ELSEVIER

Techniques in
Vascular and
Interventional
Radiology

Transcatheter Embolization for the Treatment of Upper Gastrointestinal Bleeding

Joan K. Frisoli, MD, PhD, Daniel Y. Sze, MD, PhD, and Stephen Kee, MD

Over the past 20 years, the treatment of upper gastrointestinal bleeding (UGIB) that is refractory to endoscopic treatment has been revolutionized by transcatheter embolization. Embolization techniques have evolved with the use of microcatheters and new embolic materials. The majority of patients are successfully treated by minimally invasive techniques and can avoid having surgery.
Tech Vasc Interventional Rad 7:136-142

KEYWORDS embolization, upper gastrointestinal bleeding

Upper gastrointestinal bleeding (UGIB) is defined as originating in the distal esophagus, stomach, and duodenum (proximal to the Ligament of Treitz). The most common cause of nonvariceal UGIB is peptic ulcer disease, but the differential diagnosis is diverse, including benign and malignant tumors, ischemia, gastritis, arteriovenous malformations such as Dieulafoy lesions, Mallory–Weiss tears, trauma, and iatrogenic causes.[1,2] The differential diagnosis, medical, and endoscopic treatment of UGIB are discussed elsewhere in this issue of *TVIR*. Effective treatment requires diagnosis (location and etiology), and unlike lower gastrointestinal bleeds, most patients have undergone endoscopic examination and treatment before their referral to interventional radiology. Of the small group of patients who fail endoscopic therapy, some are treated surgically,[3] but increasingly, the majority are referred for embolotherapy. Transcatheter embolization has been performed for at least three decades and has been shown to be effective at controlling hemorrhage and decreasing mortality.[4-7] This article discusses techniques and results of embolotherapy for UGIB.

Anatomy

The vascular supply to the stomach and duodenum is quite rich, with avid redundant supply. This can make successful embolization more challenging; however, it decreases the incidence of postembolization ischemia. The likelihood of successful embolization reflects prior knowledge of the location of the bleed. Localization of the bleed by endoscopy or cross-sectional imaging can allow one to focus on the likely feeding vessel and to perform the embolization even when active extravasation is not identified angiographically.

The left gastric artery (LGA) runs along the lesser curve of the stomach and supplies the stomach and distal esophagus. The LGA is most often the first branch of the celiac trunk (90%) but may arise directly from the aorta, as a lienogastric trunk, or hepatogastric trunk.[8] It anastamoses with the right gastric artery (RGA). Small distal branches anastamose with short gastric arteries (from the splenic artery) and the left inferior phrenic artery. The RGA most often originates from the proper, left, or middle hepatic artery but may also arise from the gastroduodenal (GDA) or right hepatic artery (RHA). It is typically a 1- to 2-mm vessel that runs in the gastrohepatic ligament and supplies the distal lesser curve of the stomach and the pylorus. The greater curvature of the stomach is supplied by the gastroepiploic arcade (GEA) that courses along the greater curvature of the stomach and is supplied by the right gastroepiploic artery, the terminal branch of the GDA, and the left gastroepiploic artery, a branch of the distal splenic artery. A complete arcade (rather than incomplete or weak) is present in about 65% of patients. The duodenum is supplied by the pancreaticoduodenal arcade, supplied by superior and inferior posterior and anterior pancreaticoduodenal arteries, branches of the GDA and SMA, respectively. The GDA arises from the common hepatic artery in a large majority of patients, but may also arise from the RHA, a replaced RHA branch of the SMA, or directly from the celiac axis.

Technique

By the time a patient with an UGIB reaches the interventional suite, s/he should be fluid-resuscitated, hemodynamically stable and have any coagulopathy corrected. Blood products such as fresh frozen plasma, platelets, or packed red blood

Department of Radiology, Stanford University, Stanford, CA.
Address reprint requests to Joan K. Frisoli, MD, PhD, Department of Radiology, Stanford University, 300 Pasteur Drive, Stanford, CA 94305. E-mail: jfrisoli@stanford.edu.

 1089-2516/04/$-see front matter
doi:10.1053/j.tvir.2005.02.006

cells may also be given intraprocedurally. It is desirable to correct any coagulopathy before embolization, because achieving hemostasis depends on technically successful embolization as well as the patient's ability to clot properly. Virtually all patients will also have undergone upper endoscopy in an attempt to identify and treat the source of bleeding. Angiography is performed to identify anatomy and when possible pinpoint the culprit vessel.

