Chapter 10
Bipolar and Monopolar Cautery, Clips, Bands, Spray, Injections, Embolization, and Minimally Invasive Surgery

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Introduction

Upon diagnosis of an occult GI bleed through iron deficiency anemia with or without a positive fecal occult blood test, the first step in management of occult GI bleeding is to stabilize the patient. Treatment of underlying anemia should be initiated. A careful review of the patient's medical and surgical history may help localize bleeding to the upper GI tract (esophagus to the ligament of Treitz) or lower GI tract (ligament of Treitz to the rectum) and identify any contributing underlying disease, such as portal hypertension, peptic ulcer disease/gastritis, malignancy, arteriovenous malformation/angiodysplasia, or recent surgery/intervention. In the appropriate clinical context, pharmacotherapy (proton pump inhibitors, somatostatin, etc.) may temporize active bleeding. Once the patient is stable, a variety of treatment options may be considered—including therapeutic endoscopic modalities,

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interventional radiology, and surgery. While the book's main focus is on occult GI bleeding, in order to review the principles of endoscopy, interventional radiology, and surgical treatment, there will be some degree of overlap with overt GI bleeding. Sometimes, overt bleeds can be intermittent, recurrent, and go unnoticed, and result in iron deficiency anemia and heme positive stool.

Therapeutic Endoscopic Modalities

Endoscopy is a safe and effective method for treating GI bleeds [1]. Endoscopic hemostatic methods for GI bleeding include thermal, mechanical, topical and injection therapies (Table 10.1). An overview of the treatment modalities follows, along with the effectiveness of each method.

Table 10.1 Summary of therapeutic endoscopic modalities and the lesions they are used to treat

Modality	Type	Use
Thermal	Bipolar and Monopolar Probes (ex, Gold Probe, HeatProbe, and Coagrasper)	Bipolar probes (ex. Gold Probe) are recommended as treatment for hemorrhaging ulcers and nonbleeding visible vessels. HeatProbes are used to treat peptic ulcers in the upper two thirds of the posterior wall of the lesser curvature of the corpus of the stomach and the posterior wall of the duodenal bulb. Monopolar probes (ex. Coagrasper) are effective in treating non-variceal bleeding and managing gastroduodenal ulcer bleeding
	Argon Plasma Coagulation	Recommended for use when treating AVMs, gastric antral vascular ectasias, and CRP
Mechanical	Through the Scope Clips (Endoclips)	Useful in managing non-variceal type bleeding such as Mallory-Weiss tears, Dieulafoy's lesions, diverticular bleeding, bleeding peptic ulcers, postpolyectomy bleeding, and perforations and fistulas
	Over the Scope Clips	Should be used in patients with recurrent bleeding when other therapies have not worked. Typically used to promote hemostasis of perforations and fistulas
	Band Ligation	Primarily recommended as a first treatment variceal bleeding. EBL has been shown to be effective in managing esophageal and duodenal Dieulafoy lesions, and Mallory Weiss tears
Topical	Procoagulant Spray (Hemospray)	Recommended for management of tumoral GI bleeds. Usually used as a second-line intervention when patients experience unsuccessful long-term hemostasis with the standard therapies such as in the case of unresectable cancers. Also, used in combination with thermal therapy for peptic ulcer treatment
Injection	Epinephrine	Should not be used as a monotherapy. Is recommended for use in combination therapy with thermal or mechanical therapy
	Glue (ECGI)	Useful in managing gastric varices
	Sclerosing Agents	Useful in treatment of esophageal varices (obsolete in the United States)

Thermal Therapy

Thermal or thermal coagulation therapy is a technique endoscopists utilize to promote hemostasis through cauterization of the bleeding site, resulting in coagulation of the lesion. Thermal therapy can be further categorized into contact and noncontact techniques.

Contact thermal therapy is performed through direct tissue contact with the cauterizing device. Through direct tissue contact, the device compresses the bleeding site while simultaneously cauterizing the tissue in a process called coaptive coagulation. Cauterizing devices can be further subdivided into bipolar probe (ex. Gold Probe), heater probe (ex. HeatProbe), and monopolar probe (ex. Coagrasper). These devices are especially useful in treating active hemorrhages and nonvisible vessels such as those underlying peptic ulcers.

Bipolar probes generate heat from electrical currents that pass through electrodes; the heat is transferred onto the bleeding tissue through contact (Fig. 10.1). The electrical current must be transferred to the tissue at an angle or perpendicular to the bleeding site to achieve desiccation. The current will automatically stop flowing when it reaches a specified temperature in the tissue. This makes administering thermal therapy easier and more straightforward. An inherent limitation of the probe does not allow for deep tissue penetration; this eliminates the possibility of this device causing perforation of the underlying tissue and increased rates of rebleeding [2]. Thermal therapy works by facilitating tissue damage; therefore, multiple rounds of this therapy to the same bleeding site is not recommended. Additional limitations of the bipolar probe include its dependence on the inherent tissue properties such as tissue water, resistance, or desiccation. Device properties and settings can be altered depending on the lesion that is being treated [3]. Bipolar probes are specifically recommended to manage hemorrhaging ulcers and nonbleeding visible vessels [4].

Heater probes are yet another type of contact diathermy. Although they have similar efficacy to bipolar probes, they are more difficult to use because they require perpendicular application of heat. Furthermore, the design and heating technology of the device make it easier to cause deep tissue coagulation [5]. Therefore, heater probes require experienced endoscopists to minimize the risk of perforation. When used properly, heater probes efficiently achieve hemostasis of peptic ulcers. A study

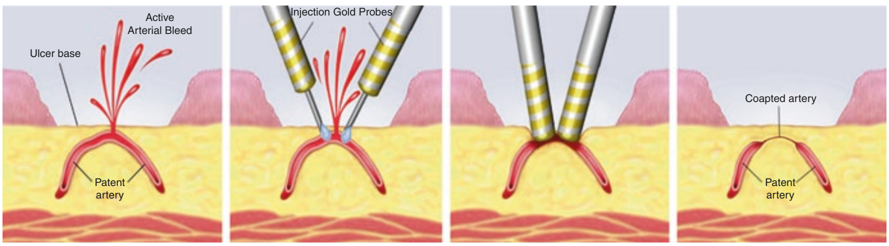

Fig. 10.1 Bipolar thermal hemostasis via Injection Gold Probe™. Copyright Boston Scientific Corporation. Courtesy of Boston Scientific

that compared the efficacy of heater probes and hemoclips (a form of mechanical therapy) found that heater probes are more successful in halting peptic ulcer bleeding in the upper two thirds of the posterior wall of the lesser curvature of the corpus of the stomach and the posterior wall of the duodenal bulb – areas that are hard reach with mechanical therapy [5].

Monopolar probes are another method of performing contact thermal therapy. Like bipolar probes, they promote coagulation through cauterization via an electric current. However, due to their one-electrode device nature, monopolar probes require grounding pads. Furthermore, the technique required to deliver the current to the bleeding site also differs from the bipolar probe technique. For monopolar probes, either the edges of the bleeding site are tautly pulled away from the GI wall and then cauterized or the probe is lightly touched to the center of the stigmata. Monopolar probes have been shown to be effective in treating non-variceal bleeding. Some disadvantages to monopolar probes include that the device has no inherent limitation on the current transferred to the bleeding site. This increases the chances of deep tissue penetration and formation of GI perforations [6]. It is important that endoscopists using this thermal modality have proper training in administering treatment. New monopolar hemostatic forceps, Coagrasper, attempt to address this limitation by maintaining the voltage at a constant level to decrease the chance of deep tissue coagulation and promoting soft coagulation. Although studies are limited, there have been promising outcomes with the use of these new devices in effectively managing gastroduodenal ulcer bleeding [7]. Small comparative studies have preliminarily shown that the Coagrasper is more effective than the heater probe and hemoclips in achieving primary hemostasis with less adverse effects and lower rebleeding rates [7, 8].

