroenterology*. 2022;162(3):689-695.
10. Saad WEA. Vascular anatomy and the morphologic and hemodynamic classifications of gastric varices and spontaneous portosystemic shunts relevant to the BRTO procedure. *Tech Vasc Interv Radiol*. 2013;16(2):60-100.
11. Saad WE. Endovascular management of gastric varices. *Clin Liver Dis*. 2014;18(4):829-851.
12. Kiyosue H, Mori H, Matsumoto S, Yamada Y, Hori Y, Okino Y. Transcatheter obliteration of gastric varices. Part 1. Anatomic classification. *Radiographics*. 2003;23(4):911-920.
13. Kiyosue H, Mori H, Matsumoto S, Yamada Y, Hori Y, Okino Y. Transcatheter obliteration of gastric varices: part 2. Strategy and techniques based on hemodynamic features. *Radiographics*. 2003;23(4):921-937.
14. Sarin SK, Kumar A. Endoscopic treatment of gastric varices. *Clin Liver Dis*. 2014;18(4):809-827.
15. de Franchis R, Bosch J, Garcia-Tsao G, Reiberger T, Ripoll C; Baveno VII Faculty. Baveno VII—renewing consensus in portal hypertension. *J Hepatol*. 2022;76(4):959-974.
16. Choe JW, Yim HJ, Lee SH, et al. Primary prophylaxis of gastric variceal bleeding: endoscopic obturation, radiologic intervention, or observation? *Hepatol Int*. 2021;15(4):934-945.
17. Vashishtha C, Sarin SK. Primary prophylaxis of gastric variceal bleeding: the choices need to be tested!! *Hepatol Int*. 2021;15(4):863-867.
18. Jachs M, Reiberger T. Prevention of variceal bleeding and rebleeding by nonselective beta-blockers: a tailored approach. *Clin Liver Dis*. 2021;25(2):311-326.
19. Tripathi D, Stanley AJ, Hayes PC, et al; Clinical Services and Standards Committee of the British Society of Gastroenterology. U.K. guidelines on the management of variceal haemorrhage in cirrhotic patients. *Gut*. 2015;64(11):1680-1704.
20. Villanueva C, Colomo A, Bosch A, et al. Transfusion strategies for acute upper gastrointestinal bleeding. *N Engl J Med*. 2013;368(1):11-21.
21. Odutayo A, Desborough MJR, Trivella M, et al. Restrictive versus liberal blood transfusion for gastrointestinal bleeding: a systematic review and meta-analysis of randomised controlled trials. *Lancet Gastroenterol Hepatol*. 2017;2(5):354-360.
22. Liu P, Hum J, Jou J, Scanlan RM, Shatzel J. Transfusion strategies in patients with cirrhosis. *Eur J Haematol*. 2020;104(1):15-25.
23. Chavez-Tapia NC, Barrientos-Gutierrez T, Tellez-Avila FI, Soares-Weiser K, Uribe M. Antibiotic prophylaxis for cirrhotic patients with upper gastrointestinal bleeding. *Cochrane Database Syst Rev*. 2010;2010(9):CD002907.
24. Fernández J, Ruiz del Arbol L, Gómez C, et al. Norfloxacin vs ceftriaxone in the prophylaxis of infections in patients with advanced cirrhosis and hemorrhage. *Gastroenterology*. 2006;131(4):1049-1056.
25. Bunchorntavakul C, Reddy KR. Pharmacologic management of portal hypertension. *Clin Liver Dis*. 2019;23(4):713-736.
26. Wells M, Chande N, Adams P, et al. Meta-analysis: vasoactive medications for the management of acute variceal bleeds. *Aliment Pharmacol Ther*. 2012;35(11):1267-1278.
27. Seo YS, Park SY, Kim MY, et al. Lack of difference among terlipressin, somatostatin, and octreotide in the control of acute gastroesophageal variceal hemorrhage. *Hepatology*. 2014;60(3):954-963.
28. Ríos Castellanos E, Seron P, Gisbert JP, Bonfill Cosp X. Endoscopic injection of cyanoacrylate glue versus other endoscopic procedures for acute bleeding gastric varices in people with portal hypertension. *Cochrane Database Syst Rev*. 2015;(5):CD010180.
