Evolution of Retrograde Transvenous Obliteration Techniques

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Abstract

Keywords

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Gastric variceal hemorrhage is a life-threatening complication of portal hypertension with a poorer prognosis compared with esophageal variceal hemorrhage. The presence of an infradiaphragmatic portosystemic shunt, often a gastorenal shunt, allows for treatment with retrograde transvenous obliteration (RTO). RTO is an evolving treatment strategy, which includes balloon-assisted RTO, plug-assisted RTO, and coil-assisted RTO, for both gastric variceal hemorrhage and hepatic encephalopathy. RTO techniques are less invasive than transjugular intrahepatic portosystemic shunt creation, with the benefit of improved hepatic function, but at the expense of increased portal pressure. This article discusses the techniques of RTO, including patient eligibility, as well as technical and clinical outcomes, including adverse events.

Objectives: Upon completion of this article, the reader will be able to discuss the various techniques of retrograde transvenous obliteration for gastric varices and hepatic encephalopathy, their indications and limitations, choice of sclerosant, and current evidence supporting their use.

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Gastric variceal bleeding is a major complication of portal hypertension, occurring in approximately 25% of patients with gastric varices a year.^{1,2} When compared with bleeding from esophageal varices, gastric varices have a worse prognosis, with mortality rates as high as 45 to 55%, and are associated with more severe blood loss, along with higher rates of rebleeding.^{3–5} In the setting of gastric variceal

hemorrhage, treatment considerations require a multidisciplinary approach, and include both endoscopic and endovascular therapies. Current practice guidelines from the American Society for Gastrointestinal Endoscopy (ASGE) and the American Association for the Study of Liver Disease (AASLD) suggest initial endoscopic management, followed by endovascular treatment, for refractory cases.^{6,7}

Typical endovascular treatment in the United States for variceal hemorrhage is transjugular intrahepatic portosystemic shunt (TIPS) creation with concomitant variceal embolization, which is 90% effective in controlling acute gastric variceal hemorrhage.^{7,8} However, patients with severe hepatic dysfunction and high model for end-stage liver disease (MELD) scores may not tolerate TIPS, and risk worsening hepatic dysfunction and encephalopathy, as blood flow is diverted away from the liver.^{2,9} Additionally, gastric varices occur at lower portosystemic gradients than esophageal varices; hence, further reduction of portal pressures may not result in resolution of hemorrhage.¹⁰

Retrograde transvenous obliteration (RTO) refers collectively to balloon-occluded retrograde transvenous obliteration (BRTO), plug-assisted retrograde transvenous obliteration (PARTO), and coil-assisted retrograde transvenous obliteration (CARTO). RTOs are an endovascular alternative to TIPS for treatment of gastric varices. In comparison

to TIPS, they are less invasive and indicated for those with compromised hepatic function.¹¹ Moreover, RTOs improve refractory hepatic encephalopathy (HE) in the presence of a splenorenal shunt.

This article details the techniques of RTO, including patient eligibility and technical and clinical outcomes, along with adverse events.

Patient Eligibility and Workup for Treatment

Endoscopy

Initial workup of patients with upper gastrointestinal bleeding is with endoscopy after hemodynamic stabilization. Endoscopy identifies gastroesophageal varices, and determines which varices are bleeding.¹¹ Hemorrhagic esophageal varices are generally controlled with endoscopic banding or sclerotherapy, with refractory cases proceeding to TIPS.^{12,13} Bleeding gastric varices with slow flow by endoscopic ultrasound are controlled by endoscopic sclerosis, often without the need for endovascular management. However, large fundal or cardiac varices with rapid flow are referred for endovascular treatment, to avoid nontarget embolization during endoscopic sclerosis.¹¹

Imaging

Once the diagnosis of bleeding gastric varices is made, preprocedure planning for RTO begins with contrast-enhanced cross-sectional imaging, either computed tomography (CT) or magnetic resonance imaging (MRI). Imaging detects and details the anatomy of an infradiaphragmatic portosystemic shunt, found in at least 10 to 20% of portal hypertensive patients.¹⁴ The gastrosplenic shunt is the most common type, and provides outflow for gastric varices in up to 85% of cases.¹⁵ The diameter of this shunt is measured at its efferent communication with the left renal vein, often at its narrowest point, where it can be safely occluded.¹¹ Afferent supply of gastric varices is typically the left gastric vein, posterior gastric vein, or short gastric veins.