Noncontact thermal therapy is performed through indirect tissue contact with the cauterizing device. This technology is used in the Argon Plasma Coagulation (APC) device. APC stimulates hemostasis with an electrical current generated from ionizing argon gas. The ionization energy is then dispersed into the nearby tissue, making this therapy less precise and able to cover large areas. Depending on the clinical situation, this can be an advantage of the APC, when compared to the contact therapy devices, by allowing the device reach to bleeding sites that are in hard-to-reach areas. APC results in more superficial coagulation because coaptive coagulation is not possible with APC treatment due to the nature of noncontact diathermy. Due to its low penetrance of tissue, APC is particularly useful in managing superficial bleeding sites such as Arteriovenous malformations (AVMs), gastric antral vascular ectasias, and chronic radiation proctitis (CRP) [9–11].

Regarding its use in treating CRP, radiofrequency ablation (RFA) is another endoscopic modality that has made headway. As its name suggests, RFA works to ablate tissue with radiofrequency energy delivered through a catheter [10]. This form of intervention has been especially successful in treating CRP in patients who have had recurrent bleeding after APC treatment. The RFA technique offers the advantage of covering broader areas and making even less superficial ablations, further lowering the complications associated with thermal therapy and decreasing the chance of rebleeding [12]. With further research, RFA may emerge as the standard treatment for individuals with complicated cases of CRP.

Mechanical Therapy

Mechanical therapy requires the use of devices that promote hemostasis by physically closing the bleeding source. Clips and Bands are the most common agents used to perform mechanical endoscopic therapy.

Clips can further be categorized as *Through the Scope Endoclips (Endoclips),* which are widely used, and *Over-The-Scope-Clips (OTSC)* (Fig. 10.2). The endoclips and OTSCs differ in how they are deployed, the amount of area they can compress, and the efficacy of the clips in treating peptic ulcers and recurrent bleeding ulcers [13–15]. The mechanical agent of choice is dependent on recognizing the type of lesion or bleeding site. There are a variety of endoclips which allow for different movements during and after deployment of the clips [4]. Endoclips are deployed through-the-scope and require trained endoscopists for proper placement (Fig. 10.3). In order to properly place the clip, it is important for the hemorrhaging area to be visible and clear to receive the clip. Poor visibility of the stigmata can lead to improper placement of the clip and increased rates of recurrent bleeding. Multimodal therapy that pairs injections with endoclips can help mitigate this problem. In spite of the advancements that have made endoclips more user-friendly, anatomical locations of lesions and difficult deployment of endoclips persist as

Fig. 10.2 Open Endoclip. (Copyright Boston Scientific Corporation. Courtesy of Boston Scientific)

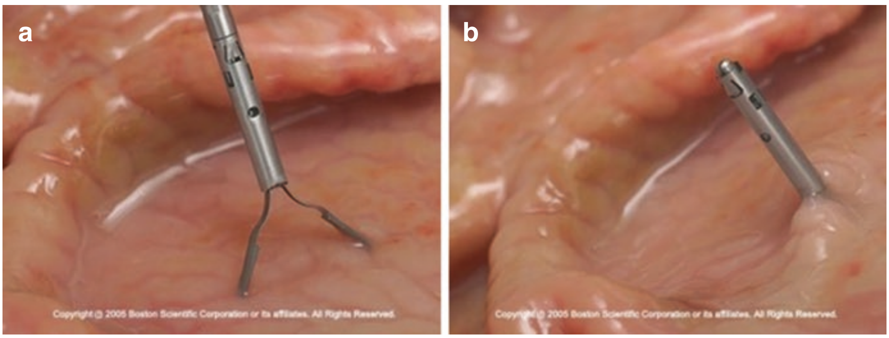

Fig. 10.3 (**a**) Open clip. (**b**) Deployed, closed clip. (Copyright 2005 Boston Scientific Corporation. Courtesy of Boston Scientific)

limiting factors in their efficacy [16]. Endoclips are recommended for achieving hemostasis in non-variceal type bleeding such as bleeding peptic ulcers, Mallory-Weiss tears, Dieulafoy's lesions, diverticular bleeding, and postpolyectomy bleeding [17–21].

As the name suggests, OTSC are deployed over the endoscope. Placement of OTSC requires clasping the edges of the hemorrhagic site and pulling them into the endoscope, effectively embedding them in the OTSC compartment (a cylindrical cap-like structure). OTSC can close bleeding sites of larger diameters than endoclips [22]. Despite this, OTSC are generally used as a second-line mechanical tool because they are more expensive and not always the most cost-effective option when compared to endoclips. OTSC can be used to treat rebleeding sites that were unsuccessfully managed by endoclips and are typically used to promote hemostasis of perforations and fistulas [14, 23–26]. Studies show that OTSC remain in situ up to 39 days longer (with an average of 25 days longer) than endoclips and result in decreased levels of recurrent bleeding [14, 27].

Some evidence suggests that clips are more efficacious than thermal therapy, especially for the treatment of ulcers. This is partly due to the way the clips result in hemostasis. Tamponade is promoted through compression of blood vessels and not through tissue damage, which is how thermal therapy works [28]. Meanwhile, other studies show that clips are less successful in achieving homeostasis of ulcers than thermal therapy [5]. Overall, more research is necessary to conclude which modality is more effective.

Endoscopic band ligation (EBL) is another mechanical tool that is used to compress the bleeding site and promote hemostasis (Fig. 10.4). The EBL is performed in a similar manner to OTSC, and rubber bands are used to compress the bleeding site instead of a cylindrical cap-like structure [29]. In contrast to clips, EBL is the preferred mechanical device used to treat variceal bleeding [30]. EBL is specifically recommended for treating esophageal varices due to decreased rebleeding rates and complications [31, 32]. The efficacy of EBL in treating non-variceal bleeding has

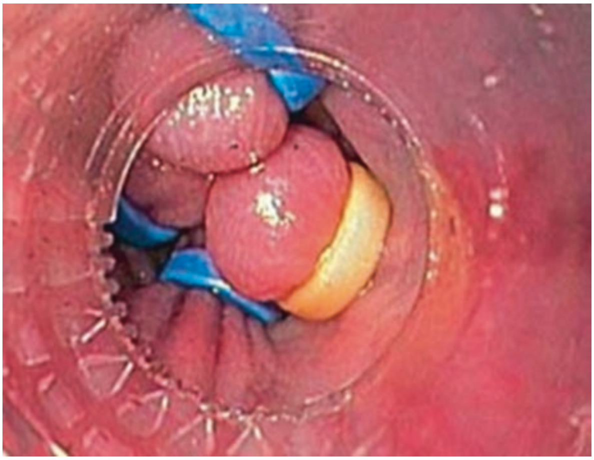

Fig. 10.4 Deployed band. (Copyright Boston Scientific Corporation. Courtesy of Boston Scientific)

also been studied. With increasing research on the use of EBL to treat non-variceal bleeding, perceptions have changed regarding the efficacy of this technique. EBL can be also used in effectively managing Dieulafoy lesions, Mallory Weiss tears, and peptic ulcers [33–35].

Injection Therapy

Injection therapy for GI hemorrhage aims to promote hemostasis through the introduction of a variety of substances into the stigmata (Figs. 10.5 and 10.6). We will be focusing on three main injectable agents: epinephrine, tissue adhesives (or glue), and sclerosing agents, all of which are further discussed below.

Fig. 10.5 Needle. (Copyright Boston Scientific Corporation. Courtesy of Boston Scientific)

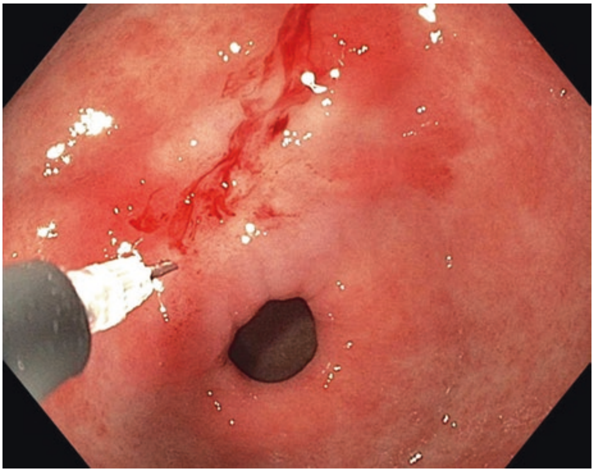

Fig. 10.6 Needle injection of an agent to promote hemostasis

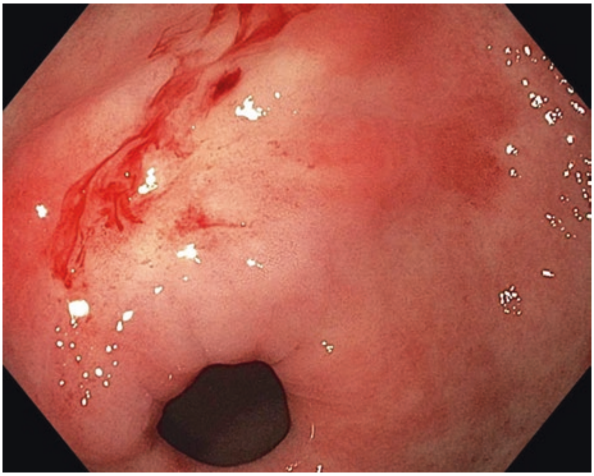

Fig. 10.7 White out effect on mucosa after epinephrine injection: it is important to realize that epinephrine is a temporary measure only and other therapeutic modalities are needed