29. Terés J, Cecilia A, Bordas JM, Rimola A, Bru C, Rodés J. Esophageal tamponade for bleeding varices. Controlled trial between the Sengstaken-Blakemore tube and the Linton-Nachlas tube. *Gastroenterology*. 1978;75(4):566-569.
30. Lee TH, Shih LN. Clinical experience of endoscopic banding ligation for bleeding gastric varices. *Hepatogastroenterology*. 2008;55(82-83):766-769.
31. Dong XJ, Chen WQ. Therapeutic efficacy of endoscopic variceal ligation to treat gastric varices: a study of 63 consecutive cases [in Chinese]. *Zhonghua Gan Zang Bing Za Zhi*. 2013;21(9):692-696.
32. Seleem WM, Hanafy AS. Management of different types of gastric varices with band ligation: a 3-year experience. *Eur J Gastroenterol Hepatol*. 2017;29(8):968-972.
33. Weilert F, Binmoeller KF. Endoscopic management of gastric variceal bleeding. *Gastroenterol Clin North Am*. 2014;43(4):807-818.
34. Desai PN, Patel CN, Kabrawala MV, et al. Use of cyanoacrylate glue in gastric variceal bleed: a modified technique without using lipiodol. *VideoGIE*. 2021;6(4):155-158.
35. Kahloon A, Chalasani N, DeWitt J, et al. Endoscopic therapy with 2-octyl-cyanoacrylate for the treatment of gastric varices. *Dig Dis Sci*. 2014;59(9):2178-2183.
36. Cheng LF, Wang ZQ, Li CZ, Lin W, Yeo AET, Jin B. Low incidence of complications from endoscopic gastric variceal obturation with butyl cyanoacrylate. *Clin Gastroenterol Hepatol*. 2010;8(9):760-766.
37. Bhurwal A, Makar M, Patel A, et al. Safety and efficacy of thrombin for bleeding gastric varices: a systematic review and meta-analysis. *Dig Dis Sci*. 2022;67(3):953-963.
38. Lo GH, Lin CW, Tai CM, et al. A prospective, randomized trial of thrombin versus cyanoacrylate injection in the control of acute gastric variceal hemorrhage. *Endoscopy*. 2020;52(7):548-555.
39. Mohan BP, Chandan S, Khan SR, et al. Efficacy and safety of endoscopic ultrasound-guided therapy versus direct endoscopic glue injection therapy for gastric varices: systematic review and meta-analysis. *Endoscopy*. 2020;52(4):259-267.
40. McCarty TR, Bazarbashi AN, Hathorn KE, Thompson CC, Ryou M. Combination therapy *versus* monotherapy for EUS-guided management of gastric varices: a systematic review and meta-analysis. *Endosc Ultrasound*. 2020;9(1):6-15.
41. Garcia-Tsao G, Sanyal AJ, Grace ND, Carey W; Practice Guidelines Committee of the American Association for the Study of Liver Diseases; Practice Parameters Committee of the American College of Gastroenterology. Prevention and management of gastroesophageal varices and variceal hemorrhage in cirrhosis. *Hepatology*. 2007;46(3):922-938.
42. Rodrigues SG, Cárdenas A, Escorsell À, Bosch J. Balloon tamponade and esophageal stenting for esophageal variceal bleeding in cirrhosis: a systematic review and meta-analysis. *Semin Liver Dis*. 2019;39(2):178-194.
43. Saad WEA, Darcy MD. Transjugular intrahepatic portosystemic shunt (TIPS) versus balloon-occluded retrograde transvenous obliteration (BRTO) for the management of gastric varices. *Semin Intervent Radiol*. 2011;28(3):339-349.
44. Saad WE. Combining transjugular intrahepatic portosystemic shunt with balloon-occluded retrograde transvenous obliteration or augmenting TIPS with variceal embolization for the management of gastric varices: an evolving middle ground? *Semin Intervent Radiol*. 2014;31(3):266-268.
45. Boyer TD, Haskal ZJ; American Association for the Study of Liver Diseases. The role of transjugular intrahepatic portosystemic shunt (TIPS) in the management of portal hypertension: update 2009. *Hepatology*. 2010;51(1):306.
46. Tripathi D, Stanley AJ, Hayes PC, et al. Transjugular intrahepatic portosystemic stent-shunt in the management of portal hypertension. *Gut*. 2020;69(7):1173-1192.