A gastrosplenic shunt affords hepatofugal flow, diverting blood away from the portal circulation. Thus, assessment for main portal vein (MPV) patency, in preparation for shunt occlusion, is an important step in the workup. With complete MPV thrombosis, the gastrosplenic shunt provides primary drainage of the splenic and mesenteric circulation. Occlusion of this shunt is contraindicated, as mesenteric venous hypertension causing mesenteric ischemia or thrombosis can occur. Compensated MPV thrombosis with cavernous transformation may have adequate flow to safely proceed.¹⁶ Redistribution of flow into the portal circulation, following shunt obliteration, can improve cases of partial portal vein thrombosis. However, if this increased flow cannot be tolerated, similar complications as complete MPV thrombosis may occur.^{11,17–20}

Relative contraindications to RTOs include large volume intractable ascites, given expected worsening with increased portal pressure after shunt occlusion, along with uncorrected coagulopathy.³ Additionally, some authors consider

the presence of hepatocellular carcinoma greater than 5 cm as a relative contraindication.^{2,11,21,22}

Treatment Options

Balloon-Occluded Retrograde Transvenous Obliteration

Traditional BRTO techniques are well documented in the literature. Briefly, via a common femoral or jugular vein approach, the outflow of the gastrosplenic shunt into the left renal vein is catheterized, followed by deployment of an appropriately sized occlusion balloon. Balloon occlusion venography is performed to define the venous drainage.^{11,20,23} The presence of collateral veins may prevent complete filling of the shunt, in which case these veins are embolized with microcoils or Gelfoam.^{11,20,23} Subsequently, sclerosant with a contrast agent is injected into the varix until it is fully opacified, typically via a microcatheter placed deep into the varix.¹¹ Embolization is complete after minimal filling of afferent portal branches, identified during balloon occlusion venography.¹¹ The use of cone beam CT can aid in evaluating this embolization end point.²⁴ The balloon remains inflated for 4 to 24 hours while the patient is immobilized in the ICU, followed by return to the angiography suite for balloon deflation.^{11,20,23} An accelerated BRTO technique can be used in small gastrosplenic shunts (<15 mm), in which traditional BRTO is followed by terminal Gelfoam plug or coil deployment, through the occlusion balloon, eliminating the need for prolonged balloon inflation.^{25,26}

Plug-Assisted Retrograde Transvenous Obliteration

PARTO utilizes an Amplatzer Vascular Plug II (AVP II) placed in the efferent limb of the gastrosplenic shunt, just proximal to the confluence with the left renal vein. Using the same approach as BRTO, the gastrosplenic shunt is accessed with an angle tip catheter and guidewire (– Fig. 1). A sheath is advanced into the outflow, which allows a catheter or wire to remain upstream during plug deployment. AVP II sizes range from 3 to 22 mm, and a plug 20 to 30% larger than the narrowest point of the varix near the left renal vein is selected to avoid migration.^{4,27–29} If subsequent contrast injection through the upstream catheter demonstrates inadequate occlusion, with continued portosystemic flow into the left renal vein, small volume Gelfoam embolization, or waiting for 5 to 10 minutes, will achieve stasis.²⁸ With contrast stasis in the shunt, Gelfoam embolization is performed through the catheter, upstream to the plug, with same end point as BRTO. Use of Gelfoam together with a sclerosant is also described.²⁶ Supplemental coil embolization of draining collaterals is rarely necessary. After confirmation of shunt occlusion, the catheter is removed, and the AVP II is detached.

Coil-Assisted Retrograde Transvenous Obliteration

CARTO utilizes double microcatheters, often after angiographic shunt evaluation, following the same initial steps as BRTO. Through a sheath placed into the left renal vein, one microcatheter is placed proximally, at the narrowest point in the efferent shunt, and one is placed upstream for Gelfoam