Epinephrine injections are administered around the source of bleeding to promote vasoconstriction, allowing for temporary hemostasis (Fig. 10.7). The volume of epinephrine injections ranges from 1 mL to 40 mL. Depending on the volume injected, epinephrine can produce different results. A larger dose produces a longer period of hemostasis and a decrease in the rate of rebleeding [36]. Advantages of epinephrine injections include straightforward application and temporary relief that clears the site of bleeding, allowing for better visibility of the stigmata. This is especially useful when following up the injection with mechanical or thermal therapy to achieve long-term hemostasis. Generally, one-time injections are rendered less efficacious than thermal and mechanical therapy. When paired with another treatment modality, injections are less likely to lead to rebleeding episodes [37–39].

Tissue adhesive injections (Glue) achieve initial hemostasis by causing temporary tissue injury. ECGI is one of the primary agents injected to promote thrombosis. ECGI is typically used in the management of gastric varices. Similar to epinephrine, it achieves short-term hemostasis [40]. Yet, recurrent bleeding post-treatment is common. Therefore, it is recommended to pair ECGI injections with another endoscopic treatment modality to achieve long-term hemostasis. An additional limitation is due to the tissue injury incurred from the injection; physicians can only administer minimal amounts of the ECGI [41]. Despite EBL being more efficacious than ECGI in treating esophageal varices, ECGI therapy is preferred over EBL to treat gastric varices due to its lower complication rate [31, 32, 42, 43].

Other injectable agents include *sclerosants*, which are not typically used during endoscopic therapy in the US. Injection of sclerosing agents results in tissue injury through endothelial damage, which leads to subsequent thrombosis and fibrosis of the area, resulting in hemostasis. Common sclerosing agents include saline, thrombin and fibrin sealant, fatty acid derivatives (ethanolamine oleate and sodium morrhuate), synthetic agents (sodium tetradecyl sulfate and polidocanol), and alcohols [44]. Saline has been shown to be less effective than epinephrine – leading to higher rebleeding rates [2]. Fibrin sealants show promising results in achieving primary hemostasis. Fibrin sealants promote coagulation through the facilitation of platelet-platelet aggregation. They have been shown to be more effective than polidocanol in preventing rebleeding events [45]. More research is needed to establish the efficacy of fibrin sealants in relation to other injectable agents and other therapeutic endoscopic modalities. Sclerosing agents are seen to be a preferred mode of treating esophageal varices, especially in developing and under resourced countries, where cost is a major barrier to care. Some case reports show that sclerotherapy has also been successful in managing non-variceal bleeding sites like Dieulafoy's lesions [44]. In terms of efficacy, there is a lot of conflicting research on which sclerosing agent is most successful. When choosing an agent, it is recommended that the physician take cost, risk for complications, and patient history into consideration. Overall, the current consensus is that injectable agents are more efficacious when used in combination therapy for ulcers, gastric varices, non-variceal bleeding, etc. [2, 37, 40].

Topical Therapy

Topical therapy is another modality used in treating hemorrhagic GI sites. Topical therapy comes in many forms, most notably as a procoagulant spray, *Hemospray*. Hemospray is an inorganic powder that is applied to the source of bleeding and causes coagulation through a couple of mechanisms (Fig. 10.8). Like mechanical agents, Hemospray facilitates a physical tamponade. Additionally, when the powder substance is dispensed, it adheres to the bleeding site and absorbs bleeding factors, creating a barrier over the source [46]. Advantages to this method of application include that it does not require much precision, it can cover large areas, and it is relatively safe to use because it does not create tissue injury.

Furthermore, the procoagulant spray is versatile and has been successfully used as a monotherapy in addition to its uses in combinatory therapy. Procoagulant spray can be used similarly to epinephrine injections where it promotes initial hemostasis to momentarily stop active bleeding [47]. Unlike epinephrine injections, procoagulant

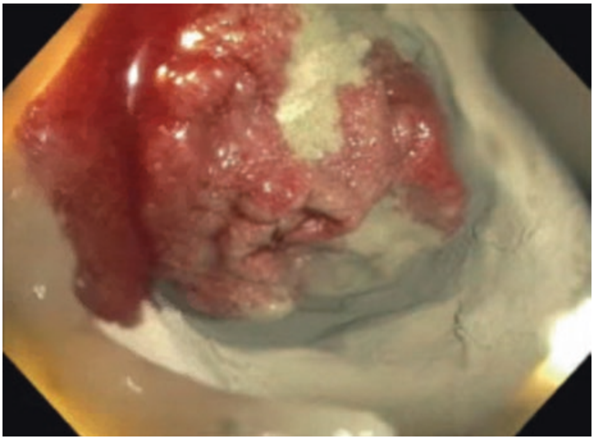

Fig. 10.8 This a picture of a small bowel tumor in the distal duodenum where active bleeding was stopped using Hemospray. Once stable, the patient underwent surgical resection

spray monotherapy has had success in achieving long-term hemostasis in patients with acute lesions that have low risks of recurrent bleeding. Disadvantages to this form of therapy include that it is relatively superficial, so it is limited to the types of lesions that it can treat and not recommended as the sole treatment of hemostasis of underlying vessels. For bleeding sites known for high recurrent rates, it is recommended that Hemospray is used in combination with another endoscopic intervention. Additionally, Hemospray presents technical challenges in how it is delivered, leading to the clogging of the endoscope [46]. Despite this, Hemospray has been demonstrated to have successful outcomes in controlling both non-variceal and variceal bleeding. Further applications of hemostatic powders include management of tumoral GI bleeds. Endoscopists are also using hemostatic spray as second-line intervention for individuals whose bleeding was unsuccessfully managed with conventional treatment (injection, thermal, or mechanical therapies) [48]. Overall, studies show that hemostatic spray is a viable modality to manage GI bleeding. As with many of the other therapeutic endoscopic modalities, more research is needed with larger experimental populations.

Combination Therapy

With lesions that have a high risk of rebleeding, it is common to use a combination of therapeutic endoscopic modalities to achieve homeostasis. A multimodal approach that pairs modalities that successfully achieve temporary hemostasis with interventions that promote long-term hemostasis is recommended for the management of peptic ulcers and actively bleeding sites [49]. For example, combining epinephrine injections, which promote immediate hemostasis, with endoclips can help the endoscopist gain better visibility of the bleeding site and decrease the chance of improper placement of the endoclip. In general, proper placement of the clips and deployment of bands is correlated with decreased chances of rebleeding. Research shows that when epinephrine injections are combined with another modality, they result in better outcomes than when used as a monotherapy [37–39]. Similarly, multimodal therapy including hemostatic powder and a conventional modality, has shown to be more efficacious than hemostatic powder alone in management of peptic ulcer bleeding [50]. However, when comparing thermal contact monotherapy with injection plus thermal contact dual therapy, there is no significant difference in patient outcomes [49]. Although there are limited studies evaluating dual endoscopy therapy, which includes a combination of thermal, mechanical, or sclerosing injections, vs. monotherapy efficacy, the present data indicates that both therapies are equally efficacious [49].

Complications of Endoscopic Therapy

Endoscopic therapy for GI bleeding has many benefits and is minimally invasive. Nevertheless, there are complications associated with endoscopic therapy. Complications can be due to procedural challenges – such as poor visualization, location of the lesion, and device limitations – and operational errors due to lack of experience. Although risks can be minimized by good technique, some complications cannot be escaped. As with any other procedure, risk of infection and trauma are high. Perforations and tissue injury are common complications, especially when using thermal therapy. Specifically, for severe cases, risk of recurrent bleeding is high. Therefore, with any patient, it is important to weigh the risks and benefits before performing treatment [51, 52].

