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Invited Review

Therapeutic Endoscopy for Nonvariceal Gastrointestinal Bleeding

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ABSTRACT

The evaluation and management of acute gastrointestinal bleeding in infants, children, and adolescents is a reason for emergency consultation frequently cited by pediatric gastroenterologists. After stabilization of the patient's condition, endoscopic evaluation remains the most rapid and accurate method to identify the origin of acute bleeding in the majority of lesions in the pediatric age group. Several endoscopic techniques may be applied to bleeding lesions to achieve hemostasis. Familiarity with the various techniques and with the specifics of their use is essential for the pediatric endoscopist. This review focuses on the endoscopic management of acute nonvariceal bleeding in infants and children. ***JPGN 45:157–171, 2007.*** **Key Words:** Therapeutic endoscopy injection—Heater probe—Argon plasma coagulator—MPEC—Band ligation—Thermocoagulation. © 2007 by European Society for Pediatric Gastroenterology, Hepatology, and Nutrition and North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition

ETIOLOGY OF BLEEDING

Acute gastrointestinal bleeding can occur from a variety of sources in pediatric patients. Upper gastrointestinal bleeding may arise from gastric, duodenal, and jejunal ulcers; esophageal, gastric, or duodenal varices; diffuse mucosal disease; portal hypertensive gastropathy; a Dieulafoy lesion; Mallory-Weiss tears; angiectasias, including those associated with blue rubber bleb nevus syndrome; tumors, including gastrointestinal stromal tumors; and Henoch Schönlein purpura, among other causes. Acute lower gastrointestinal causes of bleeding include ulcerative lesions; angiomata from a variety of causes; polyps; bleeding polyp stalks; colonic varices; hemorrhoids; diffuse mucosal bleeding due to ulcerative colitis, Crohn disease, infectious conditions, or radiation therapy; solitary rectal ulcer syndrome; Meckel diverticulum; intestinal duplications; and bleeding diverticula (extremely unusual in the pediatric age group), among other causes (1). Lesions can be divided into those that are amenable to endoscopic therapy and those that are not, and further characterized as those with high-risk stigmata (ie, characteristics associated with a high likelihood of ongoing bleeding or a high risk of rebleeding after initial hemostasis).

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INDICATIONS

Therapeutic endoscopy is indicated for patients with active bleeding at the time of endoscopy and for patients with high-risk stigmata or lesions associated with a high rebleeding rate identified at endoscopy. High-risk stigmata are typically associated with bleeding ulcers. They include an ulcer with evidence of active bleeding, an ulcer with oozing from beneath an overlying clot (sentinel clot), and an ulcer with a nonbleeding visible vessel at its base. A visible vessel may appear as a red, blue, or white plug or mound, sometimes referred to as a pigmented protuberance (Fig. 1). Lesions with high-risk stigmata have a 50% risk for rebleeding after an initial bleed. Actively spurting ulcers and those larger than 2 cm in diameter with high-risk stigmata are considered to be extremely high-risk lesions (2). This contrasts to an incidence of $\leq$10% of rebleeding with other lesions, including ulcers with an overlying clot without oozing or those with flat spots (3,4). Gastroduodenal vascular malformations, although an uncommon source of upper gastrointestinal bleeding, have a high risk of bleeding. Deep ulcers located high on the lesser curvature of the stomach or along the posterior-inferior aspect of the duodenal bulb may be particularly at risk for severe bleeding because of their proximity to large blood vessels. The Dieulafoy lesion, an isolated blood vessel

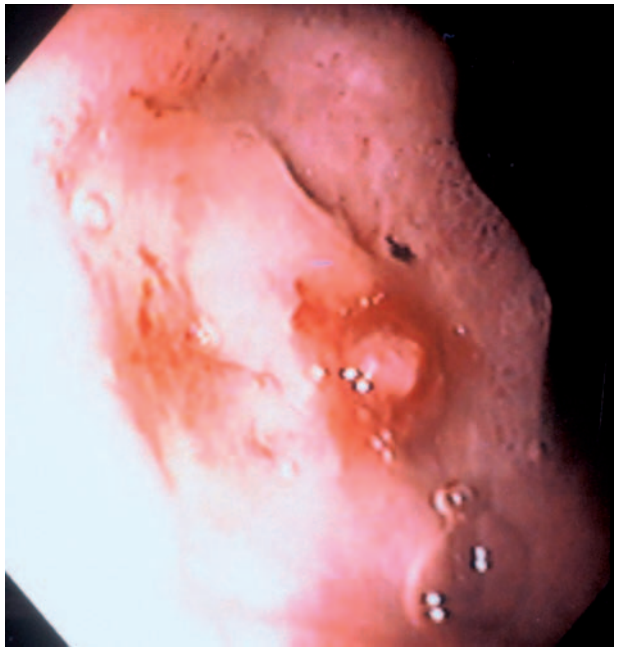

FIG. 1. Endoscopic view of a visible vessel in a duodenal ulcer in a pediatric patient.

protruding through a small nonulcer mucosal defect, is associated with a high complication rate if left untreated. The complication and rebleeding rates of this lesion significantly decrease with effective endoscopic therapy. Diffuse mucosal bleeding from duodenitis or gastritis is usually not responsive to endoscopic intervention, except for portal hypertensive gastropathy. Esophageal varices may also have endoscopic characteristics that are associated with a high rebleeding rate, but these are outside the scope of this review.

Colonic lesions amenable to endoscopic therapy include bleeding ulcers, angiomata, polyps and bleeding polyp stalks, and hemorrhoids. Diffuse mucosal bleeding due to radiation proctitis is treatable, with the recent application of the argon plasma coagulator (APC) for this indication. Colonic varices, either caused by portal hypertension or hereditary, are less amenable to endoscopic therapy than their upper tract counterparts because of their diffuse nature unless a discrete bleeding point is identified at the time of endoscopy. Some authors believe that in the colon an adherent clot in a single diverticulum or an ulcerative lesion, resistant to washing with fresh blood nearby and no other visible lesion, may also be a lesion at high risk for rebleeding and therefore be amenable to endoscopic therapy (5).

PREPARATION

Emergent gastrointestinal endoscopy carries an increased risk of complications compared with routine endoscopy. They include risk of aspiration of gastric contents in a stomach full of blood, and a higher risk associated with sedating an actively bleeding patient or a patient with decompensated cardiopulmonary or hepatic function. The increased risks associated with emergent gastrointestinal endoscopy necessitate close monitoring of the airway and cautious patient sedation. In emergency situations general anesthesia offers advantages to the endoscopist by providing a controlled airway, close monitoring of cardiorespiratory function, and an immobile patient. If conscious or deep sedation is used, then the medication dosages should be reduced to avoid further impairment of the patient's respiratory and cardiopulmonary status, and continuous monitoring of pulse oximetry and blood pressure and also intravenous access should be maintained. In a pediatric intensive care unit a pediatric intensivist may assist with the sedation and monitoring. Patients undergoing therapeutic endoscopy should be volume resuscitated before the procedure if possible in an attempt to ensure hemodynamic stability during the procedure.

Preparation for emergent endoscopy differs from that for routine procedures. The patient has not necessarily fasted for several hours before the procedure and may not have undergone an adequate colonic cleansing, in the case of colonoscopy. In upper endoscopy, placement of a nasogastric tube with irrigation and removal of the gastric contents may be helpful. A clear nasogastric aspirate does not rule out a major gastrointestinal hemorrhage. Blood from the stomach can also be removed under direct vision at the time of the endoscopy, an approach favored by many endoscopists. For colonoscopic procedures blood in the digestive tract tends to act as a cathartic, and a full preparation, although preferred, may in some cases not be required. If a patient is hemodynamically stable, then nasogastric administration of a balanced electrolyte solution (ie, a rapid purge) may increase the ability of the endoscopist to visualize a single lesion that may be acting as the bleeding source. There is also a theoretic risk of combustion in the colon when electrocautery is performed in an inadequately prepared colon (6). In most cases of gastrointestinal bleeding, the endoscopist should be prepared to perform an upper endoscopy, even if the patient presents with hematochezia. This is done to rule out an upper tract source with rapid gastrointestinal transit because of the cathartic effect of blood within the gastrointestinal tract.