A 5-Fr sheath is placed in a common femoral artery to facilitate catheter exchange and to allow hemodynamic monitoring after the procedure. Abdominal aortography is then performed to delineate the arterial anatomy and facilitate selective catheterization. In young people, patients with renal insufficiency, and patients with arterial anatomy previously depicted by computed tomography, magnetic resonance, or catheter angiography, this may be omitted to decrease contrast medium load. Extravasation is rarely seen with nonselective angiography. The celiac axis (or SMA) is then selected with a 5-Fr Cobra 2, Simmons 2, Sos Omni, or other appropriately preshaped catheter and selective angiography is performed. Subselective angiography, longer injection durations, or use of carbon dioxide for contrast medium can improve sensitivity for small bleeds.

If the bleeding vessel is identified, subselective catheterization can be performed using coaxial 3-Fr microcatheters or a 4-Fr hydrophilic catheter (Glide Catheter; Terumo/Medi-Tech, Boston Scientific, Waltham, MA) to help minimize nontarget embolization. Some sites of bleeding represent end arteries, and superselective catheterization with microcatheters as small as 1.8 Fr may further minimize nontarget embolization. Frequently, bleeding is identified in a larger bed of vessels with multiple feeding branches, and the parent vessel becomes the target of embolization. In this situation, it is critical to "bookend" embolize the vessel both proximal and distal to the suspected site of bleeding to prevent back bleeding. If it is not possible to cross the origins of the culprit branches even with a microcatheter, then a liquid embolic such as N-butylcyanoacrylate (NBCA) glue can be used to embolize both sides of the focus of bleeding. Follow-up angiography to verify hemostasis should be performed, as well as injection of the SMA and other potential sources of collateral flow.

If the site of bleeding is not identified angiographically, empirical embolization can still be effective. For instance, the LGA can be embolized if the bleed is in the fundus of the stomach or distal esophagus. Engaging the LGA may require a Waltman loop, a left gastric catheter, or a microcatheter. Bleeding in the antrum, pylorus, or duodenum can be treated by embolizing the GDA. In this situation it is critical to embolize the vessel both proximal and distal to the suspected site of bleeding to prevent back bleeding from SMA branches and the gastroepiploic artery.

Choosing an Embolic Agent

There are three main types of embolic materials, as follows: (1) coils and balloons; (2) particulate material; and (3) liquid. Most of the embolic materials currently employed to embolize UGI hemorrhage are permanent. However gelfoam is typically degraded within 2 to 4 weeks, and even vessels occluded by permanent particulate material may recanalize. Each material has advantages, and choice of embolic material may be determined by the location and etiology of the bleed as well as operator preference.

Coils and Balloons

Coils and balloons are designed for focal occlusion of single macroscopic vessels, or where the site of vessel occlusion must be extremely precise. Generally speaking, the use of coils and detachable balloons carries low risk of infarction because of the preservation of the distal microvasculature. Treatment of UGIB using coils owes its efficacy to the resultant decrease in arterial pressure in the subserved vascular bed, which can result in a more effective clotting cascade and a reduction in bleeding. Collateral supply will usually maintain adequate perfusion of the vascular bed to prevent ischemic complications.

Coils are generally fabricated from platinum or stainless steel. Helically wound pieces of wire are embedded with thrombogenic polyester fibrils, and the wires can be given tertiary preformed shapes. Generally, they are available in straight, helical, tapered helical, and complex tertiary shapes, in a range of sizes from 1 to 20 mm in diameter. Coils are generally manufactured in either a 0.018" or 0.035" system to facilitate deployment through a microcatheter or a 5-Fr catheter. The 0.018" platform coils are optimally deployed through a microcatheter with a 0.021" inner diameter (i.d.). When used in a 0.027" or larger i.d. or "high flow" catheter, the coil can become wedged between the pusher wire and the catheter wall. The coil may still be deployable by injection of fluid through the lumen, but with less predictability.

Smaller diameter coils (0.014" and 0.010") designed for intracranial applications are also available and may offer the option of detachability and retrievability. Detachable coils are affixed to the delivery wire and can be detached by a threaded, pneumatic, spring-loaded, or electrolytic mechanism of deployment. If a detachable coil is positioned suboptimally, it can be easily retracted and repositioned. Only when the operator is satisfied, the coil can then be permanently deployed. These are especially useful in aneurysmal vessels, but generally do not have thrombogenic fibers to facilitate occlusion of the vessel.