Interventional Radiology Management of Gastrointestinal Bleeding

While the primary focus of this text is the treatment of occult GI bleeding, many of the techniques discussed may be utilized in the treatment of overt/acute GI bleeding. Similarly, many disease conditions, namely portal hypertensive conditions and systemic diseases, may result in both chronic occult and overt episodes of GI bleeding. Interventional radiology therapy of GI bleeding is most successful when a bleed can be localized usually via endoscopy or non-invasive imaging. Triple phase CT angiography (CTA) without oral contrast (noncontrast, arterial phase, and venous phase) may be obtained in any patient with occult GI bleeding. Referring providers should provide a clinical history of occult GI bleeding, to indicate a desire to rule out underlying vascular anomalies rather than active bleeding. Nuclear medicine tagged red blood cell scintigraphy ("bleeding scan") has added sensitivity with the ability to detect bleeding rates as low as 0.1 mL/min; however, image acquisition is time consuming, lacks anatomic detail, and fails to identify the bleeding source in up to 50% of patients. When physicians have failed to identify and manage the bleeding source through therapeutic endoscopic modalities, IR methods can be pursued. Treatment of occult arterial gastrointestinal bleeding is via angiography and embolization. Treatment of variceal hemorrhage requires different access methods, equipment, and techniques including portosystemic shunt creation (TIPS/DIPS) and/or balloon-occluded or plug-assisted retrograde transrenal obliteration of varices (BRTO/PARTO) [53, 54].

Arterial Bleed

Introduction

Angiography may be pursued in patients whose bleeding is not controlled endoscopically or when complete workup fails to identify a bleeding source (Fig. 10.9). Catheter directed angiography is less sensitive in detecting bleeding than computed tomographic angiography (CTA) or nuclear medicine scintigraphy, but offers the benefit of concomitant therapy, namely embolization. The goal of embolization is to provide a scaffold for thrombus formation to occlude the pathologic blood vessel, reducing arterial perfusion pressure and bleeding. Embolic materials include commonly used

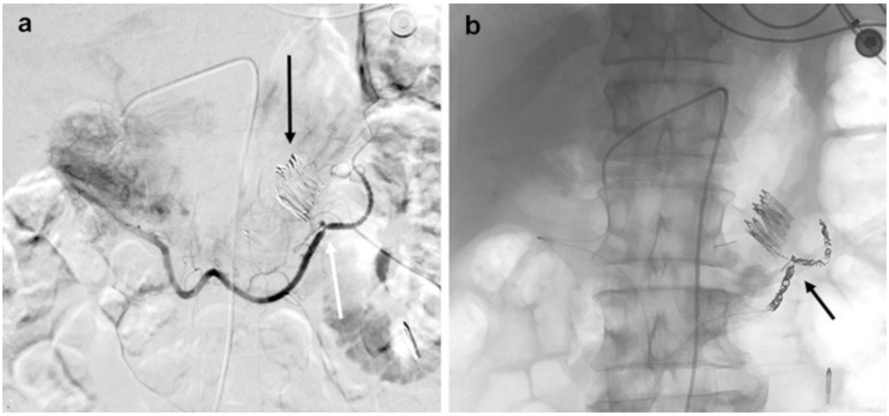

Fig. 10.9 (**a**) Selective arteriogram of the gastroepiploic artery reveals persistent pseudoaneurysm (*white arrow*) in the region of endoscoically placed clips over a suspected dieulafoy's lesion (*black arrow*) (**b**) Coil embolization was performed across the region of focal vascular abnormality (*black arrow*)

metallic coils and plugs, biologic and synthetic materials of varying shapes and sizes, and liquid glues or adhesives. These devices have varying biodegradability, onset, and visibility on fluoroscopy. Water or oil-based contrast media may be mixed with embolic agents to improve visibility on x-ray. Metallic embolic agents are generally permanent and will be visible on all of the patient's subsequent medical imaging.

Anatomy and Common Culprit Artery for Upper and Lower

The upper GI (UGI) tract is predominantly supplied by the celiac trunk. Superior mesenteric artery (SMA) interrogation is warranted if celiac interrogation does not reveal conventional anatomy. The lower GI (LGI) tract is supplied by the SMA, inferior mesenteric artery (IMA), and in cases of IMA occlusion, by the internal iliac arteries. Celiac artery interrogation may be necessary in rare instances of a replaced middle colic artery. Common culprit vessels in the UGI tract include the left gastric artery (fundal and gastroesophageal bleeding) and gastroduodenal artery (duodenal bleeding). LGI tract bleeding can be from a variety of sources and complete workup with non-invasive imaging and colonoscopy prior to angiography is highly recommended.

Access

The most common access site is via the right common femoral artery. This access point is usually palpable, offers a short distance to select the mesenteric vasculature, and offers the ability to tamponade access site bleeding with manual compression against the femoral head. Left radial artery access has emerged as an alternative to femoral arterial access, particularly in patients with increased risk of bleeding (high body mass index, chronic kidney disease, thrombocytopenia, inability to receive blood transfusion) or those with difficulty lying flat (low back pain, congestive heart failure, cognitive impairment) [55]. Radial access allows patients to sit up immediately following their procedure and is associated with increased patient satisfaction.

Prerequisite/Indications

The left gastric artery represents a special circumstance in UGI bleeding, as empiric embolization of endoscopically proven lesions is generally well tolerated due to the presence of multiple collateral vessels. Embolization for LGI bleeding is rarely empirical and recommended only upon confirmation of focal vascular anomaly or contrast extravasation due to the increased risk of bowel ischemia or delayed colonic ischemic stricture. Due to these risks, embolization for LGI bleeds may only be performed if selective catheterization is possible at the level of the mesenteric border of the colon. In the context of negative angiography and high clinical suspicion, provocative angiography may be considered to identify occult sources of bleeding localized by endoscopy or nuclear medicine scintigraphy. This approach requires an infusion of intra-arterial tissue plasminogen activator (tPA) or other thrombolytics to lyse suspected blood clots and “provoke” bleeding. Surgical consultation prior to considering this approach is prudent, as provoked bleeding may not be controllable and may necessitate emergent surgery. For this reason, provocative angiography is seldom employed [53, 56–59].

Technique

Coil embolization is the process of direct delivery of metallic coils to the area of vascular pathology (Fig. 10.10). Coils are sometimes referred to as mechanical embolic agents (in contrast with flow directed agents). Multiple coils are frequently utilized to create a “tight pack,” amenable to thrombus formation. Embolic materials may be combined to increase the likelihood and speed of vessel thrombosis at the treating physician’s discretion. If a catheter cannot be advanced close to the diseased vessel coil, embolization may still be performed across the branch vessel origin. When this approach is utilized, subsequent angiography of the Celiac, SMA, IMA, or internal iliac arteries must be performed to evaluate for collateral blood flow to the site of abnormality. In contrast to mechanical embolics, flow directed embolic agents such as N-butyl cyanoacrylate (NBCA), Onyx, spherical or irregular polyvinyl alcohol (PVA) particles, slurry or particle preparations of Gelfoam, or other spherical embolic agents, may be utilized to treat an entire vascular bed. This approach may be useful if there are multiple sources of bleeding or the cause of bleeding is determined to be an arteriovenous malformation or gastrointestinal