TECHNIQUES

Five endoscopic techniques can be used to control acute gastrointestinal bleeding: injection, coagulation/thermal therapy, laser therapy, and application of hemostatic devices or ligation devices. The specific technique used depends on equipment availability and experience of the endoscopist. The techniques seem to have roughly

equivalent efficacy, although different degrees of difficulty are associated with each technique (7).

Therapeutic endoscopy is most easily accomplished with use of a 2-channeled therapeutic scope so that therapy (eg, injection, coagulation) may be accomplished via 1 channel, and simultaneous suction, irrigation, or aspiration can be performed via the second channel or with a 1-channeled therapeutic scope. Unfortunately, therapeutic endoscopes have a larger diameter than standard endoscopes and cannot be routinely used in pediatric patients, but they may be used in some adolescents. Therapeutic endoscopy may still be performed with a single-channel scope; however, it is technically more difficult. Endoscope manufactures have adapted some current endoscopes so that irrigation can be performed using separate flushing pumps. In addition, equipment manufacturers have developed combined-use endoscopic accessories so that, for example, sequential injection and coagulation can be performed with use of a single probe to increase the efficiency of the endoscopic procedure.

Sclerotherapy needles for endoscopic injection consist of an outer sheath composed of plastic, Teflon, or stainless steel and an inner hollow-core needle, whose size may range from 21 to 25G with a needle length from 4 to 8 mm. The 23G and 25G needles are required with a 2-mm endoscopic channel; 21G needles are used with a 2.8-mm channel. Metal needles are particularly helpful for injection in the retroflexed position of the gastric cardia or elsewhere, where shearing of a plastic needle sheath may occur with repeated flexion and extension of the endoscope. A combined injection needle–multipolar probe and a combined injection needle–snare are available to allow for sequential injection and coagulation (Injection Gold Probe, Boston Scientific, Natick, MA, and iSnare US Endoscopy, Mentor, OH). These devices require a minimum 2.8-mm endoscopic channel for the smaller size (7F) probe and a 3.7-mm channel for the 10-F probe and snare. Heater probes are available in 2 sizes; the small 2.4-mm probe is used with a 2.8-mm channel endoscope, and the large 3.2-mm probe can be used in an endoscope with a 3.7-mm channel. Multipolar probes (MPEC) (BICAP, ACMI, MA; Gold Probe, Microvasive, MA) are also available in 2.4-mm and 3.2-mm sizes. The use of a laser requires at least a 2.8-mm channel. The probes for the APC are available in 2 sizes: 2.3 and 3.2 mm. The application of bands for ligation requires a standard-size adult upper endoscope. Other ligating devices and hemostatic clips also require a 2.8-mm channel.

Standard pediatric gastroduodenoscopes have a 2.0-mm channel and a 4.9- to 6.0-mm outer diameter. These endoscopes will therefore accommodate needles for injection therapy but will not allow the use of a heater probe, multipolar probe, laser, ligating, and/or hemostatic devices. Standard adult gastroduodenoscopes have a 2.8-mm channel and an outer diameter in the range of 8.6 to 9.8 mm. Although their channel size is sufficient for the small MPEC and small heater probes, the outer diameter of these endoscopes may be prohibitive in smaller pediatric patients. Adult therapeutic gastroduodenoscopes have either 1 or 2 therapeutic channels ranging in size from 2.8 to 3.8 mm and an outer diameter in the range of 11.3 to 12.9 mm. Their larger diameter usually precludes their use in younger pediatric patients (Olympus America, Inc, Center Valley, PA; Pentax Medical Co, Montvale, NJ).

Pediatric colonoscopes have a 2.8- to 3.8-mm channel and an outer diameter ranging from 11.3 to 11.7 mm. Adult standard and therapeutic colonoscopes have channel diameters ranging in size from 2.8 to 4.2 mm, with dual channel scopes available, with outer diameters ranging in size from 12.8 to 13.7 mm (Olympus America and Pentax Medical Co).

Because of the increased channel size of dedicated pediatric coloscopes, they can be used to perform injection therapy, thermocoagulation, laser therapy, and application of hemostatic and ligating devices in most patients. Representative accessories for therapeutic endoscopy are shown in Table 1.

Injection

Rationale and Mechanism of Action

Injection therapy is used for both variceal and nonvariceal bleeding. Nonvariceal injection therapy is usually performed by injection of a sclerosing agent at 3 or 4 sites around an exposed bleeding vessel and then directly at the site of the vessel (Fig. 2A). The rationale for this technique is that a visible vessel is not an end artery and that for effective hemostasis, tamponade of the feeding vessel is required (Fig. 2B). The precise mechanism of the various sclerotherapeutic agents is controversial, although most authors believe that hemostasis results from a combination of vasoconstriction, mechanical tamponade, and cytochemical mechanisms. A bleeding model using gastric serosal blood vessels in dogs suggests that a combination of factors may contribute to formation of the hemostatic plug (8). Whittle et al (8) tested hemostatic solutions of normal saline, 3% hypertonic saline, epinephrine mixed with either normal or hypertonic saline, and thrombin cocktail (thrombin, cephapirin, tetradecyl) in dogs. Significant decreases in the blood flow rate of transected vessels were achieved with all of the solutions, except for old thrombin cocktail, in comparison with control animals. However, the degree of histological damage differed among the various solutions, ranging from mild muscular hemorrhage and subserosal edema in the normal saline group to marked edema of the gastric wall with hemorrhage into the muscularis and hyaline necrosis of the muscle and blood vessels in the thrombin group. The authors concluded that the various solutions exerted a variety of

TABLE 1. *Selected endoscopic accessories*

Type	Diameter/size	Min endoscopic channel required (mm)	Representative products and manufacturers
Injection needle	23G, 25G	2.0	Various
	21G	2.8	
Injection-coagulation catheter	7F (25G)	2.8	Injection gold probe/Boston Scientific
	10F (25G)	3.7	
Injection-polypectomy snare	3.0 mm (25G)	3.7	iSnare/US Endoscopy
Heater probe	2.4 mm	2.8	Olympus
	3.2 mm	3.7	
Multipolar probe	2.4 mm	2.8	BICAP-ACMI
	3.2 mm	3.7	Gold probe/Boston Scientific, Wilson-Cook, etc
APC	1.5 mm	2.0	ERBE USA Inc
	2.3 mm	2.8	
	3.2 mm	3.7	
Hot biopsy forceps	2.5–2.6 mm	2.8	Olympus, Wilson-Cook
	3.4 mm	3.7	
Hemostatic clips	2.2 mm (7F)	2.8	Boston Scientific, Olympus, ∗Wilson-Cook, etc
	∗Triclip (8F)	3.2	
Detachable loops	2.6 mm	2.8	Olympus

Not all of the manufacturers of each accessory are included. Individuals should consult the manufacturer's Web site or product information for the most up-to-date information.

effects. Immediately after an injection, hemostasis is facilitated by compression and tamponade of the bleeding vessel by submucosal expansion (8–10). Epinephrine-containing solutions exert an additional vasoconstrictive and platelet-aggregative effect to further reduce the blood flow rate. However, this effect is transient, and therefore epinephrine is often combined with a longer-acting hemostatic or sclerosing agent. Hypertonic solutions may produce tissue edema and degeneration of the vascular lumen, thereby prolonging the effects of other injected agents (11). Although thrombin cocktail is not often used, it combines the thrombin effect of increased conversion of fibrinogen to fibrin with the sclerosant effect of alcohol. Sclerosant solutions or solutions containing ethanol may produce significant tissue damage and ulcer extension. This is particularly evident if follow-up endoscopy is performed within 24 to 48 hours after injection or esophageal sclerotherapy. Ulceration after therapeutic injection does not seem to prolong peptic ulcer healing rates. In animal models, after a standard volume of injection, there is characteristically a central area of necrosis secondary to extreme tissue dehydration surrounded by a ring of edema, and inflammation with an associated vasculitis. Nearly all of the blood vessels in the central area are thrombosed. There is a clear linear relation between the volume of alcohol injected and the extent of damage (12). Unlike epinephrine, the lesions produced after alcohol or sclerosant injection may be more pronounced in the submucosa than in the mucosa.