When used in the setting of UGIB, coils are used to occlude or reduce flow into a major vessel, which can also be treated at a more distal level with a particulate agent (usually gelfoam) to aid in hemostasis. The main advantage of using coils is that they can be delivered in a very precise fashion; the main disadvantage is that they are permanent and may preclude re-accessing the vessel in the future should it prove necessary. Figure 1 shows a typical use of coils to embolize a bleeding duodenal hemorrhage. Figure 2 illustrates use of coils to embolize a duodenal Dieulafoy lesion in a patient with more challenging anatomy.

Detachable balloons were available in a range of sizes up to 13 mm in diameter, but are no longer commercially available.

Particulate Matter

The main particulate materials available for the treatment of hemorrhage are gelatin sponge (Gelfoam, Upjohn Company, Kalamazoo, MI), trisacryl gelatin, and polyvinyl alcohol (PVA) particles. Particles are available in a wide range of sizes

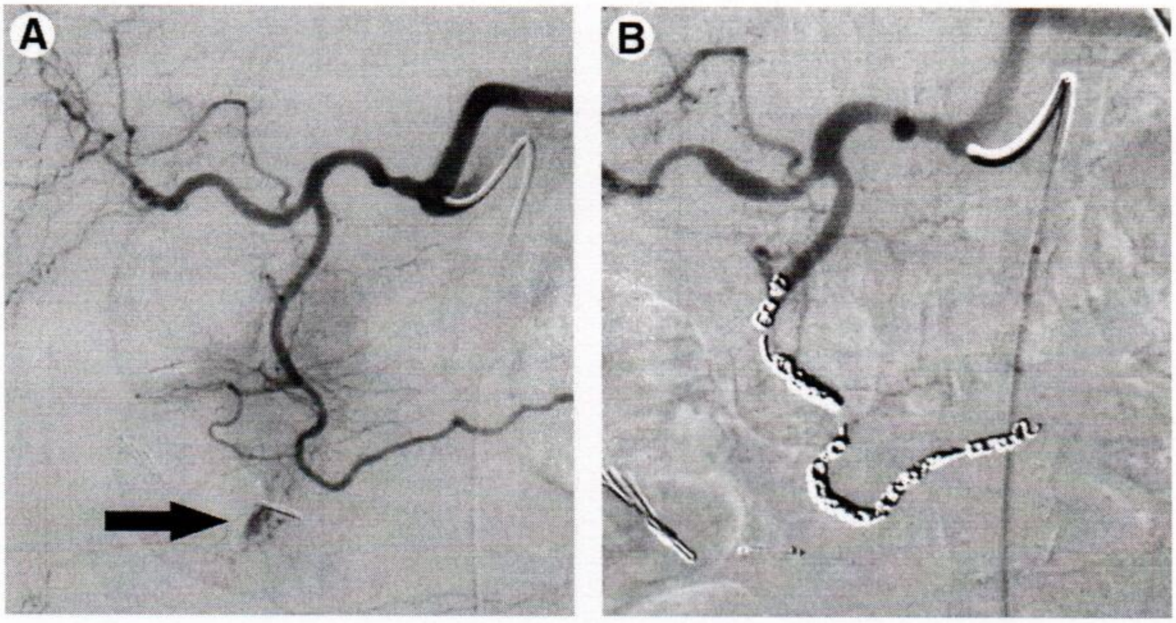

Figure 1 Seventy-six-year-old man with a bleeding duodenal ulcer. (A) Selective celiac angiogram showed active extravasation in the duodenum near some surgical clips (arrow). (B) After multiple coils were deployed in the right gastroepiploic artery distal to the site of hemorrhage to prevent back bleeding, the GDA was embolized, preserving the earliest pancreaticoduodenal branches. Follow-up angiogram showed resolution of extravasation.

and are chosen according to the size of the delivery catheter and the size of the target vessels.

