Arterial Interventions in Gastrointestinal Bleeding

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ABSTRACT

The diagnosis and management of gastrointestinal (GI) bleeding are complicated. A multitude of pathologic processes results in GI bleeding, and often, the bleeding is intermittent in nature. Of the available diagnostic tools, angiography has been the gold standard. Management of patients requires a multidisciplinary approach involving gastroenterologists, interventional radiologists, and surgeons. Therapeutic arterial interventions include pharmacologic control with the use of intraarterial vasopressin, embolization with temporary and permanent embolizing materials, and catheter-induced vasospasm.

KEYWORDS: GI bleeding, angiography, interventions, embolization

Objectives: Upon completion of this article, the reader should be able to explain (1) the etiology of GI bleeding, (2) the current role of angiography and percutaneous interventions in the management of GI bleeding, and (3) common endovascular therapeutic approaches for GI bleeding.

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Acute gastrointestinal (GI) bleeding contributes significantly to patient morbidity and mortality. The diagnosis and management of GI bleeding is complicated as a multitude of pathologic processes result in GI bleeding, and often the bleeding is intermittent in nature. In addition, there are multiple imaging modalities and therapeutic interventions that are currently used in the evaluation and treatment of acute GI hemorrhage. Angiography has been an essential tool in the diagnosis and treatment of GI hemorrhage.¹ It is interesting to note that the origin of interventional radiology can be traced back to the technique of using vasoconstricting drugs administered through the same catheter as the one

used for diagnostic arteriography.² We discuss the common etiologies, the role of imaging in the diagnosis of GI bleeding and the role of arterial interventions in its management.

EPIDEMIOLOGY

The incidence of upper GI bleeding is ~100 cases per 100,000 persons per year.³ Bleeding from the upper GI tract is ~4 times as common as bleeding from the lower GI tract and is a major cause of morbidity and mortality.³ Mortality rates from upper GI bleeding range from 6 to 10%.³

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Two large population-based studies have reported the incidence of lower GI bleeding. Vernava et al reviewed the Department of Veterans Affairs' databases for a 4-year period and found that less than 1% of 5.1 million hospital admissions were for lower GI hemorrhage.⁴ The other study was a review of the Kaiser Permanente database, which estimated an annual incidence of 20.5 patients per 100,000 (24.2 in males versus 17.2 in females).⁴ The rate of lower GI bleeding increased more than 200-fold from the third to the ninth decades of life.⁴

Anatomy Relevant to Gastrointestinal Bleeding

The first two branches of the abdominal aorta, namely the celiac axis and the superior mesenteric artery (SMA) provide a rich and well-collateralized network of branch vessels that supply blood to the upper GI tract. This collateralization protects the upper GI tract from ischemic insult and permits surgical and embolization procedures to be performed with a relatively low risk of ischemic injury. Similarly, the SMA and the inferior mesenteric artery (IMA) form a series of interconnected arcades that provide a collateralized supply throughout the lower GI tract.⁵ However, such a rich collateral pathway may decrease the efficacy of super-selective embolization due to collateral flow to the bleeding site.

DIAGNOSIS

A multidisciplinary approach, including a team consisting of a gastroenterologist, radiologist, and surgeon, is the key in the diagnosis and treatment of GI bleeding, particularly in high-risk patients.⁶ The causes of GI bleeding are listed in Table 1.

ENDOSCOPY

Upper GI endoscopy and colonoscopy are currently considered the first-line diagnostic and therapeutic procedures of choice for both upper and lower GI bleeding. They are relatively safe and allow for direct localization and characterization of the bleeding lesions within the majority of the GI tract, except for the small bowel. In addition, endoscopy provides many therapeutic options for controlling GI bleeding. Its role in the diagnosis and treatment of esophageal varices is established; however, accessing the small bowel distal to the duodenum is a major drawback.⁵

RADIONUCLIDE SCINTIGRAPHY

Noninvasive imaging with a technetium-99m- (Tc-99m-) labeled red blood cell (RBC) scan or Tc-99m sulfur colloid scintigraphy can be used to detect and localize GI bleeding. Tc-99m RBC scintigraphy is 93%