Technique

Table 2 lists the most commonly used solutions, their concentrations, appropriate volumes, and estimated maximal volumes. Several caveats should be noted. Except under unusual circumstances, injection therapy should be confined to a single solution (single agent or a combination agent) during a given injection episode. The use of 2 sequential solutions may increase the risk of complications with smaller volumes of sclerosant than would be required with a single agent alone. The injection site (into vessel vs surrounding vessel vs submucosal) is specific for certain agents. Without appropriate clinical trials, changing the site of injection is probably hazardous. Maximal volumes of sclerosant have been established in adults to minimize the risk of ulcer extension or perforation. Maximum volumes of sclerosants in pediatric patients have not been studied; however, maximal adult volumes should not be exceeded. Complications including perforation may occur with volumes of injection less than the recommended maximum volumes.

The ability to therapeutically inject a bleeding ulcer and achieve hemostatic control may also be limited by the location of the ulcer (13). In some cases tangential application of a heater probe or multipolar electrocoagulation probe may be easier to perform, especially along the lesser curvature of the stomach or the superior wall of the duodenal bulb. Successful injection of bleeding ulcers within other lesions, such as gastric leiomyomas, has also been reported (14).

Precise volumes of injection are required, and the importance of knowing the appropriate volumes of specific agents cannot be overemphasized. The volume of absolute alcohol required to achieve hemostasis may be one tenth or less of the volume required with epinephrine. Agents that require smaller volumes of injection may be more technically difficult to use. For

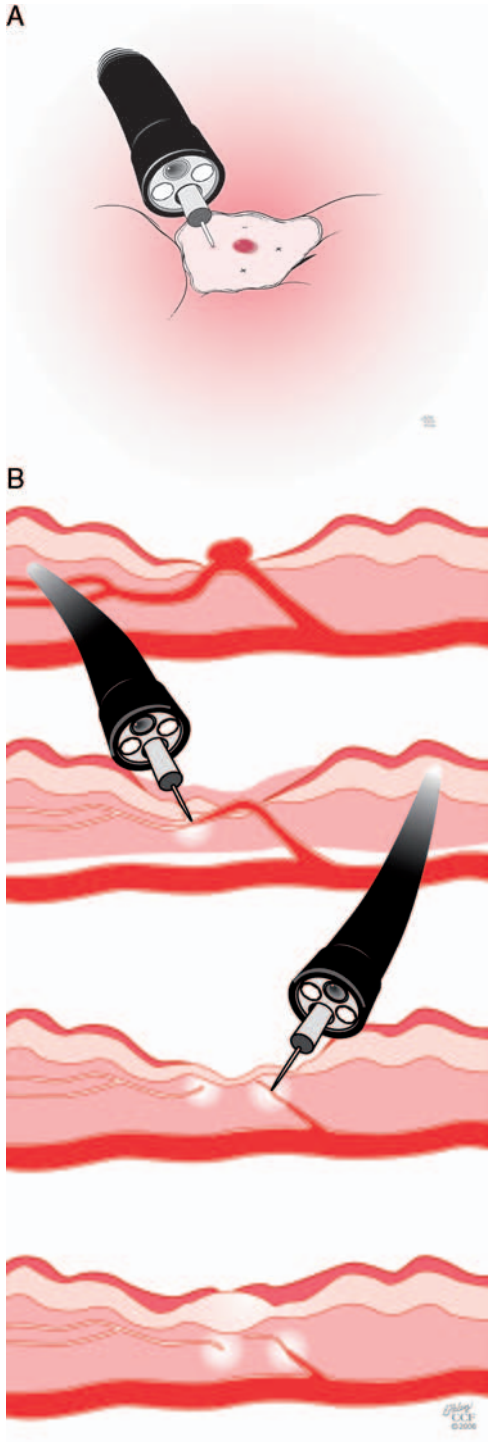

FIG. 2. Endoscopic injection of a sclerosing solution around a visible vessel. Because the vessel is not an end artery, therapeutic injection is performed circumferentially around the vessel. A, Top view. B, Side view.

example, if absolute alcohol is used as a sclerosing agent, it should be injected via a tuberculin syringe slowly at a rate of 0.2 mL/2 s with maximal total volumes of 0.6 to 1.2 mL.

Injection therapy using epinephrine in saline 1:10,000 or 1:20,000 has also been used in cases of lower gastrointestinal bleeding. In cases of active bleeding, injection may be combined with thermal therapy; if a nonbleeding visible vessel is present, thermal therapy alone may be sufficient (5). Injection therapy of the colon is most easily performed by injection of the proximal aspect of the lesion first and distally thereafter (Fig. 3). This avoids a compromised view of the lesion caused by submucosal swelling at the injection site.

Benefits

Injection therapy has been shown in several trials to be beneficial compared with sham therapy in patients with active bleeding or a nonbleeding visible vessel in a peptic ulcer. Several recent reports have demonstrated a benefit of combination therapy with injection and either thermal therapy (multipolar electrocoagulation or heater probe) or mechanical therapy (hemoclip) in comparison with either modality alone, in terms of reduction of rebleeding rate and decreased need for blood transfusions (9,10,15,16). In addition, the administration of a high-dose proton pump inhibitor after endoscopic therapy for ulcers with high-risk stigmata has been shown to reduce the rate of recurrent bleeding and need for emergency surgery (17).

Adverse Effects

The risks with injection therapy include increased bleeding, rebleeding, bowel ischemia, and perforation (11). The injection of increased volumes of a hemostatic sclerosant solution may result in bowel wall ischemia and subsequent perforation (18,19). The injection of volumes normally considered safe within the stomach may cause perforation and/or peritonitis in the thinner-walled duodenum or colon (12). The injection of a combination of agents, such as a sclerosant with epinephrine, may decrease the maximum safe volume that may be normally used with either agent alone because of potentiation of the ischemic effects of the sclerosant by the vasoconstrictive actions of the epinephrine (20).