47. Boike JR, Thornburg BG, Asrani SK, et al; Advancing Liver Therapeutic Approaches (ALTA) Consortium. North American practice-based recommen-

dations for transjugular intrahepatic portosystemic shunts in portal hypertension. *Clin Gastroenterol Hepatol*. 2022;20(8):1636-1662.e36.
48. Kao SD, Morshedi MM, Narsinh KH, et al. Intravascular ultrasound in the creation of transhepatic portosystemic shunts reduces needle passes, radiation dose, and procedure time: a retrospective study of a single-institution experience. *J Vasc Interv Radiol*. 2016;27(8):1148-1153.
49. Pillai AK, Andring B, Faulconer N, et al. Utility of intravascular US-guided portal vein access during transjugular intrahepatic portosystemic shunt creation: retrospective comparison with conventional technique in 109 patients. *J Vasc Interv Radiol*. 2016;27(8):1154-1159.
50. Lipnik AJ, Pandhi MB, Khabbaz RC, Gaba RC. Endovascular treatment for variceal hemorrhage: TIPS, BRTO, and combined approaches. *Semin Intervent Radiol*. 2018;35(3):169-184.
51. Groszmann RJ, Bosch J, Grace ND, et al. Hemodynamic events in a prospective randomized trial of propranolol versus placebo in the prevention of a first variceal hemorrhage. *Gastroenterology*. 1990;99(5):1401-1407.
52. Feu F, García-Pagán JC, Bosch J, et al. Relation between portal pressure response to pharmacotherapy and risk of recurrent variceal haemorrhage in patients with cirrhosis. *Lancet*. 1995;346(8982):1056-1059.
53. Stanley AJ, Jalan R, Ireland HM, Redhead DN, Bouchier IA, Hayes PC. A comparison between gastric and oesophageal variceal haemorrhage treated with transjugular intrahepatic portosystemic stent shunt (TIPSS). *Aliment Pharmacol Ther*. 1997;11(1):171-176.
54. Alqadi MM, Chadha S, Patel SS, Chen YF, Gaba RC. Transjugular intrahepatic portosystemic shunt creation for treatment of gastric varices: systematic literature review and meta-analysis of clinical outcomes. *Cardiovasc Intervent Radiol*. 2021;44(8):1231-1239.
55. Dariushnia SR, Haskal ZJ, Midia M, et al; Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for transjugular intrahepatic portosystemic shunts. *J Vasc Interv Radiol*. 2016;27(1):1-7.
56. RiChard J, Thornburg B. New techniques and devices in transjugular intrahepatic portosystemic shunt placement. *Semin Intervent Radiol*. 2018;35(3):206-214.
57. Pieper CC, Sprinkart AM, Nadal J, et al. Postinterventional passive expansion of partially dilated transjugular intrahepatic portosystemic shunt stents. *J Vasc Interv Radiol*. 2015;26(3):388-394.
58. Praktiknjo M, Abu-Omar J, Chang J, et al. Controlled underdilation using novel VIATORR® controlled expansion stents improves survival after transjugular intrahepatic portosystemic shunt implantation. *JHEP Rep Innov Hepatol*. 2021;3(3):100264.
59. Gaba RC, Couture PM, Lakhoo J. Gastroesophageal variceal filling and drainage pathways: an angiographic description of afferent and efferent venous anatomic patterns. *J Clin Imaging Sci*. 2015;5:61.
60. Kanagawa H, Mima S, Kouyama H, Gotoh K, Uchida T, Okuda K. Treatment of gastric fundal varices by balloon-occluded retrograde transvenous obliteration. *J Gastroenterol Hepatol*. 1996;11(1):51-58.
61. Patel A, Fischman AM, Saad WE. Balloon-occluded retrograde transvenous obliteration of gastric varices. *AJR Am J Roentgenol*. 2012;199(4):721-729.
62. Saad WEA, Kitanosono T, Koizumi J, Hirota S. The conventional balloon-occluded retrograde transvenous obliteration procedure: indications, contraindications, and technical applications. *Tech Vasc Interv Radiol*. 2013;16(2):101-151.