Table 1 Causes of Gastrointestinal (GI) Bleeding

Upper GI bleeding
Gastric ulcer
Duodenal ulcer
Esophageal varices
Gastric varices
Mallory-Weiss tear
Esophagitis
Esophageal/gastric neoplasm
Hemorrhagic gastritis
Angiodysplasia
Hemobilia
Pancreatic pseudocyst
Pancreatic pseudoaneurysm
Aortoenteric fistula
Lower GI bleeding
Diverticular disease
Diverticulosis/diverticulitis of colon
Diverticulosis/diverticulitis of small bowel
Inflammatory bowel disease
Ulcerative colitis
Crohn's disease of small bowel and/or colon
Noninfectious gastroenteritis and colitis
Benign anorectal disease
Hemorrhoids
Anal fissure
Fistula in ano
Neoplasia
Malignant neoplasia of colon, rectum, anus
Malignant neoplasia of small bowel
Coagulopathy
Arteriovenous malformation

sensitive and 95% specific for detecting a bleeding site.⁷ This technique allows detection of GI bleeding even when the bleeding rates are as low as 0.04 mL/min. In the setting of intermittent GI bleeding, delayed imaging with Tc-99m-labeled RBC scan can be very useful. However, the precise anatomic localization of the bleeding site is not possible due to the limited resolution of scintigraphy.⁷

COMPUTED TOMOGRAPHY ANGIOGRAPHY

Contrast-enhanced multidetector row helical computed tomography (MDCT) scanning has established itself as a "one-stop shop" for rapid noninvasive and accurate diagnostic method in suspected acute GI bleeding.⁸ Yoon et al conducted a four-detector row CT angiographic study of 26 consecutive patients with significant GI bleeding that resulted in either systemic hypotension (systolic blood pressure <90 mm Hg) or a transfusion requirement of at least four units of packed red cells in a

24-hour period. Their study demonstrated an overall location-based sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for CT angiography in the detection and localization of GI bleeding of 90.9%, 99%, 97.6%, 95%, and 98%, respectively. Angiography was deferred when active bleeding was not depicted on the CT examination, except in cases when the patient was unstable from massive hemorrhage.⁹

ANGIOGRAPHY

Angiography has been the gold standard test for detection of acute life threatening GI hemorrhage. Selective catheter angiography allows detection of GI bleeding when the bleeding rate is as low as 0.5 mL/min.¹⁰ However, the intermittent nature of bleeding in some patients can result in a false-negative angiographic study. Provocative angiography complements conventional angiography for detection of acute lower GI bleed.¹¹ Interventional techniques—with the use of indwelling arterial catheters, anticoagulants, vasodilators, and fibrinolytic agents—prolong, augment, or reactivate the bleeding and thus increase the diagnostic efficacy of angiography.¹²

MANAGEMENT

Arterial Interventions in Lower Gastrointestinal Bleeding

Embolotherapy in GI hemorrhage dates back to 1974 when Bookstein used an autogenous clot formed on oxidized cellulose to arrest lower GI hemorrhage in three patients.¹³ The first coil embolization for GI hemorrhage was described by Gianturco in 1975.¹⁴ In 1977, Goldberger and Bookstein described transcatheter embolization for acute diverticular hemorrhage as an alternative to surgery.¹⁵ Since then, arterial interventions in GI bleeding have significantly improved due to the advances in catheter technology and embolic materials and have resulted in fewer complications.¹⁶

There are three transcatheter options for the control of lower GI bleeding. These are (1) pharmacologic control with use of vasopressin, (2) embolization, and (3) catheter-induced vasospasm.