Gelatin sponge is the main temporary embolic agent used worldwide. It has been available for over 30 years, and the operator customizes the material to suit the application by cutting pieces of gelatin sponge into small fragments of appropriate size. Gelatin powder is also commercially available, but results in a higher incidence of ischemic complications. These fragments are then wetted by and suspended in a solution of contrast medium, which can be diluted with saline to decrease viscosity. Fragments can be further reduced in size by vigorous mixing through a three-way stopcock using two syringes. Larger pledgets of gelfoam can be used as individual torpedoes to occlude larger vessels. Torpedoes, though, may be occlusive in smaller i.d. catheters and are therefore best loaded into 1- or 3-mL syringes for delivery through microcatheters. The gelatin sponge is biodegradable and resorbable, and embolized vessels do recanalize after a few weeks. In general, the reduction in pressure head to the site of bleeding that occurs on gelfoam embolization is satisfactory to stop the patient's hemorrhaging. The advantages of gelfoam are that it is readily available, inexpensive, unlikely to cause ischemia, and allows future access to embolized vessels after resorption. The disadvantages are that it requires some time to prepare appropriate-sized particles, and the pace of recanalization is unpredictable. Therefore, gelfoam is ideal for lesions that can heal, but need some help in getting started. Figure 3 illustrates the use of gelfoam to embolize a patient with duodenal stress ulcers.

PVA particles are commercially available in a variety of sizes ranging from 50 to 3000 μm (Contour, Boston Scientific, Natick, MA; Trutill, Cordis/Johnson & Johnson, Miami, FL; PVA-Plus, Angiodynamics, Queensbury, NY). These are supplied as particles suspended in sterile saline and are mixed with contrast immediately before injection. Particle size is chosen based on the i.d. of the delivery catheter and on the size of the vessels targeted for embolization. Some brands are intentionally irregularly shaped, and others are more spherical. They are inexpensive and easy to use, but not as precisely positionable as coils. Again, it is advisable to dilute these particles in small syringes to provide enough force to clear small i.d. catheters. The use of PVA particles is generally reserved for areas where permanent embolization down to the level of the arteriolar bed is required, usually in malignant lesions. These agents have been used successfully in treating gastrointestinal hemorrhage, usually through a microcatheter and at a site distal to major vessels. Only larger particles ($>$500 μm) should be used to decrease the risk of ischemia from tissue devascularization. Larger particles, especially if nonspherical, require the use of a large i.d. catheter to prevent catheter occlusion.

The main liquid embolic materials on the market in the United States include dehydrated ethanol and NBCA derivatives. Dehydrated ethanol is generally used to necrose an entire vascular bed. The material is cytotoxic and when administered intraarterially, both arterial and venous occlusion develop rapidly. This treatment tends to be reserved for use in arteriovenous malformations or in vascular tumors such as renal cell carcinomas. There are a number of potentially toxic side effects such as severe pain on injection, bradyarrhythmias, and sudden death. NBCA derivatives are in widespread use for the treatment of neurovascular arteriovenous malformations (Trufill, Cordis/Johnson & Johnson). The agent is essentially "superglue," which can be mixed with oily contrast medium (Ethiodol, Savage Labs, Melville, NY) to make it visible and viscous, but, unlike hardware store superglue that