Systemic side effects of injection therapy are a potential complication of this modality. Epinephrine absorption does seem to occur after submucosal injection with blood levels as much as 5 times greater than preinjection levels. This effect may be especially pronounced in patients with cirrhosis or impaired hepatic metabolism (21). Rarely, significant intracerebral hemorrhage in adult patients has been reported after epinephrine

TABLE 2. *Sclerosants for nonvariceal bleeding*

Solution	Concentration	Volume/no. of injections/location	Max total volume	Comments
Hypertonic saline-epinephrine combination	3.6% saline + 1:20,000 epinephrine or	3 mL 3–4 injections at base of bleeding vessel	9–12 mL	Repeat prophylactic injections if visible vessel present 24–48 h after first hemostasis
	7.2% saline + 1:20,000 epinephrine*	1 mL 3–4 injections		For lesions with extensive fibrosis*
Epinephrine with normal saline	1 mL 1:1,000 epinephrine + 9 mL normal saline	0.5–2.0 mL injected in multiple sites around bleeding vessel and into bleeding point itself	10 mL	Larger volumes in range for spurting vessels
Epinephrine followed by polidocanol	Epinephrine 1:10,000 5–10 mL Polidocanol 1% 5 mL	Inject epinephrine into submucosa directly around blood vessel to achieve hemostasis by compression/ vasoconstriction, then obliterate vessel with polidocanol	Epinephrine 5–10 mL Polidocanol 5 mL	May substitute bipolar coagulation or Nd:YAG laser for polidocanol
Thrombin in normal saline	100 IU thrombin in 3-mL normal saline	Inject into bleeding vessel 10–15 mL total volume	10–15 mL	
Absolute ethanol	98% dehydrated ethanol	0.1–0.2 mL/injection at 3–4 sites surrounding bleeding vessel and 1–2 mm away from vessel	0.6–1.22 mL total	Inject via tuberculin syringe slowly (0.2 mL/2 s); extension/perforation significant risk if maximum volume exceeded; may be more technically difficult to control volume
Epinephrine with normal saline for polypectomy	1 mL 1:1,000 epinephrine + 9-mL normal saline	1.0–2.0 mL per injection injected in multiple sites (3–4) around polyp to be raised up	30 mL	Goal is lack of vascular markings within injection site

* 3.6%/0.005% epinephrine prepared by combining 1 part solution A (20 mL 15% NaCl solution and 1 mL 0.1% epinephrine) to 3 parts of solution B (20 mL distilled water, with 1 mL 0.1% epinephrine). 7.2%/0.005% prepared by combining equal parts (1:1) of solutions A and B.

Adapted from reference 1.

injection. The postulated mechanism is a previously unrecognized cerebral microaneurysm that bleeds as a result of an abrupt increase in intracranial pressure after a sudden rise in systemic pressure (22,23).

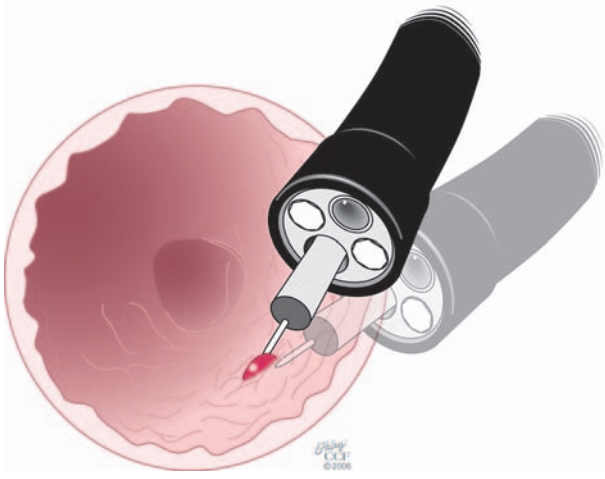

FIG. 3. Endoscopic injection of a visible vessel in the colon. The proximal aspect is injected initially to avoid a compromised view caused by submucosal swelling after injection.

Thermocoagulation

Thermocoagulation may be performed with a variety of equipment, including the heater probe, monopolar coagulator, bipolar/multipolar coagulators, and the APC. A summary of thermocoagulation techniques is indicated in Table 3.

Heater Probe

The heater probe is composed of a Teflon-coated hollow aluminum cylinder with an inner heater coil with a maximum internal temperature. A thermocoupling device at the tip of the probe maintains a constant temperature. Probe activation results in delivery of a preselected amount of energy in joules to the probe tip. Once the pulse has been initiated, the duration of activation is predetermined (10). The probe reaches its operational temperature of 250°C by 0.2 seconds and cools by 0.5 seconds. Tissue coagulation occurs by direct heat transfer. The probe is water perfused to prevent tissue adherence, an advantage over monopolar coagulation. There are small- (2.4 mm) and large- (3.2 mm) diameter probes.

TABLE 3. *Thermocoagulation*

Method	Site	Setting	Application time	No. applications	Technique	Notes
Heater probe	Upper GI tract	30 J	3–8 s	2–4	Firm tamponade, then coagulate around bleeding point, then on it	Decreased setting/ time of application in colon or thinner gut wall
Monopolar	Upper GI tract	Midrange	1–2 s/pulse		Directly on vessel <1-mm diameter; circumferentially around vessel >1-mm diameter	Perforation likely in colon
Bipolar/multipolar	Upper GI tract	15–25 W	2 s/pulse or Up to 14-s pulse	Multiple Single	Firm tamponade, then coagulate	Difficult angulation lesser curve or deformed duodenum
	Colon	5 W	2 s/pulse	Multiple		
Argon plasma coagulator	Upper GI tract	40–50 W 0.8 L/min	0.5–2 s	Multiple	Operative distance 2–8 mm	Paint confluent or near confluent areas; avoid tissue contact with probe tip; surface should be free of liquid
Hot biopsy forceps	Cecum and ascending colon	10–15 W	1–2 s		Tent mucosa away	Use for polyps ≤ 5 mm; contraindicated in upper GI tract
	Left colon	15–20 W	2 s			

Adapted from reference (1).

The probe is passed through the therapeutic channel of the endoscope. In cases of upper gastrointestinal tract bleeding the patient should be positioned so that the blood flows away from the ulcer base if possible to allow optimal probe application. Heater probe coagulation is performed by initially tamponading the bleeding vessel by direct firm pressure using the heater probe, and then by coagulating the vessel (Fig. 4). This technique, which is fundamental to the efficacy of heater probe use, is known as coaptive coagulation. If a twin-channel instrument is used, the endoscopist is able to tamponade the bleeding with the probe while simultaneously suctioning in the region of the ulcer base. Coagulation is usually performed in adults by 2 to 4 successive 30-J pulses (4). Coagulation should be around the bleeding point or stigmata first and then directly upon it. In several studies in adults the greatest success seems to be with firm tamponade on the ulcer bleeding point or nonbleeding visible vessel, and 4 pulses for a total of 120 J in succession (4). This technique of firm tamponade and high-coagulation settings increases the risk of complications when applied to other types of lesions, specifically Mallory-Weiss tears or angiomata, that traditionally occur in areas with a thinner gut wall, and modification of settings is required (4). The heater probe may also be used in cases of colonic bleeding. The number of joules per pulse should be reduced, especially in right-sided colonic lesions (5,24).

The technique of using a large probe, high setting for coagulation, and very firm pressure seems to result in a lower rebleeding rate, decreased transfusion requirement, and especially a lower emergency surgery rate in randomized control studies compared with medical therapy alone, and in equivalent results to those achieved with MPEC (4,24). One study reported higher permanent hemostasis rates when the heater probe was used than with injection therapy because of the diminished technical difficulty of heater probe application to a spurting vessel or one that requires tangential coagulation along the lesser curvature or superior wall of the duodenal bulb, compared with the greater technical difficulty of performing injection at those same sites (25). Dislodgement of the heater probe tip during therapy has been reported. In that instance the tip was retrieved by standard biopsy forceps (26). In 1% to 3% of cases perforation may occur after heater probe application for gastrointestinal bleeding because of the variable depth and extent of tissue injury after application (27). Precipitation of bleeding has been reported in up to 5% of cases after heater probe application (10).