63. Park JK, Saab S, Kee ST, et al. Balloon-occluded retrograde transvenous obliteration (BRTO) for treatment of gastric varices: review and meta-analysis. *Dig Dis Sci*. 2015;60(6):1543-1553.
64. Wang ZW, Liu JC, Zhao F, et al. Comparison of the effects of TIPS versus BRTO on bleeding gastric varices: a meta-analysis. *Can J Gastroenterol Hepatol*. 2020;2020:5143013.
65. Luo X, Xiang T, Wu J, et al. Endoscopic cyanoacrylate injection versus balloon-occluded retrograde transvenous obliteration for prevention of gastric variceal bleeding: a randomized controlled trial. *Hepatology*. 2021;74(4):2074-2084.
66. Kim DJ, Darcy MD, Mani NB, et al. Modified balloon-occluded retrograde transvenous obliteration (BRTO) techniques for the treatment of gastric varices: vascular plug-assisted retrograde transvenous obliteration (PARTO)/coil-assisted retrograde transvenous obliteration (CARTO)/balloon-occluded antegrade transvenous obliteration (BATO). *Cardiovasc Intervent Radiol*. 2018;41(6):835-847.
67. Gwon DI, Ko GY, Kwon YB, Yoon HK, Sung KB. Plug-assisted retrograde transvenous obliteration for the treatment of gastric varices: the role of intra-procedural cone-beam computed tomography. *Korean J Radiol*. 2018;19(2):223-229.
68. Lee EW, Saab S, Gomes AS, et al. Coil-assisted retrograde transvenous obliteration (CARTO) for the treatment of portal hypertensive variceal bleeding: preliminary results. *Clin Transl Gastroenterol*. 2014;5(10):e61.
69. Tian X, Wang Q, Zhang C, et al. Modified percutaneous transhepatic variceal embolization with 2-octylcyanoacrylate for bleeding gastric varices: long-term follow-up outcomes. *AJR Am J Roentgenol*. 2011;197(2):502-509.
70. Arai H, Abe T, Takagi H, Mori M. Efficacy of balloon-occluded retrograde transvenous obliteration, percutaneous transhepatic obliteration and combined techniques for the management of gastric fundal varices. *World J Gastroenterol*. 2006;12(24):3866-3873.
71. Kiyosue H, Matsumoto S, Yamada Y, et al. Transportal intravariceal sclerotherapy with N-butyl-2-cyanoacrylate for gastric varices. *J Vasc Interv Radiol*. 2004;15(5):505-509.
72. L'Herminé C, Chastanet P, Delemazure O, Bonnière PL, Durieu JP, Paris JC. Percutaneous transhepatic embolization of gastroesophageal varices: results in 400 patients. *AJR Am J Roentgenol*. 1989;152(4):755-760.
73. Saad WEA, Kitanosono T, Koizumi J. Balloon-occluded antegrade transvenous obliteration with or without balloon-occluded retrograde transvenous obliteration for the management of gastric varices: concept and technical applications. *Tech Vasc Interv Radiol*. 2012;15(3):203-225.
74. Wang G, Meng D, Huang G, et al. Balloon-assisted percutaneous transhepatic antegrade embolization with 2-octyl cyanoacrylate for the treatment of isolated gastric varices with large gastrorenal shunts. *BioMed Res Int*. 2019;2019:2674758.
75. Hu YB, Feng GS, Liang HM, et al. Long-term effects of interventional devascularization in treating cirrhosis patients with portal hypertension. *Chin J Radiol*. 2009;43(8):853-857.
76. Liu W, Chen GS, Sun HL, et al. Comparison of interventional devascularization and surgical devascularization in treatment of upper gastrointestinal hemorrhage for portal hypertensive. *Chin J Radiol*. 2009;43(7):748-752.
77. Duan X, Zhang K, Han X, et al. Comparison of percutaneous transhepatic variceal embolization (PTVE) followed by partial splenic embolization versus PTVE alone for the treatment of acute esophagogastric variceal massive hemorrhage. *J Vasc Interv Radiol*. 2014;25(12):1858-1865.
78. Saad WE, Wagner CC, Lippert A, et al. Protective value of TIPS against the development of hydrothorax/ascites and upper gastrointestinal bleeding after balloon-occluded retrograde transvenous obliteration (BRTO). *Am J Gastroenterol*. 2013;108(10):1612-1619.