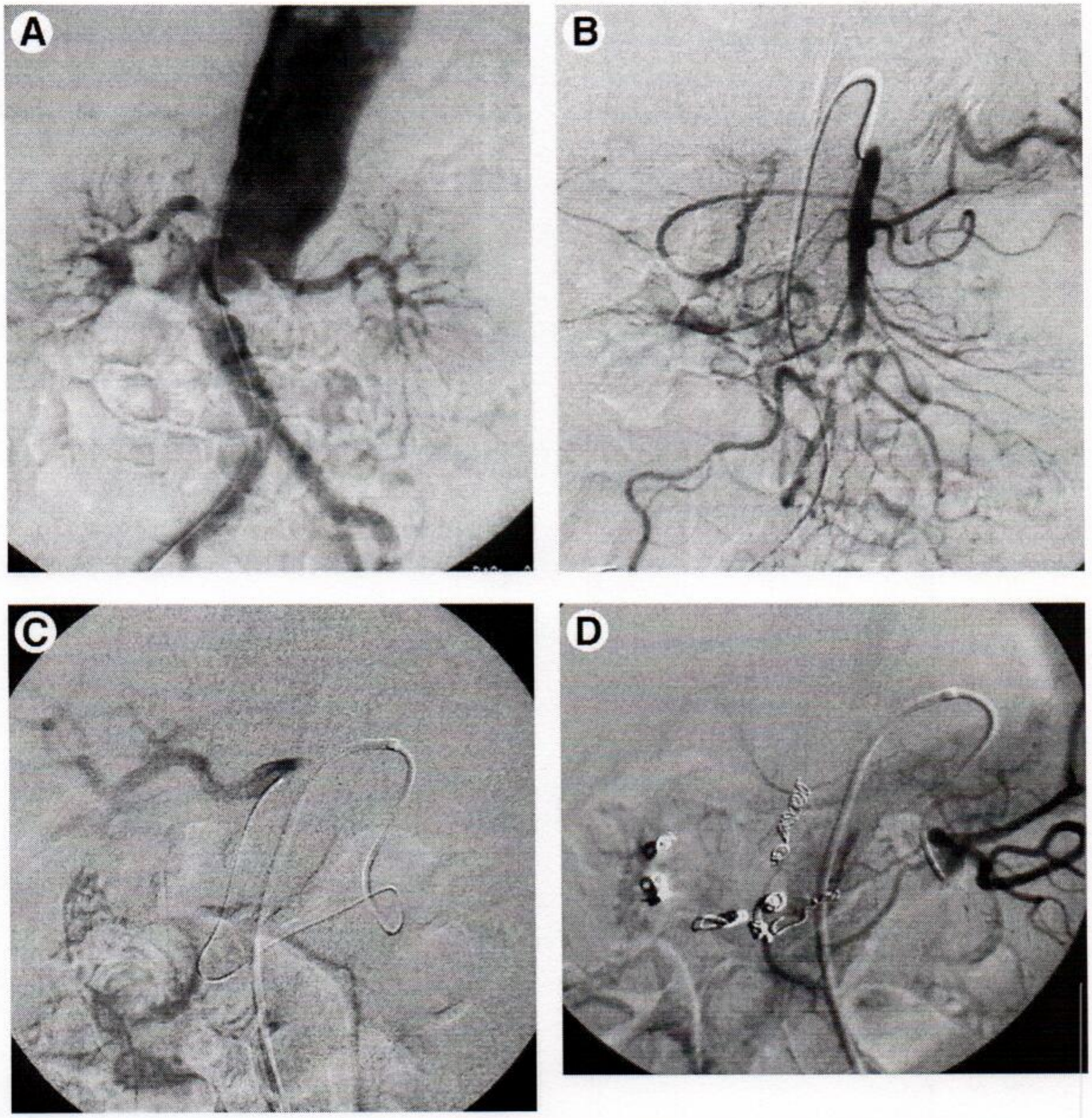

Figure 2 Seventy-eight-year-old woman with thoracoabdominal aortic aneurysm and bleeding duodenal Dieulafoy lesion that failed clipping and cauterization. After receiving 16 units of packed red blood cells and other blood products, she had an elevated INR and PTT, low platelets, and fibrinogen. (A) The abdominal aortogram showed aneurysm, with patent SMA but stenotic celiac artery. (B) Injection of the SMA showed filling of the GDA via pancreaticoduodenal branches. (C) Catheterization of the GDA via pancreaticoduodenal arcade (PDA) with a microcatheter was successful. (D) The GDA, RGEA, and PDA were coiled and follow-up angiogram showed an angiographic success.

sets after evaporation of a solvent, NBCA polymerizes when it comes into contact with ions. Depending on the degree of dilution of the agent, the material can be designed to solidify extremely rapidly, or over a prolonged period of time, up to 30 seconds. While most of the experience of these agents is in the neuro-interventional realm, a number of institutions have adapted these agents for use in both traumatic hemorrhage and gastrointestinal hemorrhage. With some experience, the viscosity and rate of polymerization can be manipulated to allow administration of the agent into a region where complete occlusion is required in a very rapid fashion. The other area where a liquid embolic agent such as NBCA can be useful is when a source of bleeding is identified and attempts to embolize both distal and proximal to this region are unsuccessful. In this situation, NBCA can be injected with moderate dilution allowing for contrast and glue to seal the site of bleeding and to occlude the parent vessel distally as well as proximally. Figure 4 illustrates the use of NBCA glue to embolize a Dieulafoy lesion. In this case the glue was diluted with Ethiodol in a 1:3 ratio to achieve embolization of small vessels feeding the lesion.