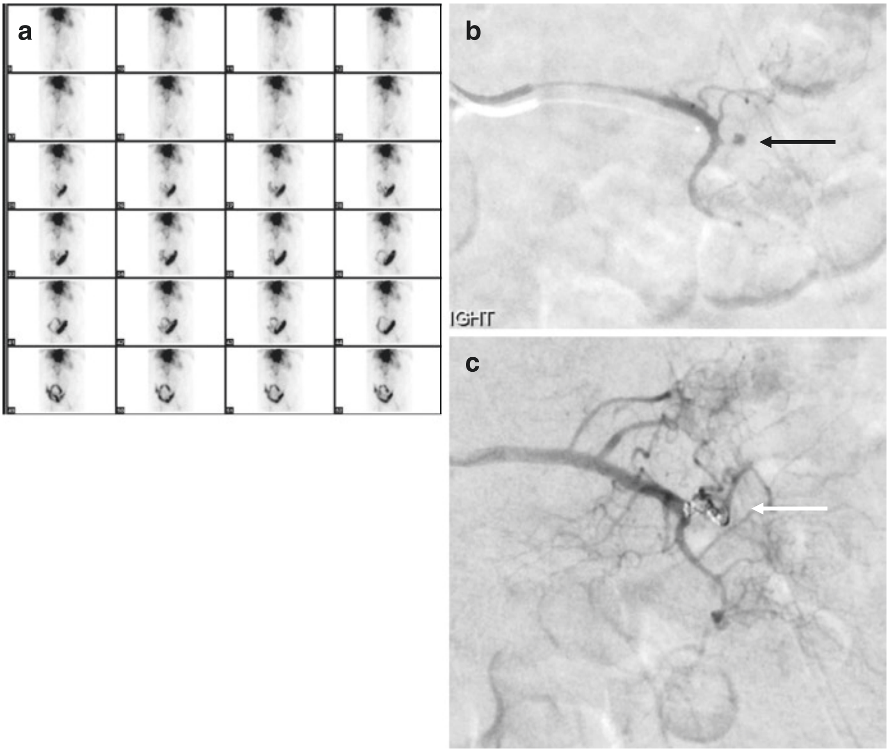

Fig. 10.10 (**a**) Selected images from tagged red blood cell scintigraphy show extravasation of radiotracer into small bowel in the left lower quadrant. (**b**) selective angiography of the jejunal artery reveals a pseudoaneurysm (*black arrow*). (**c**) coil embolization (*white arrow)* decreases filling of the pseudoaneurysm with preserved blood flow to distal small bowel

tumor. Liquid embolic agents, such as NBCA and Onyx, may be used in patients with uncorrected coagulopathy secondary to their ability to form a cast of the target vessel. Spherical embolic agents and drug-eluting beads are flow directed agents, which are advantageous in the treatment of an entire vascular bed [53]. Adequate diagnostic information regarding blood flow and experience preparing and using these agents is essential for safe deployment [53, 56–61].

Success Rate

Technical and clinical success of embolization for UGI bleeds is 93% and 67%, respectively [62]. The success rates for LGI bleeds are more varied by clinical context but average technical success is 88%, while average clinical success is 83% [63].

Complications

Arterial access for angiography is associated with risk of access site (groin) complications including hematoma (<3.1%), bleeding (<2.5%), and pain (<6.4%). Damage to the underlying artery resulting in pseudoaneurysm (<0.6%), retroperitoneal hematoma (<1%), AV fistula (<1%), or distal thromboembolism and limb ischemia (<0.4%), are rare complications, which warrant additional care and potentially subsequent procedures. All embolization procedures result in a degree of risk of subsequent bowel ischemia around 12%, which skews higher or lower based on the territory being treated and quality of collateral circulation [64]. Post procedure abdominal pain, passage of bloody stools, and occasionally fever and leukocytosis, may be encountered after embolization. The benefits of interventional radiology therapy relative to the risks should be discussed, but are generally recognized to have associated morbidity and mortality superior to surgical intervention [65].

Variceal Bleed

Introduction

Variceal hemorrhage (VH) is the leading cause of mortality in patients with portal hypertension. VH may present as occult bleeding, particularly secondary to ectopic varices, which are less amenable to endoscopic treatment [66].

Anatomy and Common Culprits

Esophageal varices (EV), gastric varices (GV), and gastroesophageal varices (GEV) make up the majority of endoscopically encountered culprits for bleeding. Ectopic varices are dilated mesoportal varices or portosystemic collaterals, which exist throughout the GI tract outside the gastroesophageal region. Ectopic varices are an underappreciated source of hemorrhage more common in extrahepatic (20–30%) versus intrahepatic portal hypertension (1–5%) [66].

Access

Clinical determination of the source of bleeding is important prior to interventional therapy of VH and access occurs via right internal jugular (RIJV) or right common femoral venous (RCFV) access rather than arterial access.

Prerequisites/Indications

Endoscopy is the preferred means of initial evaluation in patients with active or suspected VH. Since ectopic varices may be endoscopically occult, non-invasive cross-sectional imaging with portal venous or triple phase CT/CTA or contrast-enhanced MRI are recommended adjunctive testing. Patients with isolated or predominantly gastric varices may be amenable to treatment with BRTO and/or combination therapy with staged BRTO and TIPS or TIPS with antegrade transvenous obliteration or embolotherapy. Optimal management of VH requires multidisciplinary cooperation and thoughtful risk/benefit discussion with the patient prior to intervention.

Technique

TIPS RIJV is the conventional access method for TIPS. The left internal jugular vein may be utilized and is reported to offer more favorable angles for accessing the right hepatic vein, however, limited user experience may limit this benefit. Right hepatic vein access is preferred for its reliable positioning in the posterior liver parenchyma, which may be confirmed with lateral fluoroscopy. Reference to a pre-operative CT or an intra-procedural wedged hepatic CO_2 venogram may be performed to confirm the relationship of the portal vein to the right hepatic vein. A non posterior location may suggest either selection of a middle hepatic vein or accessory right inferior hepatic vein, which in the cirrhotic liver may not have a consistent relationship with the portal vein and may increase the risk of extracapsular liver puncture and subsequent bleeding. Hockey stick shaped catheters and use of hydrophilic guidewires (Glidewire or Roadrunner) may facilitate right hepatic vein selection. Measurement of hepatic portal venous pressure gradient (HVPG) may be performed prior to and following the procedure to confirm adequate decompression for the indication (HVPG<12 mmHg is favored for treatment of varices). A needle is fired generally within the proximal 2–3 cm of a hepatic vein in the direction of the portal vein and slowly retracted under aspiration until portal venous blood is aspirated. Contrast injection through the needle confirms portal venous access. Coring (Colapinto) vs non-coring (Rosch-Uchida kits) needles allow for either advancing a wire through the access needle or over-sheathing and needle retraction to secure portal vein access. Dilatation of the parenchymal tract between the hepatic and portal veins with an angioplasty balloon is required to allow for sheath advancement into the portal vein and subsequent deployment of a bile-impermeable covered stent graft. Access to the portal venous system affords the opportunity for direct treatment of varices either via obliteration/sclerosis or embolotherapy. Portal venography prior to stent deployment illustrates flow dynamics of portal hypertension and the filling of varices and other porto-systemic shunts (Fig. 10.11).

Accessing the portal vein is generally considered to be the most technically challenging step of portosystemic shunt creation. Consequently, several advanced

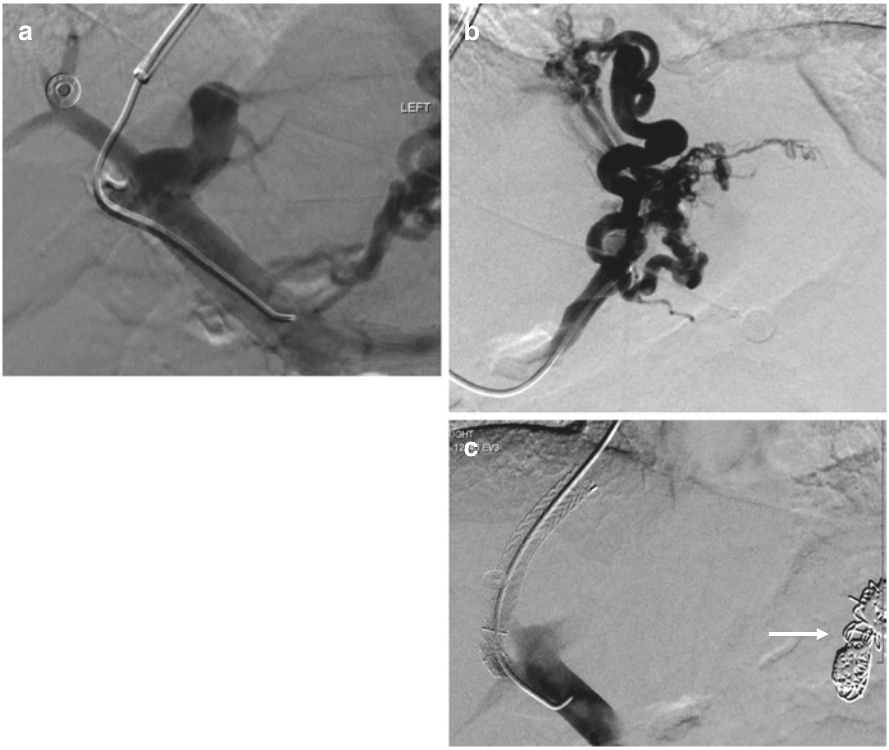

Fig. 10.11 (**a**) Portal venogram following TIPS reveals filling of gastroesophageal varices. (**b**) confirmed by selective injection of the coronary vein. (**c**) Varices are no longer filling following TIPS and coil embolization (*white arrow*)

techniques have been described in the literature to combat this challenge (Table 10.2) [67, 68]. In patients with non-opacification of the hepatic veins, as seen with Budd-Chiari syndrome, left internal jugular vein access may promote cannulation of a right or middle hepatic vein stump for wedged CO_2 portography. At the author's institution, percutaneous puncture of the liver targeting a snare in the IVC has been described as a means of creating an artificial tract through which CO_2 portography and subsequent portal vein localization may be performed. Either of these techniques carry increased risk of bleeding due to proximal puncture of the portal vein in the former case and liver capsule transgression in the latter.

