

FOCUS REVIEW

Interventional Radiology: From Idea to Device to Patient

Anthony Ciarallo, Cam-Tu Emilie Nguyen, Lawrence Stein

> "… the vascular catheter can be more than a tool for passive means for diagnostic observations: used with imagination it can become an important surgical instrument."(1)

This 1963 quote is from Dr. Charles Dotter, the man who is widely regarded as the father of interventional radiology. In addition to being used profusely in journals and textbooks of interventional medicine, this citation succeeds in capturing the essential elements that constitute modern interventional radiology (IR): firstly, the use of the words "vascular catheter" reaffirms IR as a technique-based specialty of medicine where instruments and new technologies play a crucial role; secondly, this quote foresees that angiographic catheterization will evolve from a purely diagnostic science towards a means of delivering treatment; lastly, the word "imagination" constitutes Dotter's appeal to physicians to find newer, more innovative ways of putting imaging and image-guided therapy at the service of the patient.

Over the past forty years, the scope of IR has grown incessantly to encompass all the major organ systems, while interventional radiologists continue to prove that they are among the most versatile and inventive medical specialists. Because they can be visualized precisely and instantly using modern imaging techniques and explored with increasingly sophisticated probes, blood vessels constitute ideal roads for interventionists to reach sites of pathology all over the human body. In the present article, we will try to illustrate some of the key procedures of IR through a rapid overview of angioplasty and embolotherapy. Moreover, the contribution of IR to patient management, treatment and care will be discussed through a case history.

ANGIOPLASTY

The first interventional procedure ever documented was a percutaneous transluminal angioplasty of the superficial femoral artery performed by Dr. Charles Dotter in 1964 on an 82-year-old woman with symptomatic leg ischemia and gangrene who declined amputation (2). The treatment was considered successful and percutaneous transluminal balloon angioplasty (PTA) has now evolved to become one of medicine's best known minimally invasive treatments. Using the example of peripheral vascular disease, we will see how interventional approaches can contribute to the salvage of an ischemic limb.

Patients with symptomatic peripheral vascular disease (PVD) of the lower extremities that is poorly controlled with pharmacological therapy and lifestyle changes are candidates for percutaneous or surgical revascularization. Lesions that are amenable to angioplasty of the lower extremities often have the following characteristics: short, concentric, noncalcified, solitary and nonocclusive (3). Conversely, PTA has limited benefit in patients with diffuse disease or a large, irregular atherosclerotic plaque, because of the increased risk of distal embolization (3). The choice of interventional rather than surgical treatment depends both on patient factors and disease characteristics and will not be further reviewed here.

After initiation of appropriate antiplatelet and anticoagulation therapy, and percutaneous arterial catherization using needle, guidewire and catheter, the balloon angioplasty catheter is advanced in the vessel harbouring the obstruction. Once it is positioned near the stenosis, a guidewire is used to traverse the lesion (3). The dimensions and mechanical characteristics of the balloon have previously been chosen according to the lesion and vessel being treated. The balloon is then inflated over the center of the stenosis using dilute contrast material with the goal of breaking the atherosclerotic plaque and increasing the luminal cross-sectional area (3). Moreover, catheter-delivered stents are mechanical devices that can be used to provide a rigid and permanent scaffold to the diseased blood

vessel segment, thereby maintain luminal patency and inhibiting remodelling, elastic recoil and neointimal hyperplasia, which are causes of restenosis (3). A wide variety of stents are now available on the market, including self-expanding, balloon-expandable and drug-eluting stents. The latter category of stents releases drugs such as sirolismus or paclitaxel which inhibit smooth muscle proliferation, with the objective of decreasing the incidence of restenosis (4). Their potential benefit in PVD is currently under study.

Other interventions aimed at restoring adequate blood flow include coronary artery angioplasty and stenting, carotid artery angioplasty and stenting to prevent ischemic stroke and catheter-directed enzymatic thrombolysis to remove blood clots.

EMBOLOTHERAPY

Transcatheter embolization or embolotherapy is commonly used by interventional specialists to treat vascular abnormalities (e.g., aneurysms, arteriovenous malformations, varicoceles), to eliminate unwanted tissue (e.g., neoplasms, uterine fibroids) and to control many different sources of bleeding.

For cases of acute gastrointestinal hemorrhage that do not resolve spontaneously and do not respond to fiberoptic endoscopic management, emergency angiographic intervention can be considered. The effectiveness of this method is greater when active bleeding is present, because the threshold for detection of hemorrhage using angiography is 0.5 ml/min (5). Therefore, angiographic intervention is indicated for patients with high transfusion requirements or signs of hemodynamic instability.

The primary goal of radiographic imaging is to locate the source of the hemorrhage. Visualization of contrast medium extravasation into the bowel is the only sure way to demonstrate that a blood vessel is leaking. Sometimes, specific angiographic findings can provide further clues about the etiology of the bleeding. When upper gastrointestinal bleeding is suspected, arteriographic evaluation of the celiac trunk, followed by the superior mesenteric artery is performed (5). For lower gastrointestinal bleeding, the superior mesenteric artery and the inferior mesenteric artery are assessed in this order (5). When no site of hemorrhage site is found, empiric embolization of the left gastric or gastroduodenal artery can sometimes halt a barely discernible bleed (5).