Fig. 1 A 61-year-old male with alcoholic cirrhosis presented with hematemesis and melena. Esophagogastroduodenoscopy (EGD) demonstrated dilated gastric varices without active bleeding. (a) Contrast enhanced computed tomography (CT) scan demonstrates enhancing dilated gastric varices extending to the gastric mucosal surface (arrow), along with a large gastrorenal shunt draining into the left renal vein. Cirrhotic liver morphology and mild ascites is noted. (b) Selective catheter venography was performed of the gastrorenal shunt through coaxial sheaths via a right transjugular approach, followed by advancement of a microcatheter into the proximal shunt. (c) Following deployment of a 14-mm Amplatzer II Vascular Plug near the left renal vein confluence, 40 cc of thick Gelfoam slurry was injected into the gastrorenal shunt until complete retrograde shunt opacification (including the mucosal gastric variceal component) was attained. (d) Contrast-enhanced CT scan 24 hours postprocedure demonstrates no residual enhancement within the persistently dilated gastric mucosal varices. (e) Contrast-enhanced magnetic resonance imaging (MRI) scan 1 year postprocedure demonstrates obliterated gastric varices and gastrorenal shunt, without evidence of residual enhancement. Moderate interval increase in ascites was noted (asterisk). No esophageal varices were identified. The patient had complete periprocedural resolution of hematemesis and melena, without recurrence at 1 year.

embolization. Through the proximal microcatheter, appropriate sized coils are selected for shunt occlusion. Once angiographic shunt occlusion is confirmed, the shunt is embolized with Gelfoam through the upstream microcatheter, similar to the mentioned PARTO technique.

Sclerosants

Various sclerosants with diverse safety profiles are utilized in RTO procedures. Ethanolamine oleate (EO), the traditional sclerosant used in Asia for BRTO, causes direct endothelial damage and permanent vascular occlusion. Hemolytic effects of EO can lead to hemoglobinuria and renal failure.^{5,30} Although haptoglobin administered during the procedure reduces risk of renal toxicity, haptoglobin is not approved by the Food and Drug Administration in the United States.³⁰ Additionally, EO is associated with pulmonary edema, disseminated intravascular coagulation, and cardiogenic shock.^{28,31} Limiting the total volume of 5 to 10% EO to 20 to 30 cc (or <0.4 mL/kg), or dividing treatment into multiple sessions may mitigate these risks.^{2,30,32}

Polidocanol, a relatively new sclerosing agent in the United States, is used in foam form for varicose vein sclerotherapy and BRTO. In a retrospective review by Itou et al, 41 patients with gastric varices underwent BRTO with EO ($n = 20$) or BRTO with polidocanol foam ($n = 21$).³³ Three percent polidocanol and air were combined in a 1:4 mixture per the Tessari method, and a total volume of 13.5 ± 6.8 mL was injected; significantly less than 30.6 ± 15.6 mL of 5% EO; $p < 0.01$.^{34,35} The smaller volume of polidocanol required for variceal embolization minimizes sclerosant-related complications, and eliminates the need for haptoglobin administration.^{34,35} Polidocanol is not available in high concentrations in the United States, which limits utilization.^{34,35}

Sodium tetradecyl sulfate (STS), a common sclerosant in the United States, is a chemical irritant causing permanent endothelial damage beginning as early as 2 minutes after exposure to 3% STS, with progressive thrombus formation over 30 minutes.³⁶ A combination of gas (air or carbon dioxide), 3% STS, and lipiodol, in a ratio of 3 mL:2 mL:1 mL is used to create STS foam. This foam mixture generates vessel wall contact as it expands.² Sabri et al calculated a mean volume of 11.4 mL of 3% STS foam used in 22 patients undergoing BRTO for bleeding gastric varices, compared with mean volumes of 23 to 26 mL of 5% EO reported in other series.^{10,30,37} Rare side effects of STS sclerosis include pulmonary edema and portal vein thrombosis.^{29,35,37}

Substituting traditional sclerosants for Gelfoam introduces an embolization agent with no dose limitations, along with greater safety profiles and familiarity among interventionalists.^{28,33} However, higher rates of gastric variceal recurrence are reported after PARTO with Gelfoam versus BRTO with EO or STS. Although this recurrence was not directly attributed to Gelfoam, periprocedural shunt thrombosis followed by recurrence may relate to recanalization before complete variceal obliteration.³¹ Reports of minimal systemic leakage of Gelfoam resulted in no clinically evident pulmonary or arterial embolization.²⁸ Importantly, Gelfoam

eliminates the need to embolize small draining collateral veins, a requirement in BRTO to avoid systemic leak of sclerosant.