PHARMACOLOGIC CONTROL WITH USE OF VASOPRESSIN

Rösch et al described super-selective visceral arteriography for infusion of vasoconstrictors in 1971¹⁷ and super-selective embolization of the mesenteric vessels as an alternative technique to treat massive lower GI bleeding in 1972.¹⁸ Their initial experience with vasopressin infusion was reported in 1972.¹⁹ The preferential use of transcatheter embolotherapy to transcatheter vasopressin infusion is still a matter of debate and further studies are needed for a definitive conclusion.²⁰

Technique In general, the devices needed for vasopressin infusion are cheaper and less complex than those used for embolization. In this technique, the SMA or IMA is catheterized and vasopressin is infused through the catheter.²⁰ Typical vasopressin therapy involves an initial 20-minute infusion at a rate of 0.2 U/min followed by repeated arteriography to determine whether bleeding has stopped and that the artery is not over-constricted.^{21,22} The infusion rate can be incrementally increased to 0.3 U/min and then to 0.4 U/min, if bleeding continues. Each change in infusion rate must be followed by a waiting period (20 minutes) for the increased drug dose to take effect and then another arteriogram to assess the effect. The infusion is continued for another 12 to 24 hours. The vasopressin infusion is then replaced with a saline solution infusion for 6 to 12 hours.²³ The catheter is then removed if there are no clinical signs of bleeding but, by this time, the average time the catheter is in situ is 1–2 days. Unlike embolotherapy, the ability to stop bleeding relies on patient factors such as atherosclerosis and coagulopathy. Atherosclerotic arteries do not constrict in response to vasopressin, which may result in inadequate hemostasis or recurrence.¹⁹

Results Transcatheter vasopressin infusion has been used extensively and may achieve hemostasis in 60 to 90% of patients.²⁴ Vasopressin infusion is particularly useful when applied to lower GI hemorrhage (Fig. 1). Its success rate in the control of upper GI bleeding is still as low as 15 to 31% of pyloroduodenal bleeding.^{23,24} The

Figure 1 Superselective injection into the ileocolic artery reveals active extravasation (arrow) of contrast material from a peripheral branch. Accessing this vessel is difficult, and vasopressin infusion is an ideal option.

rate of recurrent GI bleeding on discontinuation of vasopressin therapy is as high as 71%.²⁴ Thus, vasopressin may be used as a temporary measure to stop acute bleeding prior to surgery.

In addition, the ability to maintain the catheter in the proper position is an important element of the overall outcome. Kadir and Athanasoulis reported 10 cases among 525 patients (2%) in which catheter dislodgment led to recurrent bleeding.²⁵

Complications Vasopressin therapy was associated with major complications in 0 to 21% of cases and, in as many as 9%, the results were fatal.^{26–28} Prolonged presence of the catheter or catheter motion can lead to thrombosis^{26,29} or dissection²⁷ of the artery undergoing

infusion. Dislodgement of the catheter into another nontarget artery, such as the renal artery can cause flank pain and hematuria. Similarly, dislodgment of the catheter into the phrenic artery can lead to chest pain and arrhythmias.²⁵ Other systemic complications due to vasopressin infusion include arrhythmias (bradycardia or ventricular tachycardia), hypotension, angina, and cardiac arrest. Some of these systemic complications may be decreased by adding an intravenous nitroglycerin infusion. Other regional complications of vasopressin infusion include mesenteric artery thrombosis, bowel infarction, and spontaneous bacterial peritonitis. Minor complications related to arterial access include hematoma, pseudoaneurysm, arterial spasm, and infection.

Figure 2 (A) Superior mesenteric arteriogram shows active bleeding (arrow) from a branch of the ileocolic artery. (B) Superselective injection into ileocolic artery confirms the bleeding site (arrow). (C) Postembolization angiogram shows no more active extravasation. Embolization was performed with polyvinyl alcohol (PVA) 500–700 μ particles.

EMBOLIZATION

Embolization is defined as the deliberate occlusion of vessels for a therapeutic purpose. Various embolic materials have been used for this purpose. The choice of embolic material depends on many factors including the size of the vessel being occluded, the level of vascular occlusion desired, and whether the occlusion is temporary or permanent.

