CHAPTER 34

Angioscopically Assisted Thromboembolectomy

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Introduced in 1963, the balloon embolectomy catheter has proved to be an important contribution to the development of endovascular devices to assist in the treatment of peripheral vascular occlusive disease (1,2). It has also provided a template for the design of other, more specialized catheter tools to address the removal of the residual thrombus associated with incomplete thromboembolectomy. Before the advent of balloon embolectomy catheter technique, surgical procedures for removing thrombus were fraught with complications that resulted in high patient mortality and morbidity. Using the embolectomy catheter to remove acute peripheral emboli has improved surgical outcome and consequently patient survival. Independent studies conducted by Tawes et al. (3), Elliot et al. (4), Abbott et al. (5), and Cambria and Abbott (6) have shown limb salvage rates of 85% to 95% with attendant mortality rates reduced to 10% to 20%.

Going beyond the basic embolectomy procedure, new catheter-based technologies, developed from a more in-depth knowledge and understanding of the etiology of the vascular occlusive disease process, have emerged to address the various progressive stages of disease. In so doing, the less invasive, endovascular field has evolved to include many new modalities whose primary application is not to physically remove thromboembolic material but to provide assistance in 1) diagnosis, 2) facilitation of the therapeutic endovascular surgical procedure, and 3) postoperative evaluation of the resultant efficacy of the surgical intervention. These modalities include angioscopy that allows a 360° endoscopic visualization of vessel lumen, and the more recently introduced intraluminal Doppler ultrasonic imaging, which provides an echo image of the intima and surrounding tissue structures. The following will describe applications suited to angioscopy and will specifically address the advantages and disadvantages associated with the use of angioscopy in thromboembolectomy.

Angioscopy

Angioscopy may be defined simply as the endoscopic inspection of the interior of a blood vessel (7). Constrained by the inappropriately sized instrumentation available at the time and the difficulties with light transmission, the earliest attempts at endoscopic visualization of blood vessels had limited success. Early endoscopes were large and inflexible and offered poor visualization in an opaque visual field. Over the past 20 years the development of smaller, flexible, and maneuverable endoscopes, videocamera technology, and improved
irrigation management has allowed surgeons to more accurately visualize the intraluminal field.

Angioscopy experienced increased usage within the vascular surgery specialty after the benefits of using laparoscopies within the general surgery field were documented (9). Currently, angioscopic instrumentation not only offers valuable diagnostic capability but also may be used adjunctively with other endovascular therapeutic devices. Angioscopy is used as a method of “controlled guidance” to aid visualization within vessels when patients undergo procedures such as thromboembolectomy, atherectomy, arteriovenous fistula graft revision, in situ bypass, venous valvulotomy, and stent deployment.

Potential diagnostic applications for angioscopy have been extensively described in the literature (9-11). They include, but are not limited to, the following:

1. Intraluminal evaluation of traumatic arterial injury
2. Intravascular occlusion, defining the character and consistency of plaque, whether it is thrombotic or atheromatous
3. Direct correlation of angiographic findings
4. Diagnosing pulmonary embolism
5. Assessing the integrity of vascular reconstructions
6. Directly interrogating veins for bypass suitability
7. Localizing discrete venous valves and branches in vein preparation for in situ bypass
8. Evaluating coronary arteries
9. Evaluation and location of multifocal lesions to choose a therapeutic modality
10. Detection of potentially significant intimal flaps and thrombi undetectable by Doppler ultrasonic examination
11. Providing an alternative to angiographic assessment of reconstructions and detection of vessel abnormalities

As a monitoring tool, angioscopy is used in the treatment of vascular disease, to provide direct visualization during or after the following interventional procedures:

1. Infusion therapy (i.e., thrombolytic, vasodilator treatment)
2. Thromboembolectomy
3. Balloon dilation or angioplasty
4. Atherectomy
5. Endarterectomy
6. Valvulotomy
7. Vein branch ligation

Proper angioscopic evaluation has been shown to affect the duration of a patient’s hospitalization (12) and has been shown to be a safe, simple, effective alternative or adjunctive procedure to intraoperative angiography (13). To better appreciate the application of angioscopic assistance in thromboembolectomy, the basic angioscopic system components and functionality should be understood.

### Angioscopic Instrumentation

#### Angioscope

The viewing tip of the angioscope is shown in Figure 34.1. It consists of a flexible catheter comprising one or two fiberoptic light bundles, a fiberoptic image bundle, and a working channel that is frequently used as an irrigation port or to introduce guidewires or other intravascular tools. Currently angioscopes come in lengths of 20 to 100 cm with distal tips ranging in diameter from 0.6 to 7 mm. The degree of variation in angioscope components is directly related to the diameter of the catheter. In smaller-diameter angioscopes, fewer fiberoptic fibers can be accommodated, necessitating exclusion of the working channel in many instances. As stronger, more intense light sources become available, it may be possible to decrease the light bundles from two to one, thus allowing room to accommodate the important working channel in all angioscopes.