NBCA is fast and permanent, and the degree of emboliza-

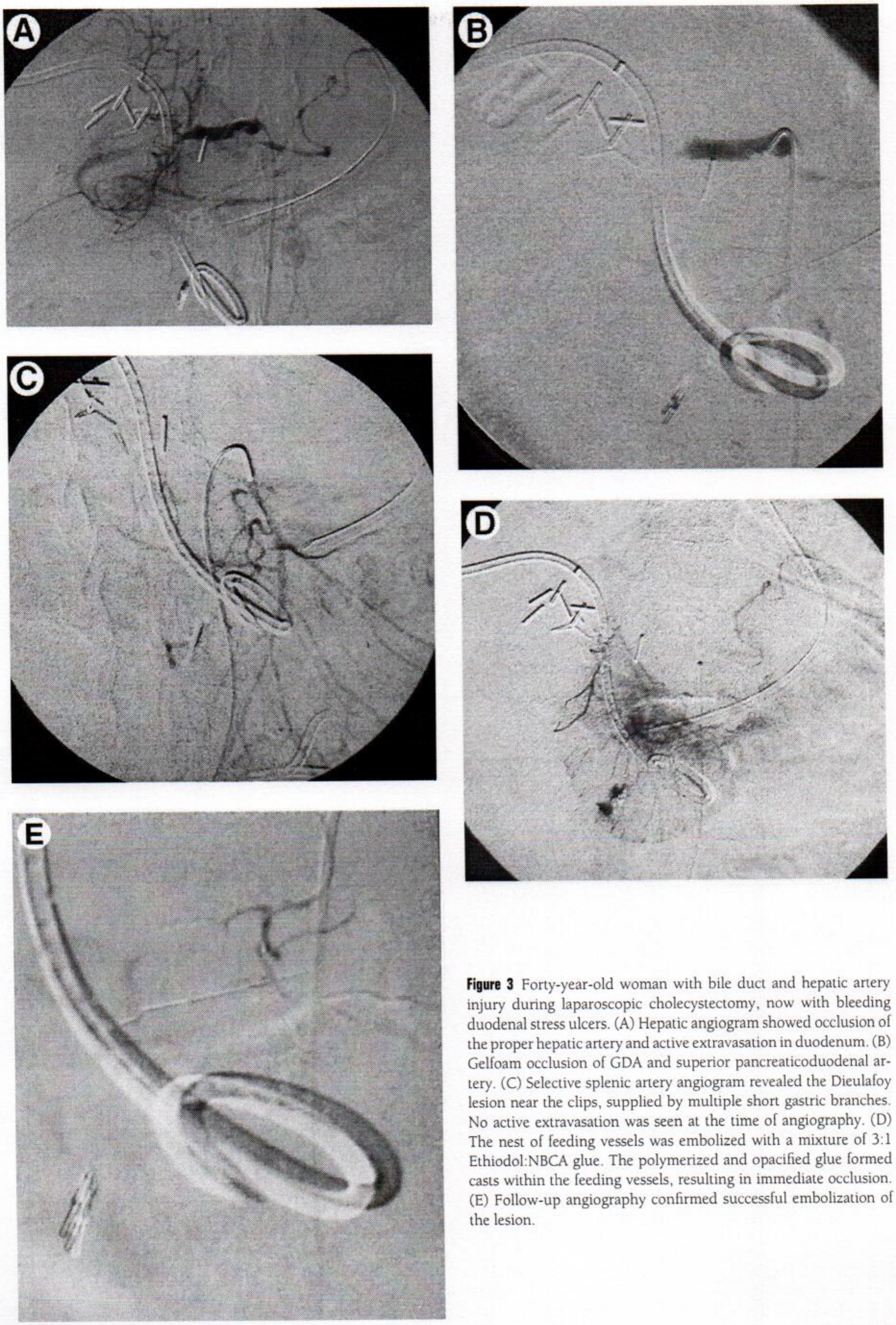

Figure 3 Forty-year-old woman with bile duct and hepatic artery injury during laparoscopic cholecystectomy, now with bleeding duodenal stress ulcers. (A) Hepatic angiogram showed occlusion of the proper hepatic artery and active extravasation in duodenum. (B) Gelfoam occlusion of GDA and superior pancreaticoduodenal artery. (C) Selective splenic artery angiogram revealed the Dieulafoy lesion near the clips, supplied by multiple short gastric branches. No active extravasation was seen at the time of angiography. (D) The nest of feeding vessels was embolized with a mixture of 3:1 Ethiodol:NBCA glue. The polymerized and opacified glue formed casts within the feeding vessels, resulting in immediate occlusion. (E) Follow-up angiography confirmed successful embolization of the lesion.