Electrocoagulation

There are 2 main types of electrocoagulation probes: monopolar probes and bipolar or multipolar probes (MPEC). In monopolar coagulation a continuous or intermittent current is passed via the tip or side of the probe. The current is conducted to the patient's ground plate. The current is converted to high-temperature heat at the tissue contact point, which coagulates the tissue, causing collagen contraction and vessel shrinkage. For vessels <1 mm in diameter, the electrode is placed directly on the vessel, and pressure is applied directly on the vessel to coapt it. With larger vessels the coagulating current is placed circumferentially around the vessel until bleeding stops. Usually a midrange setting is used

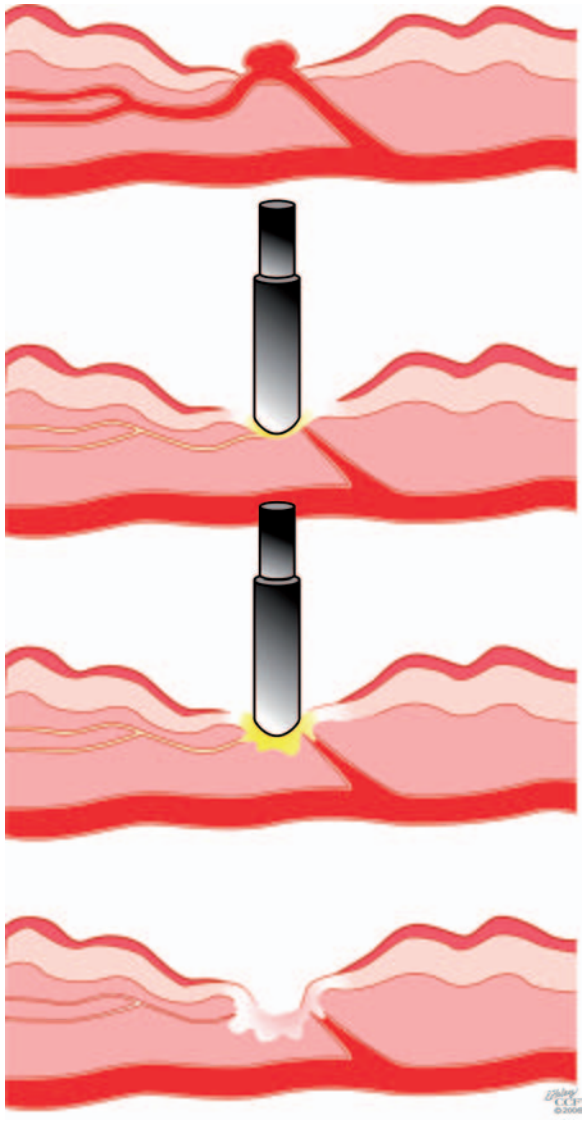

FIG. 4. Coaptive coagulation using a heater probe. A, B, Initially the exposed vessel is tamponaded by direct firm tangential pressure, using the heater probe until blanching of the vessel occurs. C, The heater probe is then used to coagulate the blood vessel. D, After coagulation, the exposed vessel appears blanched.

for 1 to 2 seconds per pulse at a distance of 2 to 3 mm from the vessel. This is necessary because an artery in an ulcer base may bleed from either side because it is not an end artery; therefore, a ring of tissue must be treated around the bleeding point to ensure adequate hemostasis. The aim is to achieve hemostasis of the underlying artery, not the overlying clot. There are 2 main problems with monopolar coagulation. The first is that the depth of the burn is difficult to regulate, and perforation is therefore possible. This is especially true in the colon. Deep necrosis, perforation, and delayed massive bleeding have been reported with monopolar electrocoagulation. The second problem is that especially in nonirrigated systems, there is a moderate amount of electrode adherence to the underlying tissue at the treated site, and poor visibility is an additional problem. A third technical problem is the need to clean the tip of the probe because the coagulum accumulates during electrocoagulation.

Because of these limitations, the bipolar probe or MPEC is more commonly used. In contrast to monopolar coagulation, a grounding plate is not required. Current is transmitted from 1 electrode on the probe to another electrode. Energy is delivered when any pair of electrodes is in contact with the bleeding target. MPEC probes may have 6 points through which current can be passed; contact between any 2 is sufficient, allowing for tangential contact. The maximal temperature achieved with this method is significantly less than that of monopolar coagulation or the Nd:Yag laser, resulting in less tissue injury and also greater efficacy for vessels <2 mm in diameter (28). Two sizes of probes are available: 2.3 mm and 3.2 mm. As with the heater probe, the correct technique is to compress the bleeding vessel first, then to coagulate. Forceful application of the larger probe seems to increase the hemostatic bond strength and the area and depth of coagulation (28). The greatest depth of coagulation is usually achieved with a low- to mid-range setting (l5–25 W). Higher watt settings produce more rapid tissue desiccation. Because tissue water is necessary to complete the electric circuit between 2 electrodes on the bipolar probe, higher settings in effect terminate the production of thermal energy earlier, thereby reducing hemostatic efficacy (29). Pulses should be applied as short, multiple pulses (2 seconds long) or a single pulse as long as 6 to 10 seconds (28). In adults, up to 40 seconds total of electrocoagulation may be required (28). Increased bleeding after bipolar coagulation has been reported in cases with a visible vessel; usually this bleeding is controllable with further bipolar coagulation, but on occasion surgery has been required.

The therapeutic endpoint for ulcer bleeding is when the bleeding stops, the visible vessel is flat, or there are flat stigmata in cases of a nonadherent clot. MPEC seems to be equally effective to heater probe in terms of hemostasis, incidence of rebleeding, transfusion requirement, and need for emergency surgery. Several studies report a hemostasis rate in the range of 90% for both modalities (28,30). Difficult positioning of the MPEC probe along the lesser curvature or in a deformed duodenum may make pressure application more difficult (30). Combination therapy for ulcers with high-risk stigmata using injection and thermocoagulation, as discussed earlier, seems to be associated with higher initial hemostasis rates and a decreased incidence of rebleeding (9,16,27,31). In addition to sequential combination therapy, a combination probe (Injection Gold Probe) is available that allows for sequential injection and coagulation without the use of a

dual-channel endoscope or catheter exchange. Both 7F and 10F probe sizes are available.

Angiodysplasia, involving either the stomach (gastric antral vascular ectasia, also known as watermelon stomach) of the colon, has been treated successfully by MPEC. In cases of angiodysplasia, especially in the thin-walled colon, a maximal depth of coagulation is not desirable. Therefore, the MPEC probe should be applied with decreased force, with lower watt settings, and for shorter intervals (5,10,29). Identification of colonic vascular ectasias may be enhanced in some cases by intraprocedural naloxone administration (32). Hemorrhagic proctocolitis with recurrent bleeding after radiation therapy has also been successfully treated with MPEC, although the APC is becoming increasingly popular for this indication.

Argon Plasma Coagulator

The APC is a noncontact electrocoagulation device that results in delivery of high-frequency monopolar current through ionized gas (argon plasma) to targeted tissue (33). The system requires a high-frequency monopolar electrosurgical generator, an argon gas source, disposable flexible probes, a grounding pad, and foot controls that result in synchronous gas release and electrical current delivery (10). The probes, consisting of a Teflon tube with a tungsten monopolar electrode contained in a ceramic nozzle close to the distal end of the probe, are 2.3 or 3.2 mm outer diameter and are available in lengths of 220 or 440 cm. Probes are available to direct plasma either parallel or perpendicular to the axis of the catheter (10). Gas flow rates can be varied from 0.5 to 7.0 L/min, the power settings vary from 0 to 155 W, and the generator voltage ranges from 5000 to 6500 V. Argon gas passes through the coagulation probe with an electrode at its tip. The electrode is activated by the foot switch, resulting in a flow of electrically activated ionized gas from the probe to the tissue (33). Ionization of the gas and the presence of a return electrode (the grounding pad) results in conduction of the spark to the nearest contact point. Arrival of the current at the tissue results in coagulation. If no electrical energy is discharged by arcing to nearby tissue, then no ignition occurs, and activation of the foot switch results only in insufflation of inert argon gas. After thermal coagulation, a thin superficial electrically insulating zone of desiccation occurs. After desiccation, the electrical resistance of the treated area increases, prompting the current to move to another area of lower resistance (ie, an untreated area) (10). The depth of coagulation is dependent on the power setting, the gas flow rate, the duration of application, and the distance between the probe tip and the target tissue. The noncontact nature of the technique makes it possible to treat large areas rapidly, in comparison with the heater probe or MPEC (34).