Portal vein thrombosis is a rare situation which necessitates portal vein recanalization for successful shunt creation. Recanalization may proceed via transhepatic, transjugular, transmesenteric, trans-splenic, or combined surgical approaches. Wedged CO_2 portography and pre-procedural CT are again used to localize the main portal vein. Once access is obtained, a stiff, angled Glidewire and angiographic catheter are used to secure access and enable recanalization via either mechanical or Fogarty thrombectomy, catheter directed thrombolysis, or stenting.

Table 10.2 Complex portal vein access strategies

Problem	Technique	Special considerations
Hepatic vein occlusion	LIJ access and HV stump CO_2 portography	Increased bleeding risk
Hepatic vein occlusion	DIPS Transcaval puncture	Increased bleeding risk Special IVUS catheter is recommended
Intrahepatic tumor, cysts, poor IJ/SVC HV access	Pre-procedural CT localization, hybrid imaging	Increased radiation dose, increased procedure time, possibly increased bleeding risk, potential for malignant seeding
Inability to puncture portal vein despite multiple attempts	"Gun-sight" technique	Multiple punctures increase bleeding risk, increased radiation dose
Portal vein thrombus	Portal vein recanalization	Increased bleeding due to multiple punctures and/or procedures
Difficulty with portal vein localization	Marking hepatic artery with microcatheter Snare, basket, or wire deployment in portal vein via para-umbilical vein, direct varix access or trans-splenic puncture	Multiple access required, increased bleeding risk

Failure to localize the portal vein, despite wedged CO_2 portography and multiple puncture attempts, may be addressed with "gun-sight technique," described by Haskal et al. [68]. This technique involves placement of a snare within both the IVC and portal vein through access conventionally described via a recanalized para-umbilical vein, although trans-splenic puncture may enable similar snare deployment. As described, a large snare is deployed within the IVC and small snare within the portal vein, which are aligned on fluoroscopy allowing for needle puncture traversing both snares and through and through wire access. As with other advanced methods, bleeding risk is the primary concern given the need for additional punctures.

The presence of intrahepatic tumors, cysts, or no suitable hepatic vein access may necessitate transcaval shunt creation. Pre-procedural CT and/or hybrid imaging modalities (live fluoroscopy and either cone beam or pre-procedural CT) are essential to select an appropriate level for caval puncture in the direction of the portal vein. Portal access needles must be modified to assume an almost 90-degree angulation to allow for portal vein puncture, and caution to avoid capsule transgression is needed to minimize bleeding risk. The use of intravascular ultrasound (IVUS) to localize the portal vein from the IVC is the basis for the DIPS procedure described below.

Access to the portal vein may be obtained via a recanalized umbilical vein or via percutaneous trans-splenic puncture of a dilated splenic vein. These access routes allow for a snare to be deployed in a portal vein branch and targeted on fluoroscopy.

DIPS Direct intrahepatic portosystemic shunt arose as an advanced technique to portosystemic shunts directed at patients with absent jugular or SVC access to the hepatic veins, Budd-Chiari patients, and patients with pre-existing occluded TIPS. The portal vein is localized utilizing an intravascular ultrasound (IVUS) catheter positioned within the IVC via RCFV access. A modified needle is then fired into the portal vein under ultrasound guidance with the remaining steps identical to TIPS.

Balloon-occluded Retrograde Transvenous Obliteration (BRTO) and PARTO Unlike TIPS/DIPS, transvenous obliteration procedures are directed towards direct treatment of isolated gastric varices. These procedures do not alleviate and may exacerbate portal hypertension and associated sequelae (esophageal varices, ascites, pleural effusion, etc). A balloon or vascular plug is utilized to occlude the drainage of a gastrorenal or splenorenal shunt, prior to introduction of sclerosant to confine the sclerosant to varices (Fig. 10.12). The balloon is placed via a vascular access sheath and must be left inflated for up to 4 hours, after which the patient should have imaging to evaluate efficacy of variceal obliteration. Alternatively, coils and plugs may be utilized to permanently occlude shunt drainage, which eliminates the need for subsequent angiography, yielding a logistical improvement in patient management [69].

Success Rate

Combination of TIPS and embolotherapy is associated with statistically lower rebleeding rates when compared to TIPS alone in 5 of 8 studies performed between 2005 and 2014 [70]. Initial clinical success with TIPS is high (97–100%); however, rebleeding rates secondary to GEV's are as high as 20% and 20–40% for ectopic varices [59, 71]. DIPS is associated with a greater risk of extrahepatic puncture and bleeding relative to traditional TIPS, but has similar outcomes [72]. BRTO is successful in controlling bleeding from gastric varices in greater than 95% of patients and has significantly lower rates of hepatic encephalopathy when compared with TIPS (1% vs 30%). Efficacy of transvenous obliteration procedures for ectopic varices is not well established and requires further research [71].

Complications

TIPS is a generally safe procedure with a complication rate for experienced operators of 5% and a mortality rate of less than 2% in elective cases. Complications associated with right internal jugular vein access are rare with ultrasound guidance, but include carotid or subclavian artery puncture, pneumothorax, and injury to adjacent cervical structures. Guidewires advance into the right atrium or right ventricle may induce a cardiac arrhythmia which is typically transient and resolves with retraction of the offending catheter or guidewire. Rarely sustained arrhythmias may