The rationale for using embolotherapy in acute gastrointestinal hemorrhage is that it is possible to selectively interrupt the blood flow to the bleeding artery while avoiding intestinal ischemia, because of the rich network of collaterals formed by the arterial arcades. Selective catheterization of the culprit vessel, the key step to successful embolotherapy, is now achieved using coaxial microcatheters inserted through the diagnostic catheter. “[D]istal embolization at the level of the vasa recta feeding the bleeding site” is the favoured technique, as it reduces to a minimum the length of bowel at risk of ischemia (3).

The choice of the embolic agent to be delivered through the end-hole catheter to the site of bleeding greatly depends on the accessibility of the vessel for selective catheterization, which in turn depends on the vascular anatomy. For instance, if the rupture site can be crossed, it is possible to perform the sandwich technique utilizing coils as embolic agents (5). Metallic coils placed both proximal and distal to the site of vessel rupture will mechanically obstruct blood flow as well as promote thrombosis, thus causing hemostasis. Furthermore, if the catheter cannot reach the lesion site, particulate embolization can be considered. The size of particles used is determined by the diameter of the vessel to occlude. The released particles are directed distally by the bloodstream and find themselves shunted towards the point of least resistance, usually the site of vessel breakage.

CASE REPORT: CESSATION OF A LOWER GASTROINTESTINAL HEMORRHAGE USING MICROCATHETER ANGIOEMBOLIZATION

Introduction

Lower gastrointestinal (GI) hemorrhage is a significant source of morbidity and mortality in the aging population (6). Diverticulosis, neoplasms and angiodysplasia are among the most common etiologies responsible for lower GI bleeding. Clinically, they share many similarities which render them virtually indistinguishable upon presentation. For this reason, the acuity of a GI hemorrhage ultimately determines the management. Small bleeds are mainly managed using a conservative medical approach. On the other hand, severe hemorrhages are handled mostly via interventional angiography, especially in hypotensive patients who need emergent treatment. Angiography provides an effective approach for localizing and embolizing the source of the GI bleed in a relatively short period of time with a minimal amount of preparation.

Angioembolization is establishing its place in the management of gastrointestinal hemorrhage largely due to the advent of microcatheter technology. Initially, its use was limited by procedural complications such as ischemic colitis and bowel infarction (7-9). The objective of the procedure is to adequately reduce the perfusion pressure in a hemorrhagic region such that it facilitates hemostasis without causing total

devascularization and infarction. Superselective embolization allows specific targeting of the distal marginal mesenteric arteries thereby achieving the desired degree of hemostasis within the affected territory while minimizing complications.

CASE REPORT

A 78 year-old male patient presented to emergency on the day of admission with diminished mental status and bradycardia of 38 bpm. His past medical history is significant for diabetes mellitus II, hypothermia secondary to autonomic dysfunction, anemia, chronic renal failure, and hypertension. A few days after admission, the patient was noted to have epistaxis with subsequent melena. His hemoglobin fell from 90 to 69g/l and he received two units of packed red blood cells. ENT was consulted and concluded that the epistaxis was unlikely to be the cause of the melena or the marked decline in hemoglobin. The esophagogastroduodenoscopy (EGD), performed to rule out an upper GI bleed, revealed multiple duodenal bulb ulcers but failed to demonstrate active bleeding.

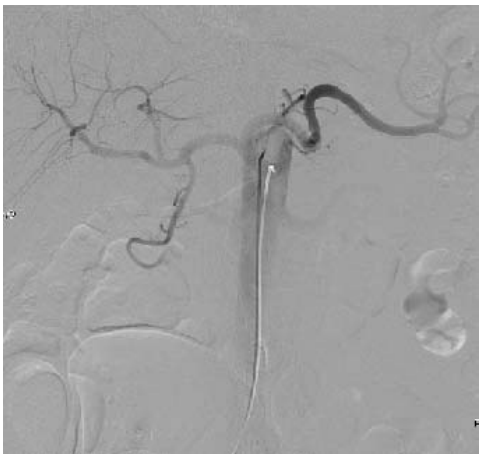

Figure 1. **Visualization of the celiac trunk**. The injection of contrast material demonstrates normal vascular integrity in the distribution of the celiac trunk.

The patient remained hemodynamically stable over the course of the following week until he passed new melena with fresh blood per rectum. His blood pressure dropped to 80/50 mm Hg and his hemoglobin level reached a nadir of 56g/l. The patient was transfused with a total of 6 units of pRBC, 10 units of platelets, and 2 units of fresh frozen plasma within the two days following the episode. A second EGD revealed no change from the previous. The patient was then sent for a colonoscopy in attempts to identify a source of bleeding from the lower GI tract. A very large amount of fresh blood was found in the rectum and sigmoid colon along with moderately severe diverticulosis in the sigmoid. The source of bleeding, however, could not be identified because the abundance of blood and clots precluded proper visualization of the intestinal mucosa. Therefore, the patient was sent for an emergent

Figure 2. Left colic artery. The catheter was placed through the inferior mesenteric artery into the branch of the left colic. Injection of contrast material demonstrates extravasation into the lumen of the descending colon (arrow).