Embolization agents can be classified into temporary embolics (such as Gelfoam[®]; Pfizer Pharmaceuticals, New York, NY) and permanent embolics, which may be either solid or liquid. Solid permanent embolic materials include polyvinyl alcohol (PVA), tris-acryl gelatin microspheres (Embospheres[®]; Biosphere Medical, Inc., Rockland, MA), detachable fiber coils, platinum coils, and detachable balloons. Liquid embolic

Figure 3 (A) Superior mesenteric arteriogram reveals active bleeding (arrow) from the ileocolic artery. (B) The bleeding vessel was super-selectively cannulated with a microcatheter. (C) Postembolization angiogram reveals no more active contrast extravasation. The bleeding vessel was embolized with polyvinyl alcohol (PVA) 500–700 μ particles.

materials include absolute alcohol, *N*-butyl cyanoacrylate (NBCA), and Onyx[®] (an ethylene vinyl alcohol copolymer; Ev3 Endovascular, Inc. Plymouth, MN).

Microcoils (complex helical fibered platinum coils) range from 2 to 12 mm in diameter and are available in various lengths. These coils are highly radiopaque and can be precisely deployed. Once deployed in a distal artery, they decrease the perfusion pressure allowing thrombosis of the bleeding vessel. However, the collateral flow prevents bowel infarction. Coils are easy to use and pose a lesser threat of ischemia than PVA particles, which may disseminate to the smaller vessels. Recent literature supports the use of microcoils as the embolic agents of choice.³⁰ Among the variety of embolic agents, coils are usually preferred for embolization of pseudoaneurysms.

NBCA is an effective, rapid, and safe embolic material, which may be lifesaving in emergent situations.³¹ *N*-butyl cyanoacrylate has several advantages. It

allows for rapid and permanent embolization due to its fast polymerization when it comes in contact with blood. A single injection may provide complete hemostasis through simultaneous embolization of collateral vessels connected to the bleeding focus. It is useful in patients with coagulopathy as the vessel occlusion is independent of the coagulation process.

Polyvinyl alcohol and Gelfoam[®] are commonly used (Figs. 2–4). There are certain disadvantages. Both agents are more difficult to control than microcoils because neither can be seen during fluoroscopy. An additional disadvantage of polyvinyl alcohol particles is that the particles may reach intramural circulation beyond the level of collateralization leading to bowel infarction or may reflux into nontarget arteries.³²

Technique CT angiography has a crucial role in preprocedure evaluation of a patient with GI bleeding, as it provides clinically relevant information about the

Figure 4 (A) Delayed phase contrast-enhanced computed tomography (CT) scan of the abdomen shows active contrast material extravasation (arrow) into a jejunal loop consistent with active gastrointestinal bleeding. (B) Superior mesenteric arteriogram shows active extravasation (arrow) of contrast material from a branch supplying the jejunum. (C) The bleeding vessel was selectively catheterized. (D) The bleeding vessel was embolized with polyvinyl alcohol (PVA) 500–700 μ particles. Postembolization angiogram shows no more active contrast extravasation.

anatomic variation of the mesenteric vessels, the site of active GI bleeding, and the vascular supply to the bleeding site. This information allows faster catheterization of the bleeding vessels, and helps decrease the number of digital subtraction angiographic exposures, the amount of contrast material used during angiography, and the procedure times. It may also reduce radiation exposure to the patient and the operator in the

angiography suite. CT angiography may also provide etiology of the GI bleeding in many cases, thus helping triage patients to surgery, embolotherapy, or conservative management.⁵

Careful attention to the hemodynamic status of the patient is of utmost importance in the management of GI bleeding. Oxygen saturation, blood pressure, and heart rate and rhythm are continuously monitored.

Figure 5 A 44-year-old man presented with upper gastrointestinal bleed. (A) Common hepatic arteriogram reveals a tumor blush (arrow) supplied by the gastroduodenal artery. (B) Selective superior pancreaticoduodenal arteriogram confirms tumor vascularity (arrow). (C) Postembolization angiogram following embolization with 300–500 μ polyvinyl alcohol (PVA) particles, shows complete absence of tumor blush. (D) Intraoperative image shows a pedunculated tumor arising from the duodenum.

Figure 6 (A) Left gastric angiography reveals vascular blush in the fundus of the stomach. No active bleeding noted. (B) The artery was embolized with 500–700 μ polyvinyl alcohol (PVA) particles.