Applications for the APC include hemostasis of vascular ectasias, including gastric antral vascular ectasia, angiectasias, and radiation-induced enteropathy/proctopathy; treatment of bleeding ulcers; treatment of residual adenomatous tissue; and for ablative therapy (33,35–39). The primary pediatric indication is likely to be treatment of symptomatic gastrointestinal vascular lesions. Superficial vascular lesions in adults are typically treated with low power settings and gas flow rates. Multiple therapy sessions are frequently required, spaced several weeks apart to allow for interval healing. In adults, settings are in the range of 20 to 50 W with flow rates of 0.8 to 1.0 L/min (34,35). In cases of vascular malformations the treated mucosa should be rendered nonviable (whitish appearance) but not charred (black appearance). Right-sided colonic lesions may be elevated with a saline cushion before treatment to reduce the risk of perforation, and the minimum number of accurate pulses should be administered in this location (34). Appropriate modifications will be required in pediatric patients, with current generators having minimum gas flow rates of 0.5 L/min. Postprocedure management for upper tract lesions may include a period of fasting or dietary restriction and administration of a proton pump inhibitor for several weeks. Repeat sessions for vacular lesions are typically scheduled in 4 to 6 weeks to allow for interval healing and are then performed as needed (34). In addition to vascular lesions, the APC has been used in combination with injection therapy for adults with peptic ulcer bleeding and high-risk stigmata. APC in combination with epinephrine seems to be equally efficacious as combination therapy consisting of heater probe and epinephrine injection in terms of initial hemostasis rates (96% to 98%), risk of recurrent bleeding, and requirement for surgery in a large series of adult patients (27).

Optimal use of the APC generally requires an operative distance of 2 to 8 mm between the probe tip and the tissue (33). The lower power settings allow for closer tissue contact. Arcing of the current with depression of the foot pedal will not occur if the correct operative distance is exceeded. The surface to be treated should optimally be cleared of liquid and blood, limiting the usefulness of the APC in cases of active bleeding. If the overlying surface is not clear, then a coagulated film may develop and the tissue beneath the surface may not be adequately treated (33). The correct technique is to ''paint'' the surface to be treated. This is most easily accomplished by extending the probe to an optimal operating distance and moving the endoscope shaft to ''paint'' the confluent area to be coagulated. Application may be either en face or tangential and is usually performed in short bursts up to 2 seconds (33,35). The probe tip should not contact the tissue because this is a monopolar probe and deep tissue injury may occur with contact, although the safety of the technique is not forfeited by occasional inadvertent tissue contact (34). Care must also be taken to continuously

aspirate the argon gas, which is flowing under steady pressure whenever the foot switch is activated during the procedure, because failure to do so can result in overdistension of the stomach or bowel, especially in smaller patients. In patients in whom the procedure is performed without benefit of a 2-channel endoscope, this requires intermittent probe removal to optimize aspiration of gas. To date there has been 1 pediatric series of 13 patients using the APC primarily for bleeding (40). In that series the APC was effective in achieving primary hemostasis after the first session in 66% of patients, with a 25% rebleeding rate and a 17% minor complication rate. Complications have been reported in 0% to 24% of patients in various adult series (33–37) and include gaseous distension, pneumatosis intestinalis, pneumoperitoneum, pneumomediastinum, subcutaneous emphysema, pain at the treatment site, chronic ulceration, stricture, bleeding, transmural burn, perforation, and death. In comparative trials the APC seems to be associated with a lower complication rate than laser therapy (34). The APC is more costly than a heater probe, but the costs are less than those associated with the Nd:YAG laser. The APC generator can in addition be used for other applications.

Laser Photocoagulation

Laser photocoagulation is another modality occasionally used to achieve endoscopic hemostasis. There are 2 main types of laser: argon and neodymium:yttrium-aluminum garnet (ND:Yag). The usefulness of the argon laser is limited because of light absorption by surrounding red blood. To use the argon laser, therefore, overlying blood must be eliminated with a coaxial air jet. Clinically, the argon laser is used primarily for right-sided colonic lesions. In comparison with the Nd:Yag laser, it has a lower power and depth of tissue penetration. However, mucosal abnormalities, including arteriovenous malformations, absorb light energy well in the argon wavelength.

The ND:Yag laser is the predominant laser used in gastrointestinal endoscopy. This laser admits a continuous wave of infrared light of a wavelength of l064 with a power up to 100 W. This light is transmitted via a 600-μm glass fiber in a 2.5-mm Teflon catheter passed via the endoscopic channel. Carbon dioxide is passed coaxially along the catheter to disperse blood away from the bleeding site and to keep the fiber tip cool and free of debris. A filter is attached to the eyepiece to prevent reflected laser light from entering the endoscopist's eye. The intense laser light is directed to coagulate tissue circumferentially around the bleeding site. The recommendation when a noncontact laser is used in adult patients is to deliver 0.5-second pulses, at 80 W of energy, from a distance of l cm, and at least 2 to 3 mm away from visible arterial segments for upper gastrointestinal lesions. Recommendations for contact application are also available.

Use of the laser in the colon requires modification of both technique and power settings. The thermal effects of a laser beam on tissue vary according to the power density (the amount of energy converted to heat at the point where the laser beam strikes tissue) and the size of the contact area. Although the power setting and the exposure time can be preset, movement, especially in the right colon, and varying wall thickness, especially in the thin ascending colon, can change the time of exposure required to produce perforation (41). Instead of coagulation of tissue, vaporization of tissue can occur. Colonic perforation secondary to laser photocoagulation is a serious risk, is more frequent in the cecum and right colon, and occurs more frequently with the Nd:Yag laser. Laser burns may present with nausea, vomiting, and air in the colon wall in cases of serosal burns with or without associated free intraperitoneal air. Lasers have been used for congenital vascular lesions (hereditary hemorrhagic telangiectasia, blue rubber bleb nevi syndrome) and for superficial vascular lesions including angiodysplasia, telangiectasias, and arteriovenous malformation in the small bowel and colon (42,43). Asymptomatic, nonbleeding angiodysplasias are not treated. Histological diagnosis may be difficult after laser application because of tissue destruction. As with other methods of thermocoagulation, laser therapy can also provoke bleeding; this usually can be stopped with additional laser coagulation. A long learning curve is associated with use of the laser, and this modality should be used only by experienced operators. The laser seems to offer little advantage over the heater probe, MPEC, and APC, and because of its increased cost and decreased portability, the other modalities are likely to predominate in the foreseeable future.