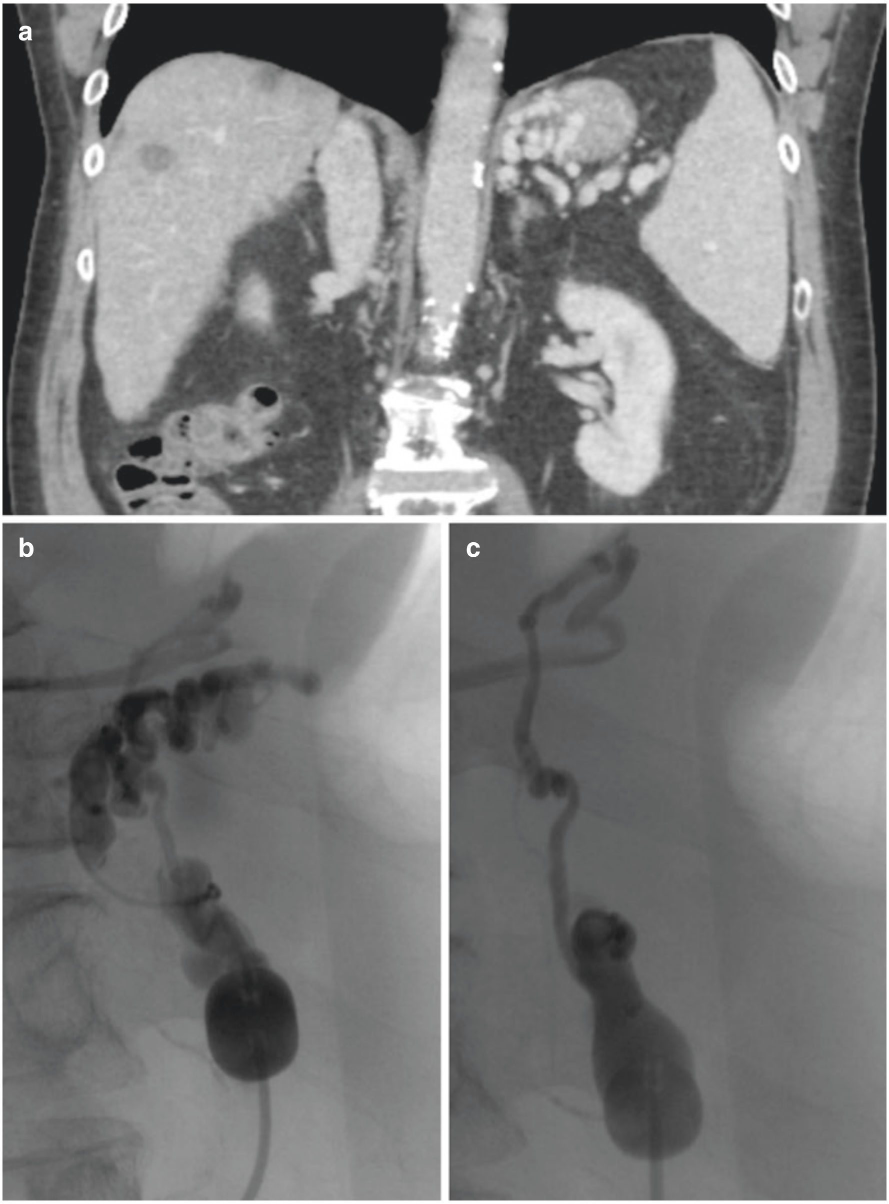

Fig. 10.12 (**a**) Coronal contrast enhanced CT shows filling of gastric varices. Additional images revealed the source as a prominent gastro-renal shunt. (**b**) Balloon assisted retrograde venogram of a gastrorenal shunt opacifying gastric varices. (**c**) Venogram following administration and indwelling of sodium tetradecyl sulfate foam and lipiodol shows reduced filling of gastric varices

be encountered including supraventricular or ventricular tachycardia. The most serious early complication associated with TIPS is intraperitoneal bleeding secondary to either extrahepatic portal vein puncture (2%) or extracapsular liver puncture (5%). Transgression of the liver capsule may allow for injury to extrahepatic organs such as bowel, kidney (1.5%), or gallbladder (10%) [73]. Intrahepatic biliary duct puncture (5%) is a complication of more commonly historically with the use of non-covered stent grafts [73]. Hemobilia related to biliary duct puncture or inadvertent hepatic arterial puncture (<1%) are rare but may require subsequent angiography embolization if there is suspicion of significant bleeding. Wedged hepatic venography, particularly with carbon dioxide can cause laceration of the liver parenchyma or liver capsule rupture if injections are performed too forcefully.

The most common early complication following TIPS is worsening of hepatic encephalopathy (20–50%), which is managed medically, but in less than 10% of cases may necessitate revision or occlusion of the portosystemic shunt. Additional complications ranging in incidence between 2–10% include hemobilia, portal vein thrombosis, stent migration/misplacement (<1%), infection/biliary peritonitis, nephropathy, and hemolysis [59, 74].

Complications of BRTO/PARTO are associated with exacerbation of the patient's existing portal hypertension and associated sequelae. The most notable of these is esophageal varices, which are expected to enlarge (30–68%) and potentially bleed (17–24%). Other complications include portal hypertensive gastropathy (5–13%), ascites (0–44%), and hydrothorax/pleural effusion (0–8%) [69].

Future IR Therapies

Embolization therapy for other indications, specifically bleeding secondary to hemorrhoids, is currently under investigation. Small case studies outside the United States have reported clinical success between 72–97% following either coil or coil and particle embolization of the superior rectal arteries. These treatment methods must first be validated, but in the future, they may offer an additional minimally invasive treatment strategy for GI bleeding secondary to hemorrhoids [75–77].

Surgical Management of Gastrointestinal Bleeding

For any patients with bleeding, the therapeutic protocol should include a thorough initial evaluation to classify the bleeding as occult, obscure, or overt, and then detect the source of bleeding through endoscopy and/or angiography. Resuscitation, medical therapy, and correction of coagulopathy are essential [78, 79]. Indications for surgical management of GI bleeds include inadequate resources for the management of GI bleeds, such as lack of skilled endoscopists, repeated hospitalization for GI bleeding, other indications for laparotomy, and, most importantly, failure of at least two attempts at endoscopic management [80–83]. The operative approach is dictated by the etiology of bleeding, the patient's hemodynamic status, whether the bleeding is obscure, and the location (known vs. unknown site of bleeding). With the advances in surgical techniques, most of the surgeries are now minimally invasive and done laparoscopically.

Upper GI Bleed

Peptic Ulcer Bleeding

The overall goals of surgery for peptic ulcer bleeding include control of bleeding, suppression of gastric acid secretion with or without an accompanying drainage procedure, eradication of *Helicobacter pylori* infection, and exclusion of cancer.

Surgical strategies that are used in clinical practice to control bleeding in the stomach secondary to peptic ulcer disease include:

- *excision of ulcers* in more proximal locations,
- distal *gastrectomy*, or
- simple *suture ligation* (a less morbid and preferred option).

Control of bleeding typically involves *over-sewing* of ulcers that occur in areas that are not easily amenable to resection, such as in the duodenum or the proximal stomach. Following a distal gastric resection, reconstruction can be done in two configurations: a gastroduodenostomy (***Billroth I reconstruction***) or a gastrojejunostomy (***Billroth II reconstruction***) [83]. A Billroth I reconstruction involves the creation of an anastomosis between the duodenum and the gastric remnant, while a Billroth II reconstruction consists of an anastomosis between the stomach and a jejunal loop. Based on the location and pathogenesis, gastric ulcers can be categorized into the five types. Type 1 ulcers occur in the body of the stomach, high along the lesser curvature near the incisura, and are associated with *H. pylori* infection. Type 2 ulcers usually occur in the pre-pyloric area and are often associated with duodenal ulcers. Type 3 ulcers occur in the antrum. Type 4 ulcers occur along the lesser curvature of the stomach near the gastroesophageal junction (GEJ). Type 5 ulcers are diffuse ulcerations of the gastric mucosa associated with nonsteroidal anti-inflammatory drug use. This classification of gastric ulcers not only reflects the pathogenesis but also determines the surgical management, which often includes a combination of the strategies discussed (Table 10.3).

Bleeding from a duodenal ulcer occurs when the ulcer posteriorly erodes into the gastroduodenal artery. This bleeding can be surgically controlled by simple suture ligation through an opening in the anterior duodenal wall (*anterior duodenotomy*). A generous Kocher maneuver is performed to mobilize the duodenum followed by an anterior duodenotomy over the first and second portions of the duodenum through the pylorus. Once the site of bleeding is exposed, direct digital pressure should be applied immediately, followed by placement of 3 to 4 U sutures around the bleeding ulcer using non-absorbable suture material. Finally, the duodenostomy should be closed in a transverse fashion.