Intravenous glucagon (1 mg) or scopolamine butyl bromide (Buscopan[®]; Boehringer Ingelheim, Ingelheim, Germany—not approved by the U.S. Food and Drug Administration [FDA]) is administered at the discretion of the radiologist to decrease bowel peristalsis.³³ In our experience, general anesthesia is highly useful during angiography as it not only provides better hemodynamic control, but also effectively reduces motion artifacts (from breathing and bowel peristalsis) during digital subtraction angiography.

Flush aortogram is rarely performed. Selective injections into the celiac axis, SMA, and IMA are routinely obtained. It is important to cover the entire

abdomen during injections into the SMA and the IMA. Once the bleeding source is localized angiographically, a 3-French microcatheter is advanced coaxially to the bleeding site through the indwelling 4- or 5-French catheter. Attempts are made to position the catheter as close to the bleeding site as possible. In the IMA distribution, the catheter is advanced to the marginal artery or the terminal artery if possible. In the SMA, the catheter is advanced to the vasa recta. If spasm occurs, intraarterial papaverine (25 mg) may be administered. Embolization is performed only when the catheter can be advanced to or distal to the mesenteric border of the colon. Embolization is performed until no further

Figure 7 (A) Selective gastroduodenal arteriography revealed a pseudoaneurysm (arrow) arising from the superior pancreaticoduodenal artery. (B) The pseudoaneurysm was successfully treated with coil embolization of the artery (arrow).

Figure 8 (A) Delayed image of proper hepatic arteriogram shows a large pseudoaneurysm arising from the gastroduodenal artery. (B) The aneurysm was treated with coil embolization of the aneurysm and feeding artery. Coil migration was noted during the procedure. However, patient had an uneventful recovery.

arterial extravasation is seen. Technical success is defined as cessation of bleeding as seen on angiography. Clinical success is defined as cessation of bleeding without further surgical or endoscopic intervention.³³

During the procedure, NBCA is mixed with iodized oil in ratios varying from 1:1 to 1:3³⁴ and the microcatheter must be flushed with 5% dextrose solution prior to injection to prevent premature polymerization of NBCA within the catheter. Injection is stopped when extravasation of the mixture occurs from the bleeding site or when an underlying pseudoaneurysm is completely opacified.

In general, coils are preferred for embolization of pseudoaneurysm as they allow precise placement. However, it is often difficult to selectively place the catheter close to and beyond the pseudoaneurysm in small or tortuous vessels.³⁵ Furthermore, when there are multiple efferent arteries from the pseudoaneurysm, or when multiple collaterals from adjacent arteries feed the aneurysm, embolization with coils may be time-consuming and technically difficult. Although catheterization may be possible, it may be difficult to deliver the coils because of the tortuosity of the vessels.³⁵ In such instances, NBCA can be a good choice due to its low viscosity.

When a bleeding vessel is inaccessible for selective catheterization, embolotherapy may be abandoned and vasopressin infusion may be undertaken for control of GI bleeding. Embolotherapy is not suitable in patients with "surgical lesions" such as tumors and diverticula. In such patients, selective catheterization of the bleeding vessel may help the surgeon identify the segment quickly during surgical exploration.

Results In contrast to older techniques, which had a reported recurrence rate of 11%,^{32,36–38} present studies

based on super-selective techniques reveal a recurrence rate of nearly 19%.^{33,39–42} This may be due to increased collateral perfusion or recanalization of the embolized artery. In some cases the "rebleeding" was also seen to originate from a new source. The overall rate of recurrent bleeding is lower with embolotherapy than with vasopressin infusion.²⁰

Complications Major ischemic complications may occur with embolization procedures. These include bowel infarction and gangrene. Other complications include arterial dissections and nontarget embolization due to migration of the embolic materials. Transcatheter embolization with NBCA has the potential risk of embolization of the proximal segment without adequate embolization at the bleeding site due to rapid polymerization. In addition, distal embolization of the nontargeted sites may occur due to too rapid injection of the NBCA mixture or an excessively prolonged polymerization time and reflux of NBCA into another nontarget vessel due to overinjection.⁴³ In general, embolization is safer than vasopressin infusion as it has lower access site complications due to the shorter catheter dwell times, and absence of systemic vasoconstrictive effects associated with vasopressin infusion.