Hot Biopsy Forceps

An additional coagulation device, used primarily in the colon, is the hot biopsy forceps. These forceps are used primarily for simultaneous biopsy and coagulation of small sessile colonic polyps and allow for preservation of histological features after coagulation. In addition, they have been used for the treatment of vascular ectasias (44,45). The forceps require a minimum 2.8-mm endoscopic channel. This technique combines the principles of endoscopic biopsy and monopolar electrocoagulation. Grounding of the patient is required. The lesion to undergo biopsy is grasped in the jaw of insulated biopsy forceps, including polyps up to 5 mm. The forceps are used to tent the mucosa upward away from the colonic muscular layer. A brief electrocoagulating current passes through the forceps to the mucosa and sometimes submucosa, causing coagulation at its base while preserving the histological integrity of the specimen. The unit is set on coagulation, no cutting, at a setting of 10 to 15 W for 1

to 2 seconds in the cecum and ascending colon, or up to 15 to 20 W for 2 seconds in the left colon. Small angiomata of the colon may be coagulated by use of a similar technique for 1 to 2 seconds (45). Higher settings or longer application times have been associated with an increased risk of perforation, especially in the right colon (44,46).

Perforation has also been reported after the use of hot biopsy forceps in the upper gastrointestinal tract, both in the stomach (secondary to increased gastric thickness limiting tenting of the mucosa) and in the duodenum and ileum (secondary to thinness of the bowel wall and variable depth of penetration.) (44) In the colon the risk of perforation seems to be intermediate at 0.05%, less than that associated with snare polypectomy but greater than associated with routine biopsy. Snare polypectomy is preferred for lesions larger than 5 mm because of the increased risk of transmural injuries and complications with hot biopsy forceps. Significant hemorrhage has been reported after the use of hot biopsy forceps. Failure to hold the forceps perpendicular to the mucosa increases the risk of this complication. Short-circuiting of the current between the forceps tip and the noninsulated portion of the forceps with resultant massive hemorrhage has been reported if the forceps are held at an angle of 15° or less to the bowel wall (46). Hemorrhage may be immediate or delayed as long as 1 week after biopsy and may not respond to conservative therapy. Perforation may also occur if the tip of the polyp being coagulated or the forceps touches the opposite colonic wall, with subsequent transmural injury. Injection, MPEC, and clipping, discussed below, are therapeutic options for postpolypectomy hemorrhage.

Hemostatic Clips

Over the past several years, metallic clips have been developed that can be passed through the endoscope channel and deployed for a variety of indications, including hemostasis, attachment of catheters or tubes, marking, and closure of fistulas, leaks, tears, and perforations. Originally, clips were deployed with reusable deployment devices. Loading the clips with these devices was cumbersome and time-consuming, limiting their application. Subsequently, preloaded single-use clips were developed. Because of their ease of use, this technique has found increased application, and both rotatable clips and clips with reopening and therefore repositioning capabilities are commercially available. In addition, preloaded multiclip devices are under development. Clip specifications vary according to the manufacturer. The majority of clips are stainless steel, with a delivery deployment catheter consisting of a metal cable within a metal coil sheath within a 2.2-mm Teflon catheter (47). Therefore, the majority of the clips require a 2.8-mm endoscope channel for deployment. Most clips are 2-pronged; a 3-pronged clip is available that requires a 3.2-mm endoscopic channel (TriClip, Cook Endoscopy Inc, Winston Salem, NC). The 2-pronged clips are approximately 1.2-mm wide, available in several lengths with opening angles in the range of 90° to 135° and open from 6–12 mm depending on the specific clip used (47,48). A 2-pronged clip with reopening and repositioning capability up to 5 times before deployment is available (Resolution Clip, Boston Scientific). The different clips seem to be equivalent in animal models in ease of application and initial hemostasis rates but differ in duration of retention (49).

Clipping for hemostasis requires identification of the exact bleeding point (48). In contrast to injection or thermal techniques, the preferred technique is to clip the bleeding point first and then to apply additional clips around the bleeding point if necessary. Because this is a mechanical technique, secure clip deployment is achieved with maximal capture of tissue around the bleeding vessel (ie, not just the arterial base but also some of the surrounding mucosa) (48). In addition, because there is no surrounding field effect, unlike injection therapy, precise positioning is required (50). Optimal clip positioning is best achieved with the clip extended a relatively short distance from the endoscope tip. This allows for more precise clip application and allows for exertion of downward force on the clip during its placement. The correct technique is to position the clip slightly away from the arterial base, allowing for an en face or tangential approach, and to push the open clip downward while simultaneously applying suction. The clip should be slowly closed and, if optimally positioned, deployed (48). Reopening clips can be repositioned before deployment if required.

The limitations of clip application relate to the location of the lesion and to size criteria. The proximal lesser curvature and gastric cardia may be difficult to approach for clipping directly or in the retroflexed position, and in some cases it is easier to carefully expose the clip before retroflexion. Duodenal ulcers may also be difficult to clip, depending on their location, especially those involving the posterior wall of the duodenal bulb. Fibrotic ulcers or lesions may be difficult to clip. An arterial vessel larger than 2 mm in diameter may not be amenable to clipping, and there are other published criteria for size limitations in cases of perforations, mucosal defects, and polyps (2,31,48). In most cases the clips dislodge spontaneously within 2 to 4 weeks and pass in the stool, although some have been in place for >1 year (47). Although no adverse effects have been reported, magnetic resonance imaging may be contraindicated if clips are present.

Clipping for acute nonvariceal hemostasis is associated with primary hemostasis rates in the range of 84% to 100%, with low rebleeding rates, comparable with those achieved with injection, thermal, and combination

therapies (31,47,50,51). As with thermal therapy, hemostatic clipping has been used as part of combination therapy in conjunction with epinephrine injection. For patients with a nonbleeding visible vessel, clipping is typically performed first, followed by epinephrine injection as previously described. In cases of active bleeding, some endoscopists will inject epinephrine first, followed by clip application (2). Although initial hemostatic rates are comparable, prospective series demonstrate significantly decreased rebleeding rates and surgical requirements in patients undergoing combination therapy (clip and injection) in comparison with injection alone (2).

Clipping and other mechanical techniques have been shown to be more efficacious and are associated with a lower rebleeding rate than nonmechanical therapies for patients with Dieulafoy lesions, especially those with high-risk stigmata (52,53). These lesions, most frequently located in the proximal part of the stomach, may in some cases be more difficult to approach with an endoscopic clip because of flattening of the angle between the end of the clip and the lesion. However, the ability to clip both the lesion and the surrounding normal mucosa is a benefit of this technique (53). Other hemostatic applications for hemoclips include Mallory-Weiss tears and for colonic bleeding after biopsy, after polypectomy, from hemorrhoids, or from solitary rectal ulcer syndrome (Fig. 5). There is a single case report of clipping as adjuvant therapy for temporary cessation of rectal bleeding due to Klippel Trenaunay syndrome (54). Complications after clipping are extremely rare but include a case wherein a clip inadvertently perforated a gastric ulcer and was applied to the splenic artery, and a case of colonic perforation thought to be due to clip placement for postpolypectomy bleeding (47,55).

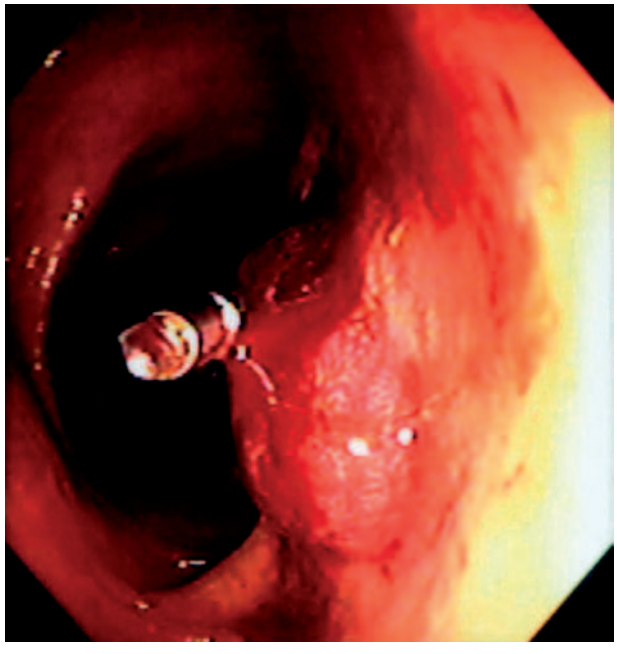

FIG. 5. Hemostatic clip applied in the rectum to a bleeding polyp stalk. The stalk was initially injected with 1:10,000 epinephrine, and subsequently the clip was applied.