Outcomes

Technical Success

Definition of technical success varies in the literature, including successful gastrosplenic shunt cannulation, deployment of the occlusion device, and/or filling of the entire shunt with the embolic agent. For BRTO, PARTO, and CARTO, this ranges from 79 to 100%, 94.7 to 100%, and 100%, respectively.^{2,4,5,27–29,31,38,39} In a recent retrospective study comparing BRTO and PARTO, Kim et al reported similar technical success rates of BRTO with EO (93.9%) or STS (92%), and PARTO with Gelfoam (100%).³¹ Notably, the success rate of BRTO increases from 84–98% to 98–100% when used in conjunction with balloon-occluded antegrade transvenous obliteration (BATO), although combination therapies are beyond the scope of this article.^{23,40}

Saad and Sabri classified causes of technical failures after 160 BRTO procedures into four main categories.² Type I failures were defined as a failure to cannulate the gastrosplenic shunt, which occurred in 1.3% of cases.^{41–43} The angle of the left renal vein has been associated with this type of failure.³¹ Type II failures, described as an inability to occlude the shunt due to large size occurs in 3.1% of BRTO failures.^{31,41–43} Type III was the most common, occurring in 3.8% of cases, and defined as an inability to opacify the shunt, due to complex/multicollateral drainage or retroperitoneal extravasation of contrast.^{41–43} Type IV consisted of balloon rupture with subsequent systemic release of sclerosant, which occurred in 2.3 to 8.7% of cases.^{31,41–43}

Clinical Success and Survival

Clinical success is defined as resolution of gastric variceal hemorrhage without recurrent bleeding, and/or complete shunt obliteration on follow-up imaging/endoscopy. For BRTO, PARTO, and CARTO, clinical success ranges from 91 to 100%, 90.6 to 100%, and 100%, respectively.^{2,4,24,27–29,31,38,39} Kim et al detected similar clinical success rates (defined as lack of variceal enhancement on postprocedural CT and cessation of bleeding on endoscopy) between BRTO with EO (93.9%) or STS (92%) and PARTO with Gelfoam (100%).³¹

Acutely bleeding gastric varices carry a high mortality with limited treatment options. Emergent BRTO and PARTO are safe and effective options for control of hemorrhage.^{27,44}

Long-term survival rates after BRTO in a 154-patient cohort, including patients with acute variceal hemorrhage, at 1, 3, and 5 years were 91, 76, and 72%, respectively.⁴⁵ Increased patient survival after BRTO compared with TIPS with 1-, 3-, and 5-year survival rates of 96, 83, and 76% versus 81, 64, and 40%, respectively ($p < 0.01$), is attributed to redirection of portal flow.^{2,3,46} Importantly, this increased survival was significant only in patients with Child-Pugh A disease.

Clinical success of shunt occlusion performed for HE is defined as improvement of HE, reduction in ammonia levels, and/or reduction of medications used to manage HE (► Fig. 2).

Fig. 2 A 48-year-old male with history of primary sclerosing cholangitis status post liver transplant in 2014, with recurrent cirrhosis and medically refractory hepatic encephalopathy. (a) Contrast-enhanced CT scan demonstrates enhancing dilated gastric varices and a large gastrorenal shunt draining into the left renal vein (arrow). (b) Selective catheter venography of the gastrorenal shunt via a right femoral approach demonstrated band-like segments of narrowing at the distal portion (likely valves), just proximal to its confluence with the left renal vein. (c) Following deployment of an 18-mm Amplatzer II Vascular Plug near the left renal vein confluence, 25 cc of thick Gelfoam slurry was injected via a microcatheter placed into the proximal gastrorenal shunt. Image obtained just prior to plug detachment. (d) Contrast-enhanced CT scan 48 hours postprocedure demonstrates no residual enhancement within persistently dilated gastric varices. Small focus of gas within the shunt is noted (arrow), related to Gelfoam embolization. (e) Contrast-enhanced CT scan 3 months postprocedure demonstrates significant interval decrease in size of the gastric varices and gastrorenal shunt, without evidence of residual enhancement. No evidence of esophageal varices or ascites was noted. Complete resolution of hepatic encephalopathy was noted 3 months postprocedure.

Mukund et al reviewed 20 patients treated with BRTO for HE, identifying a 80% improvement in HE at 24 months, along with a significant reduction in serum ammonia levels.⁴⁷ Inoue et al reported a significant decrease in ammonia levels in 19 patients, up to 3 years after BRTO ($p < 0.01$), which accompanied improvement in clinical symptoms.⁴⁸

Adverse Events

Complications of Portal Hypertension

Worsening of esophageal varices occurs secondary to the redirection of blood flow into the portal circulation with occlusion of a spontaneous portosystemic shunt. A similar occurrence is reported with BRTO and CARTO of 27 to 35%, and 23% at 1 year, respectively, and 22 to 33% for PARTO from 3 to 9 months.^{2,4,5,27–29,31}

Incidence of new or worsening ascites or hepatic hydrothorax is 0 to 44% after BRTO, 23% after PARTO at 3 months, and 25% after CARTO at approximately 1 year^{2,4,5,39} (►Fig. 1e).