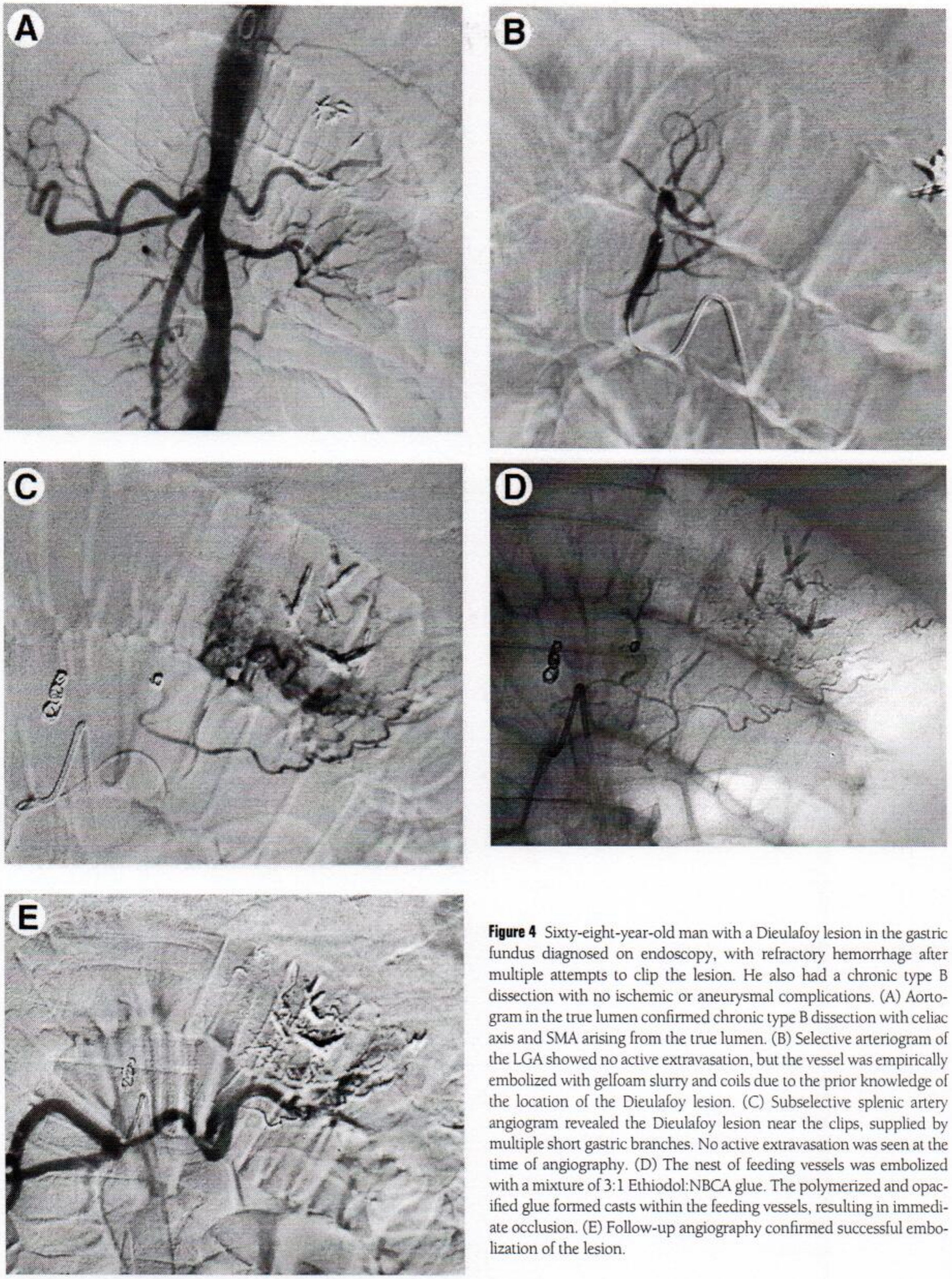

Figure 4 Sixty-eight-year-old man with a Dieulafoy lesion in the gastric fundus diagnosed on endoscopy, with refractory hemorrhage after multiple attempts to clip the lesion. He also had a chronic type B dissection with no ischemic or aneurysmal complications. (A) Aortogram in the true lumen confirmed chronic type B dissection with celiac axis and SMA arising from the true lumen. (B) Selective arteriogram of the LGA showed no active extravasation, but the vessel was empirically embolized with gelfoam slurry and coils due to the prior knowledge of the location of the Dieulafoy lesion. (C) Subselective splenic artery angiogram revealed the Dieulafoy lesion near the clips, supplied by multiple short gastric branches. No active extravasation was seen at the time of angiography. (D) The nest of feeding vessels was embolized with a mixture of 3:1 Ethiodol:NBCA glue. The polymerized and opacified glue formed casts within the feeding vessels, resulting in immediate occlusion. (E) Follow-up angiography confirmed successful embolization of the lesion.

tion can be controlled by titrating the viscosity of the mixture. Reflux of glue can result in nontarget embolization, and even a small amount of glue can cause complete occlusion of a nontargeted vessel. The delivery catheter can also become adhered to the walls of a vessel, making its removal difficult or impossible. For these reasons NBCA glue is best reserved for difficult situations and should be used by physicians with adequate training and experience.