Mechanical Ligation (Loops and Bands)

Detachable nylon loops (Endoloop, Olympus America) are now available and can provide mechanical ligation without cauterization. The sheath of the loop is Teflon coated and has an outer diameter of 2.6 mm, requiring a 2.8-mm channel for deployment and a working length of 230 cm. Both reloadable and single-use preloaded devices are available. The loop is passed through the endoscope accessory channel and placed over the targeted lesion in a manner similar to the technique of polypectomy snare placement. The maximal loop opening width is 30 mm. The loop is tightened with advancement of a silicon-rubber stopper (10). The loop is then detached after hemostasis is achieved without transecting the lesion. The primary indication for loop placement is for the prevention or management of postpolypectomy bleeding. When the loop is applied before polypectomy snare placement, care must be taken to avoid entanglement of the loop in the polypectomy snare. Before polypectomy, detachable loop placement should result in change of the color of the polyp head without transsection. If the loop is applied too tightly, then amputation of the polyp may occur with resultant bleeding; if it is too loose, then bleeding may occur after polypectomy. Placement of a detachable loop for postpolypectomy bleeding may be difficult because of stalk retraction, but techniques such as the lift and ligate technique using a 2-channel scope are available for this condition. Hemostatic loop placement has also been effective in the management of bleeding Dieulafoy lesions and has been used for bleeding gastric varices (10,53).

Band ligation for hemostasis is an extension of the ligation technique used to treat esophageal varices. Ligation is typically performed with a multiband ligator, available from several manufacturers. After identification of the lesion to be treated, the endoscope is withdrawn, the friction fit adaptor of the band ligator is placed on the tip of a standard-size adult upper endoscope, and a drawstring that extends from the cylinder is backloaded through the endoscope working channel and connected to the spool of the cranking handle at the inlet port (51). The endoscope is repassed to the lesion to be treated, and a band is deployed and applied by suctioning the lesion into the friction fit adaptor and simultaneously turning the handle; suction is subsequently released, and the efficacy of hemostasis can be determined. In cases of nonvariceal bleeding, deployment of only a single band may be sufficient. When multiband ligators are used, it may be helpful to predeploy some of the bands

outside the patient to improve the view, especially if only 1 ligating band may be required.

Band ligation is most effective for bleeding from nonfibrotic lesions and has been used to treat varices—esophageal, gastric, and colonic, Dieulafoy lesions, bleeding internal hemorrhoids, Mallory-Weiss tears, angiectasia, duodenal ulcers, and polypectomy sites (51,56). Ligation seems to be an extremely efficacious method of treating Dieulafoy lesions, especially those located where hemostatic clip application is difficult, such as the proximal gastric body (53). Ulceration after ligation has been reported, similar to that which occurs after variceal ligation. This has not been associated with recurrent bleeding in the case of Dieulafoy lesions (53).

Studies on resected specimens suggest that ligator use in anatomically thin segments of the bowel (ie, the small intestine and right colon) may be associated with an increased risk of perforation caused by entrapment of all layers of the bowel wall (57,58). Caution should be exercised with endoscopic band ligation with avoidance of excessive tissue aspiration by careful application of suction and use of banding caps that are 7 mm deep or less (58).

New and Emerging Technologies

Two endoscopic techniques have recently been developed that may one day be used in pediatric patients as part of the management of acute gastrointestinal bleeding. The technique most likely to initially be used is double balloon enteroscopy (DBE). This technique allows for extensive antegrade or retrograde evaluation of the small bowel by passage of a specialized commercially available endoscope. The primary indication for this type of examination is for evaluation of unexplained acute, recurrent, or obscure gastrointestinal bleeding in a patient who has previously undergone both esophagogastroduodenoscopy and colonoscopy. Additional indications for DBE include evaluation and therapy of polyposis syndromes, Crohn disease, and abdominal pain. The endoscopes have a working length of 200 cm, an outer diameter in the range of 8 to 8.5 mm, a therapeutic channel of 1.8 to 2.8 mm, and a balloon at the tip; the endoscope is passed in conjunction with a flexible overtube with a balloon at its tip. The overtubes are 140 to 145 cm long and have an outer diameter of 12.0 to 13.2 mm (59–61) (Fujinon Corp, Saitama, Japan). Available accessories that can be passed through the endoscope channel include biopsy forceps, an electrocautery snare, injection needles, and a thin APC catheter (ERBE, Tübingen, Germany) and hemoclips in the scopes with a larger channel (59,61).

DBE is performed after small bowel preparation and consists of a series of insertion and withdrawal maneuvers, accompanied by serial inflation and deflation of the endoscope and overtube balloons to reduce small bowel loops, resulting in relative straightening of the small bowel and scope advancement (60). Fluoroscopy is performed at the time of the procedure to evaluate scope position and extent of evaluation. Examination times are typically prolonged, in the range of 60 to 360 minutes, although recent large series may have shorter procedural times (60,61). Lesions identified during the procedure can be biopsied or can be treated with available accessories, allowing for cauterization, resection, and histological evaluation. DBE has been particularly useful for the identification of small bowel lesions associated with bleeding, such as gastrointestinal stromal tumors, polyps, and various types of angiodysplasia (60,61). Endoscopic biopsy may yield the diagnosis in some cases, and in others acute bleeding may resolve after injection or coagulation performed via the DBE channel. Bleeding as a result of diagnostic or therapeutic maneuvers during the procedure can be treated as described earlier for other segments of the gastrointestinal tract, using small-diameter accessories with appropriate modifications in settings or volumes of injection based on the anticipated small bowel wall thickness.

DBE examination in the pediatric patient is limited by the large outer diameter of the overtube and the prolonged procedure time and has been reported only as part of a large adult series to date (61). It is anticipated that with technological advancements and increasing application of the procedure, it may be performed in older pediatric and adolescent patients.

The newest development in the field of therapeutic endoscopy is natural orifice transluminal endoscopic surgery. This technique uses commercial endoscopes to create a controlled transvisceral incision, usually in the stomach, to enter the peritoneal cavity as an alternative to conventional surgery (62,63). The technique has primarily been studied in animal models and is in the developmental phase at present, with gastroenterologists and surgeons interested in identifying applications of this approach in adults. As experience with this approach in a variety of gastrointestinal conditions grows, natural orifice transluminal endoscopic surgery may in the future be performed for selected pediatric patients.

CONCLUSIONS

Several techniques are available to the pediatric endoscopist in the management of acute gastrointestinal bleeding. Many excellent reviews of the comparative techniques are available to the endoscopist, and technology status evaluation reports are published and updated by the American Society for Gastrointestinal Endoscopy and other gastrointestinal societies that are invaluable resources for the treatment of patients with acute gastrointestinal bleeding (2,10,15,16,64). The choice of therapeutic endoscopic technique depends to

a significant extent on the origin of the bleeding, the patient's size, the availability of equipment, and the training of the endoscopist. If the endoscopy is properly performed, then the rates of primary hemostasis and rebleeding are similar between injection, thermocoagulation, and mechanical therapy. Improved initial hemostasis rates and a further reduction in recurrent bleeding rates and need for emergency surgery occur with combination therapy. Certain lesions may be more amenable to 1 endoscopic technique over another on the basis of their anatomic location or briskness of bleeding.

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