Table 10.3 Summary of surgical management for GI bleeding

Source of GIB	Treatment options	Notes
Type 1 gastric ulcer	Distal gastrectomy (antrectomy) and Billroth I*	Type 1 gastric ulcers are higher on the lesser curvature and do not have elevated acid production
Type 2 gastric ulcer	Antrectomy and Billroth I/II and Vagotomy*	Associated with a duodenal ulcer and acid hypersecretion
Type 3 gastric ulcer	Antrectomy and Vagotomy*	Prepyloric ulcer. Acid overproduction
Type 4 gastric ulcer	No consensus on treatment. Subtotal gastric resection or distal gastrectomy often pursued	Near GEJ
Type 5 gastric ulcer	Packing of the stomach and subtotal gastrectomy	
Duodenal ulcer	1. Oversew + Truncal Vagotomy+ Pyloroplasty 2. Oversew + Truncal Vagotomy + Antrectomy 3. Oversew only**	
Mallory-Weiss tears	Over-sewing	
Dieulafoy lesions	Over-sewing	
Aorto-enteric fistulas	Graft explantation, extraanatomical bypass, enterotomy repair	
Hemobilia	Angiography	
Hemosuccus pancreaticus	Angiography	
Small bowel bleeding	Segmental resection	
Colonic bleeding	Segmental resection	
Bleeding esophageal varices	• Portocaval shunt • Splenorenal shunt • Esophagogastric devascularization and transection	
Sinistral hypertension	Splenectomy	

*For unstable patients, biopsy and oversew or wedge resection should be done instead.
**For unstable patients

After control of bleeding, it is important to initiate treatment to suppress gastric acid production. This can be effectively achieved with medications, and this strategy should be considered as first-line therapy in patients with bleeding peptic ulcers, who have not received prior treatment and are compliant with the regimen. Vagal denervation of the stomach effectively reduces acid secretion and contributes to duodenal ulcer healing. A *vagotomy* is achieved by severing the vagus nerve at three possible levels. Based on the level at which the nerve is cut, a vagotomy is classified into truncal, selective, or highly selective vagotomy. Truncal vagotomy involves transection of the vagus proximal to GEJ. Selective vagotomy involves transection of the vagus below the GEJ with preservation of the hepatic and celiac branches. Highly selective vagotomy involves transection of only those branches of the vagus that supply the stomach, with preservation of the hepatic, celiac, and antral branches. Emergency truncal vagotomy is necessary only for patients who have failed proton pump inhibitor (PPI) therapy or are allergic to PPIs. Selective vagotomy is time consuming and is not useful for the surgical management of peptic ulcer-induced bleeding [84]. Vagotomy induced acid suppression results in altered gastric emptying secondary to denervation of the pylorus and antral hypergastrinemia with gastrin cell hyperplasia. Highly selective vagotomy can effectively minimize hypergastrinemia and altered gastric emptying. However, highly selective vagotomy is associated with weaker acid suppression and a higher risk of ulcer recurrence.

Vagotomy should be accompanied by a *drainage procedure* as a counter-regulatory mechanism for vagotomy induced delayed gastric emptying. A *Heineke-Mikulicz pyloroplasty* and *antrectomy* (removal of the pylorus) are examples of drainage procedures. The Heineke-Mikulicz pyloroplasty is a simple and rapid procedure. Antrectomy offers the advantage of including a bleeding ulcer in the resection and eliminates the parietal cells, resulting in greater acid suppression. However, performing an antrectomy is time consuming and is therefore not ideal in emergencies. Other complications of a vagotomy include dumping syndrome and post-vagotomy diarrhea.

In summary, surgical options for bleeding duodenal ulcers include the following:

- simple suture ligation through an anterior duodenotomy,
- suture ligation, antrectomy, and truncal vagotomy for stable patient's refractory to acid suppression therapy, or alternatively,
- suture ligation, vagotomy, and duodenoplasty.

Most of these procedures can be performed using minimally invasive technique; however, these techniques are not advisable in emergent situations.

Following gastric acid suppression, a urea breath test, fecal antigen test, or biopsy based tests should be performed for *H. pylori* testing, and antibiotics should be administered for eradication [85]. Lastly, cancer is ruled out by evaluation of biopsy specimens obtained from the edge and base of an ulcer [86].

Non-Peptic Ulcer Bleeding

Non-peptic ulcer bleeding includes bleeding from varices, tumors, Mallory-Weiss tears, Dieulafoy lesions, aorto-enteric fistulas, hemobilia, hemosuccus pancreaticus, as well as iatrogenic and traumatic injuries. Management of bleeding in such cases depends upon the specific lesion.

Bleeding from Mallory-Weiss tears is usually self-limited and rarely requires surgical intervention [87]. Dieulafoy lesions cause intermittent bleeding and are difficult to localize. In both cases, surgery when required, involves *over-sewing* of the lesions (the mucosa and the bleeding vessel, respectively) through a gastrotomy

[88]. Management of GIB is most challenging in patients with diffuse erosive gastritis refractory to medical management. Hemodynamic instability in patients necessitates packing of the stomach as a temporary measure, intra-arterial vasopressin injection, and ultimately subtotal or near-total gastrectomy [89–91]. In patients with benign or malignant GI tumors, partial gastric resection is often indicated [92].

Variceal Bleed

Sengstaken-Blakemore tube or self-expanding metal stent placement is useful to tamponade the bleeding site and stabilize patients with variceal bleeding that is refractory to multiple endoscopic treatments. This procedure provides adequate time for initiation of resuscitative measures, correction of coagulopathy, and optimization for further intervention [93]. Depending on the availability of surgeons with the required expertise, patients with active bleeding and acceptable surgical risks should be considered for portacaval (nonselective) shunt placement. For patients without active bleeding, a more selective distal splenorenal shunt should be considered. Complete esophagogastric devascularization and transection (the *Sugiura* procedure) may be performed as a last resort in patients in whom shunt placement is not possible. However, this approach is associated with a significantly high mortality rate [94].

Poor surgical candidates with variceal bleeding, who are otherwise stable, should undergo transjugular intrahepatic portosystemic shunt (TIPS) placement. However, careful patient selection is important because of serious complications, such as worsening encephalopathy associated with this procedure. Patients deemed appropriate candidates for the TIPS procedure should undergo evaluation for liver transplantation at a transplant center. For patients with noncirrhotic sinistral (left-sided) portal hypertension, the approach to treatment is different. Noncirrhotic sinistral portal hypertension results from occlusions in prehepatic structures, most commonly the splenic vein, which leads to the redirection of blood from the portal venous system to the systemic circulation, often causing isolated gastric varices. Pathological processes in the pancreas like pancreatitis, tumors, etc. can cause splenic vein obstruction. For patients with bleeding gastric varices secondary to noncirrhotic sinistral portal hypertension resulting from splenic vein thrombosis, *splenectomy* is curative and the treatment of choice [95].

Special Causes

Aorto-enteric fistula management necessarily involves surgical intervention owing to a breach in the integrity of the aortic wall and graft infection. Most patients undergo ligation of the aorta, and *explantation of the graft* with the placement of an *extra-anatomical bypass* (e.g., an axillary-to-femoral bypass). Alternatively, the infected aortic graft can be replaced with a femoral vein or cryopreserved aortic allograft. The enterotomy, which is commonly located in the third portion of the duodenum, should be resected with subsequent reconstruction [98].

Colonic Lower GI Bleed

Right or left hemicolectomy or any other segmental resection is recommended for patients with lower GIB that can be localized to the colon, provided the bleeding site can be accurately localized and/or embolized; blind total colectomy should be avoided. Depending on the size and spread, resection of an underlying tumor is often done through minimally invasive laparoscopic or laparotomic techniques. Both techniques have comparable outcomes, although laparoscopic resection lessens recovery time [96, 97].

Small Bowel Bleed

The small bowel should be suspected as the site of bleeding in patients with obscure GIB in whom mesenteric angiography, esophagogastroduodenoscopy, capsule endoscopy, colonoscopy, tagged red blood cell scan, enteroclysis, Meckel's scan, and enteroscopy are all non-diagnostic. The recommended course of action is to avoid exploratory procedures in patients in whom the source of bleeding cannot be confirmed. The most common source of bleeding in the small bowel is arteriovenous malformations (AVMs), which cannot be identified through visual inspection or palpation. Therefore, *intraoperative endoscopy* is essential in patients transferred to the operating room for management of obscure bleeding. The endoscopic procedure is performed to evaluate the small bowel lumen, and the surgeon feeds the small bowel on to the endoscope. The surgeon carefully manipulates the small bowel loops so that the endoscope can accurately capture views of most segments of the small bowel to evaluate as much of the small bowel lumen as possible. The combination of endoscopic luminal visualization, palpation of the bowel, and trans-illumination increases the rate of detection of AVMs, masses, or any mucosal defects. Endoscopic sclerotherapy, endoscopic coagulation, or resection of the affected small bowel segment can be performed following accurate localization of bleeding sites. Meckel's diverticulum and masses are more obvious pathologies, which are treated with segmental small bowel resection.

Conclusion

Gastrointestinal bleeding can be approached in a myriad of ways. Due to the variety of lesions, pathologies, and lack of large randomized control trials, there is no standardized treatment for GI bleeding. Therefore, management of the bleeding site is based on the location, type of lesion that is being treated, and available expertise. Generally, physicians tend to start with the least invasive therapies—endoscopic hemostasis—and then progress to more involved interventions such as embolization and minimally invasive surgery, and ultimately open surgery.

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