Figure 3. Coil insertion. The vascular distribution of the left colic artery is shown with contrast following placement of two 2mm by 4mm coils (arrows) in the affected marginal branch. The absence of extravasated contrast confirms that this was the source of the hemorrhage.

angiography.

Using the transfemoral approach, a 5F sheath was placed in the right femoral artery and 5F Cobra catheter was advanced to the origin of the celiac truck using a standard 0.035 in. Terumo guidewire. The celiac angiogram failed to show any abnormality in the gastroduodenal region (Figure 1). Catheterization of the inferior mesenteric artery demonstrated an extravasation of contrast material from the left colic artery into the colonic lumen indicating an active hemorrhage in the mid descending colon (Figure 2). A Renegade 3F microcatheter was negotiated through the notably tortuous terminal branches of the left colic artery. The affected branch was successfully embolized using two microcoils, 2mm in diameter and 4mm in length (Figure 3). The procedure was well tolerated by the patient despite suffering a right inguinal hematoma.

One week after the angioembolization, the patient underwent a repeat colonoscopy for the purpose of identifying a more specific source of bleeding. A complete colonoscopy was performed with visualization of the appendiceal aperture. With exception to diverticulosis of the sigmoid and descending colon, the examination was otherwise normal. During his admission at the hospital, the patient was subsequently diagnosed with a factor XII deficiency coagulopathy. Despite this, he has not experienced a recurrence of GI hemorrhage.

DISCUSSION

The inception of angioembolization in the 1970s was curtailed by its high complication rate. Bowel infarction was estimated to range from 13-33% and was largely attributed to embolization of proximal vessels (7-9). The catheter caliber was simply too large to selectively target distal mesenteric hemorrhages. Embolization of a proximal vessel involves a relatively large vascular territory and increases the risk of ischemic events due to inadequate collateral supply. Since then, the introduction of microcatheters has renewed interest in angioembolization. The improved precision of the procedure has been documented in numerous cases and the incidence of major ischemic complications has declined to 0-5.9% (10-15). It should be noted that the rate of overall complications is higher, but the vast majority are not clinically significant.

Angioembolization has been reported to effectively stop GI bleeding in 70-100% of patients (10, 12, 13, 16-20). However, the outcome of the procedure may depend on the etiology and location of the GI hemorrhage. It has been demonstrated that right-sided colonic bleeds are more likely to recur compared to those on the left side (15, 16). Incidentally, the observation that angiodysplasias are more common on the right side whereas diverticulosis is more common on the left may provide a reason as to why that is (21, 22). According to the natural history, angiodysplastic lesions have a propensity to rebleed 85% of the time versus 10-20% in diverticular disease (23-25). Moreover, the risk of recurrent bleeding following embolization is intuitively higher in patients with extensive or multifocal disease of the bowel since they are more likely to bleed from multiple sites.

CONCLUSION

Advances in microtechnology over the last 20 years have paved the way for superselective microcatheter embolization of end arteries. The management of lower gastrointestinal hemorrhage has especially benefitted from this achievement as it is becoming more widely used in various centers. This targeted approach has shown to reduce the risk of ischemic bowel complications and has resulted in improved safety as well as efficacy in the management of gastrointestinal hemorrhages.

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Anthony Ciarallo (MDCM 2008, MSc) is a 4th-year medical student at McGill University with an interest in interventional radiology.

Cam-Tu Emilie Nguyen (MDCM 2009) is a 3rd-year medical student at McGill University. She is also the *MJM*'s 2006-2007 Focus Editor, a position that allows her to combine her passions for medicine, journalism and writing. She has been involved in clinical research in the fields of endocrinology and cardiology. Her favourite literary figures include George Eliot and Virginia Woolf.

Dr. Lawrence A. Stein, MD, FRCPC, is Chief of Diagnostic Radiology at the Royal Victoria Hospital and Associate Professor of Radiology at McGill University. He was also the past-President of the Canadian Association of Radiologists After obtaining his medical education at McGill University in Montreal , Dr. Stein undertook his residency in the Department of Diagnostic Radiology of McGill, following which he obtained further subspecialty fellowship training in abdominal imaging at the University of California. Dr. Stein has been involved in all aspects of abdominal imaging and is very active in interventional techniques related to the G.I. tract. He has been director of the division of angiography and interventional radiology at the MUHC (McGill University Health Centre). He has authored or co-authored many publications related to abdominal imaging and intervention. Teaching has been one of Dr. Stein's major loves in medicine. He has served as and has tutored or supervised hundreds of elective medical students in Radiology. Many of their projects are on the Internet and used by medical students worldwide.