The presence of portal gastropathy after BRTO and CARTO is 5 to 13% and 20%, respectively.^{2,5,39}

Recurrence of Gastric Varices

Gastric variceal recurrence after RTO is unlikely utilizing any of the mentioned oblitative techniques. Specifically, BRTO performed with 5% EO in 147-patient cohort showed no recurrence with median follow-up of 30 months.⁴⁵ Similarly, a 6% recurrence rate was identified after BRTO with STS on CT/endoscopy at a median of 142 days.²⁸ PARTO demonstrated no recurrence by CT or endoscopy with ≥ 3 months of follow-up⁴; and CARTO in a 20-patient cohort, with mean follow-up of 384 days, also showed no gastric varix recurrence by imaging or endoscopy³⁹ (►Figs. 1e and 2e). As mentioned, a comparative effectiveness study suggests a higher rate of gastric variceal recurrence with PARTO as compared with BRTO with STS.

Rebleeding rates after successful shunt obliteration vary based on definition. For BRTO, most studies report a rate of gastric variceal rebleeding between 0 and 10%.¹¹ A similar rebleeding rate is seen after PARTO of 11% (2 of 18 patients) at 1 year.³¹ CARTO performed in a single center identified no gastric variceal rebleeding over a mean of 384 days.³⁹

Procedure-Related Complications

Minor complications including access site bleeding or infection occur in 5% of patients after BRTO.²⁵ Additional transient postprocedural complications include fever (33%), chest/epigastric pain (56%), hypertension (35%), nausea/vomiting (21%), and gastric ulcers (9%).³⁷

Major complications after BRTO often relate to balloon rupture (2.3–8.7%) and subsequent release of sclerosant.^{31,41–43} Nontarget embolization including pulmonary embolism, and portal or renal vein thrombus, arises in 1.5 to 4.1%, 4.7%, and 5% of cases, respectively.² Anaphylactic reactions, attributed to systemic effects of sclerosant, are seen in 2.2 to 5% of patients.²

A recent meta-analysis of patients undergoing BRTO for gastric varices identified two procedure-related deaths

(<24 hours) in a total of 1,016 patients (0.2%), both of which had hepatocellular carcinoma, and one of which had tumor thrombus in right portal vein before BRTO. Although uncertain, a possible cause of death was multiorgan failure.⁵ In a retrospective review of 20 patients treated with CARTO for non-esophageal variceal bleeding, 1 death (4%) occurred 24 days after CARTO. This was attributed to systemic and portal vein thrombosis, along with multiorgan failure, possibly related to a hypercoagulable cascade induced by Gelfoam.³⁹

Although hematuria occurs after BRTO (15–100%) and PARTO (15.8%), only BRTO demonstrated progression to renal failure in 4.8% of cases.^{2,28} Lee et al reported no cases of renal failure in 20 patients after CARTO.³⁹

Contrast leakage or extravasation of Gelfoam into the retroperitoneum during BRTO and PARTO is a self-limiting complication in 4 and 21% of patients, respectively.^{28,49,50} This is due to rupture of small collateral vessels during pressurized injection, and no clinically significant outcome or retroperitoneal abnormality was detected on follow-up CT after PARTO²⁸ (►Fig. 3). Additionally, a rare complication of transient adrenal insufficiency was identified in 1 of 19 patients (5%), secondary to left adrenal vein occlusion after PARTO.²⁸

Discussion

RTO techniques are effective for gastric variceal bleeding, including acute bleeding, and HE, thus providing a treatment alternative to TIPS, especially in patients with hepatic decompensation. Increased hepatic portal perfusion, after portosystemic shunt occlusion, improves hepatic function in patients for 6 to 12 months, with eventual return to baseline.^{2,4,28,51} In comparison, patients with gastroduodenal shunts, not treated with shunt obliteration, have a progressive decline in hepatic function.³