CATHETER-INDUCED VASOSPASM

This technique has been shown to be effective in adequately controlling a bleeding site by temporary occlusion of the vessel due to vasospasm. The decrease in blood flow and pulse pressure caused by vasospasm would allow normal physiologic thrombosis of the bleeding site. In time, the spasm would resolve, thereby allowing restoration of the blood flow and keeping the risk of intestinal ischemia or infarction to a minimum.

Repeat angiography may help confirm the transient nature of the vasospasm and its effectiveness in controlling the GI bleeding.

This technique may be employed as primary therapy in patients who cannot tolerate vasopressin or when embolotherapy is difficult or not feasible. This technique is associated with less intestinal ischemia than that found with embolization. In addition, vasodilators can be given to reverse the vasospasm, if there is concern of prolonged bowel ischemia during the procedure.

Disadvantages of this technique are the need for super-selective catheterization (as in embolotherapy) and the theoretic risk of recurrent bleeding due to its temporary action.⁴⁴

Arterial Interventions in Upper Gastrointestinal Bleeding

Arterial interventions have been used to control major nonvariceal upper GI hemorrhage. The method is usually considered when conservative medical management and

Figure 9 A 50-year-old man with pancreatitis presented with gastrointestinal (GI) bleeding. (A) Superior mesenteric arteriogram reveals a pseudoaneurysm from a jejunal branch, which was successfully treated with coils (B). (C) Another pseudoaneurysm in a branch of the right hepatic artery is also treated with coils (D).

endoscopic therapy have failed because the mortality rate after urgent surgery for gastroduodenal bleeding varies between 17 and 43%.⁴⁵⁻⁴⁷ Although arterial infusion of vasopressin has been used with success in these situations,^{27,28} embolic therapy usually allows earlier and more durable control of GI hemorrhage, which can be achieved, in 52 to 90% of cases.^{29,48-51} Embolic therapy may also be performed in acutely bleeding surgical lesions (such as tumors and diverticulae) to temporarily stop bleeding (Fig. 5). In patients with endoscopy-proven nonvariceal gastric bleeding, embolization of the left gastric artery is often practiced even no active extravasation is found on angiography (Fig. 6). Embolization of active bleeding or pseudoaneurysm from branches of the gastroduodenal artery may be achieved with particles or coils (Figs. 7, 8). Pseudoaneurysms secondary to pancreatitis may result in upper or lower GI bleeding depending on the location of the aneurysm. These can be successfully embolized with coils (Fig. 9). Variceal bleeding is treated with transjugular intrahepatic portosystemic shunt (TIPS) and retrograde embolization of the varices and it is beyond the scope of this article.

Dieulafoy lesion is an uncommon cause of massive GI hemorrhage, in which bleeding occurs through a mucosal erosion from an abnormally dilated submucosal artery. Dieulafoy lesion is usually located in the stomach, although it may occur anywhere in the GI tract.⁵² Both endoscopy and angiography have been used for the diagnosis of a Dieulafoy lesion.^{53,54} Transcatheter arterial embolization has been reported for gastric Dieulafoy lesions, with variable results.^{55,56}

Portal vein thrombosis may have either an acute presentation like variceal hemorrhage and ascites or, a chronic course with late variceal bleeding. Partial splenic embolization is effective at reducing variceal bleeding regardless of the underlying cause of the portal hypertension. Recent portal vein thrombosis may recanalize with systemic anticoagulation in 80% of patients.⁵⁷ Transsplenic recanalization of the portal vein has been described in children. Splenic arterial embolization can be performed before the transsplenic procedure to reduce splenic vein flow and prevent bleeding.⁵⁸ Similarly, isolated gastric varices secondary to splenic vein thrombosis may be treated with splenic embolization or splenectomy.

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