Discussion

Despite improvements in medical therapy for peptic ulcer disease, acute nonvariceal UGIB remains a significant medical problem with an incidence of 1 in 100,000 and a high mortality rate of up to 25%.[9-10] Although endoscopy remains the first line approach to diagnosis and therapy, catheter-directed embolization has been shown to be successful in achieving hemostasis and, most importantly, improving survival.[7,11-12] In one large series of 178 patients who underwent embolotherapy for UGIB, mortality was decreased sixfold from 68% in patients in whom technical success was not achieved to 11% for patients who were successfully embolized.[11] As expected, patients with acute, reversible illnesses such as trauma fared best, and chronically ill, coagulopathic patients showed less dramatic advantage. However, embolization can even be effective in coagulopathic patients, where technical and clinical success can be achieved in 43 to 46% of patients.[6,11] Furthermore, transcatheter embolization has been shown to be equally effective as surgery in the treatment of UGIB. Despite an older patient cohort with more comorbidities, embolotherapy resulted in similar rates of mortality and clinical failure (rebleeding) when compared with surgery for the treatment of UGIB from peptic ulcer disease.[13] As is true of most other minimally invasive and image-guided interventions, embolotherapy has supplanted surgery in most communities as the treatment of choice for endoscopy-refractory UGIB.

Conclusions

The past three decades have seen enormous advances in endovascular device development and treatment of a wide variety of hemorrhagic conditions. The safety and efficacy of transcatheter embolization for the treatment of life-threatening UGIB is now widely accepted and is considered the gold standard for endoscopy-refractory patients. Embolization may be effective for even the most gravely ill patients for whom surgery is not a viable option.

References

1. Huang C, Lichtenstein DR: Nonvariceal upper gastrointestinal bleeding. Gastroenterol Clin North Am 32:1053-1078, 2003
2. Rollhauser C, Fleischer DE: Nonvariceal upper gastrointestinal bleeding. Endoscopy 36:52-58, 2004
3. Schoenberg MH: Surgical therapy for peptic ulcer and nonvariceal bleeding. Langenbbecks Arch Surg 386:98-103, 2001
4. Rosch J, Dotter CT, Brown MJ: Selective arterial embolization. A new method for control of acute gastrointestinal bleeding. Radiology 102: 303-306, 1972
5. Funaki B: Endovascular intervention for the treatment of acute arterial gastrointestinal hemorrhage. Gastroenterol Clin 31:701-713, 2002
6. Encarnacion CE, Kadir S, Beam CA, et al: Gastrointestinal bleeding: treatment with arterial embolization. Radiology 183:505-508, 1992
7. Lang EV, Picus D, Marx VM, et al: Massive arterial hemorrhage from the stomach and lower esophagus: impact of embolotherapy on survival. Radiology 177:249-252, 1990
8. Kadir S: Normal and Variant Angiographic Anatomy. Philadelphia: WB Saunders, 1991
9. Rockall TA, Logan RFA, Devlin HB, et al: Incidence of and mortality from acute upper gastrointestinal haemorrhage in the United Kingdom. BMJ 311:222-226, 1995
10. Rockall TA: Management and outcome of patients undergoing surgery after acute upper gastrointestinal haemorrhage: steering group for the National Audit of Acute Upper Gastrointestinal Haemorrhage. J R Soc Med 91:518-523, 1991
11. Schenker MP, Duszak R, Soulen M, et al: Upper gastrointestinal hemorrhage and transcatheter embolotherapy: clinical and technical factors impacting success and survival. J Vasc Interv Radiol 12:1263-1271, 2001
12. Aina R, Oliva V, Therasse E, et al: Arterial embolotherapy for upper gastrointestinal hemorrhage: outcome assessment. J Vasc Interv Radiol 12:195-200, 2001
13. Ripoll C, Banares R, Beceiro I, et al: Comparison of transcatheter arterial embolization and surgery for treatment of bleeding peptic ulcer after endoscopic treatment failure. J Vasc Interv Radiol 15: 447-450, 2004