BRTO is the prototypical RTO with pooled technical and clinical success rates of 96 and 97%, and a major complication rate of 2.6%, in a recent meta-analysis.⁵ Balloon inflation provides stasis within the shunt to promote thrombosis, and to prevent systemic leakage of sclerosant.³⁹ However, prolonged balloon inflation (up to ~24 hours) increases risk of complications, including access site bleeding and infection, along with resource demands due to prolonged admissions.^{30,39} Additionally, balloon rupture, either during or after the administration of sclerosant, can release sclerosant resulting in nontarget embolization or systemic toxicity.^{2,5,30,52,53} Choice of sclerosant is operator dependent; however, STS foam demonstrated a reduction in complications and procedure time compared with EO.³¹ An accelerated BRTO technique, using a terminal Gelfoam plug or coils, reduces balloon inflation times, yet is only described in small gastroduodenal shunts (<15 mm).^{25,26}

PARTO is a significantly shorter procedure compared with BRTO. Park et al reported a mean time of 20 minutes (range: 5–90 minutes) from plug deployment to detachment with PARTO, compared with a procedure time of 139.7 minutes (range: 40–360 minutes) for BRTO with EO and 114.8 minutes (range: 90–163 minutes) for BRTO with STS; $p < 0.05$.³⁸ Along with reduced procedural times, the presence of a plug rather than balloon reduces risk of nontarget embolization, a

Fig. 3 A 57-year-old male with alcoholic cirrhosis presented with hematemesis. EGD demonstrated dilated gastric varices without active hemorrhage. (a) Contrast-enhanced CT scan demonstrates enhancing dilated gastric varices extending into the gastric mucosal surface (arrow), along with a large gastroduodenal shunt draining into the left renal vein. Cirrhotic liver morphology is noted. (b) Intraprocedural cone beam CT demonstrates Gelfoam contrast throughout the mucosal portion of the gastric varix, along with extravasation of Gelfoam into the left retroperitoneum (arrow). The patient tolerated the procedure without immediate periprocedural complication. (c) Contrast-enhanced CT scan 48 hours postprocedure demonstrates no residual enhancement within persistently dilated gastric mucosal varices. Small foci of gas within the shunt are related to Gelfoam embolization. Left retroperitoneal extravasation of Gelfoam contrast is improving (arrow). The patient had complete resolution of hematemesis and no significant complication of retroperitoneal Gelfoam extravasation on 6-month follow-up.

complication of BROTO reported in up to 5% of cases.² However, use of a plug typically blocks future vascular access, thus increasing the difficulty of repeat treatments.²⁹

Shunt angle and size limit plug-assisted occlusion. The maximal AVPIL plug diameter is 22 mm, and as such, shunts greater than 18 mm at the left renal vein confluence are not routinely occluded.²⁸ Conversely, small shunts can limit catheter placement upstream from the plug.³⁹

The double microcatheter technique of CARTO, and range of manufactured coil sizes, allows CARTO performance in both smaller and larger vessels not amenable to plug or balloon placement. Lee et al reported successful coil embolization with complete occlusion of shunts measuring up to

25 to 30 mm.³⁹ However, mean procedure times for CARTO (2.82 hours $\pm$ 0.56 hours) are longer than those of PARTO (20–68 minutes).^{26,39}

A prospective evaluation of 73 patients treated with PARTO for gastric varices and HE demonstrated a technical success rate of 100% and clinical success rate of 98.6%. Among 60 patients with follow-up beyond 3 months, portosystemic shunts were occluded by imaging in all patients and no patient had recurrent gastric variceal bleeding. Given the high technical success and durability, the authors suggest PARTO as a first-line therapy for treatment of gastric varices and HE in the presence of a portosystemic shunt.⁴

Conclusion

Portosystemic shunt occlusion via RTO affords treatment of bleeding gastric varices and refractory HE in the presence of a gastroduodenal shunt. In patients who are poor candidates for TIPS, these procedures have the benefit of decreased invasiveness, augmentation of portal flow (resulting in preservation or improvement of hepatic function), along with mitigation of HE. However, shunt occlusion results in increased portal pressure, along with its complications. Methods of shunt obliteration vary from BRTO utilizing sclerosants, either in liquid or foam form, with prolonged balloon inflation, to accelerated versions, namely PARTO and CARTO, which utilize Gelfoam rather than sclerosants. These procedures mechanistically differ from the traditional practice of portal decompression in the United States, and a growing body of evidence and experience will help define their utilization in a complex patient population.

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