Fiberoptic bundles can either be drum wound (fused bundles), consisting of individual fibers bound at the ends, or three glass (fused bundles), which allows the scope size to be reduced by fusing individual fibers into one cohesive strand. The drum wound angioscopes are nondisposable owing to their high cost, while the fused bundle units are less expensive and disposable. The angioscope is steered by passive guidance, tracking with a guidewire, or activating tip deflection manually with a control button on the angioscope handle. More advanced designs have incorporated an operator-controlled deflecting tip allowing greater maneuverability of the angioscope within the vessel. This feature gives the surgeon the ability to guide the angioscope into the appropriate vessel conduit when encountering bifurcations or to more easily visualize branches or tributaries. Two-way deflecting systems will allow 45° deflection in one direction and up to 90° deflection in the opposite direction for a more complete endoluminal interrogation. The flexibility of these soft deflecting tips reduces the potential for intimal damage.

The proximal end of the catheter is attached directly to the angioscope. The angioscope usually supports an irrigation port, an attachment to the light source, and an attachment to a miniature camera. This camera acts as a small telescope outputting to an observation site, which may be the viewer’s eye, or through a standard video cassette recorder to a high-resolution monitor. The video display provides real-time visual feedback during the procedure and a video record of the intervention for later use and procedure documentation.

#### Camera System

The camera system on an angioscope converts the image picked up at the proximal end of the scope, projected via the fiberoptic bundles, into a digital image that is transmitted to the eyepiece or the display on the video monitor. A few manufacturers include a camera...
system as part of the total angioscope system, but as most operating rooms have several camera systems utilized by other specialties, adapters may be acquired to allow interface of the angioscope to these existing devices. This time-sharing of cameras from one department to another can decrease costs considerably, which may be especially important to financially constrained institutions.

Another integral component to the camera system is the camera coupler, which magnifies the transmitted image up to 20 times its original size. It allows 360° rotation and supports the focusing ring for image quality adjustment. This is a reusable component, which once again provides a financial saving when used with disposable angioscopes.

**Light Source**

Another important part of the angioscope system is a focused light source. Typically angioscopic illumination is produced with xenon, the whitest and most efficient light source, emitting a range of between 75 and 300 W of power. Light output from the angioscope tip is typically 2 to 20 mW/cm². Quartz halogen light sources of 150 W generally do not provide adequate lighting because they are less efficient. Both are cold light sources to avoid heating the delicate fiberoptic bundles. The light sources are equipped with different brightness settings that are indicated by a visual display, generally a light-emitting diode bar-graph or liquid crystal display readout. Some angioscopic systems also may contain a filter wheel that provides options for correction when Polaroid or indoor film is used during the procedure (7).

The angioscope is connected via a fiberoptic light cord to the light source. The light cord properly aligns the light source with the fiberoptic bundles to achieve adequate endovascular illumination. Most newer systems automatically adjust the light source in response to the reflected light to preserve image integrity.

The angioscope operator must become fully familiarized with the various light source modalities to obtain maximum display quality. As an example, flexible angioscopes used in the endovascular setting require more light than rigid rod-lens scopes frequently used in arthroscope and urologic evaluations (14). Conversely, in smaller vessels, less light intensity is required for a good image; excessive light can produce a white or blanched image. Proper manipulation of light intensity can significantly reduce the time taken to complete a procedure and thereby improve image display quality and decrease the possibility of misinterpreting or entirely overlooking pertinent pathology.
Video Monitor

A high-resolution color video monitor is an indispensable part of an angioscope system. This technology emerged from the gastrointestinal endoscopic system that demonstrated the superiority of direct videoendoscopy. Early angioscope designs incorporated eyepieces similar to a urologist's cystoscope for direct visualization of the intraluminal space. This visualization technique proved cumbersome for the vascular surgeon who is often required to move about within the sterile operating field or change position during an operation. The video monitor alleviates these mobility constraints and provides the opportunity for the entire surgical team to monitor the procedure. In most modern operating rooms, angioscopic monitoring is viewed on a color video display.

The video monitor display is especially useful as a tool to assist in training clinicians in angioscopic technique. The angioscopic image is displayed as a small bright circle on the video monitor. Newer systems allow digitization of the image to fill the entire screen for easier viewing. A high-quality monitor capable of displaying crisp, clean color images will enable precise differentiation of endoluminal disease characteristics. As in the previous discussion of light source coupling, proper connection of camera elements to video display is critical to clear visualization.

Irrigation System

Irrigation systems are critical to an angioscope system, yet are one of the most overlooked components. The vascular system, unlike the gastrointestinal, urologic, or arthroscopic fields, poses a unique challenge in that its visual field is obscured by pulsatile, swirling, opaque blood. As endoluminal angioscopic technology has been borrowed from these other endoscopic modalities, the irrigation systems successfully used in general surgery have proved to be inappropriate for endovascular applications. Overcoming this obstacle by finding better ways to eliminate backflow and displace blood from the visual field is still an area of development. Recognizing the strengths and limitations of current irrigation systems will improve the video image and minimize complications associated with fluid overload. Currently, three types of irrigation system are available to the vascular surgeon (Fig. 34.2).

The basic irrigation system consists of a saline bag with a line directly attached to the irrigation port on the angioscope (Fig. 34.2A). The irrigating solution bag, when suspended on a pole used for intravenous drip, provides a source of constant passive pressure that clears the visual intraluminal field. Alternatively, an assistant may squeeze the bag, either by hand or with a blood pressure cuff placed around the bag, while pinching off the direct line to provide varying amounts of pressure as deemed appropriate to clear the field. The disadvantages of this somewhat cumbersome technique are twofold: monitoring the amount of fluid infused into the vessel often can be unreliable, and it is difficult to accurately regulate the fluid pressure. This initial approach has been largely abandoned.

A more advanced infusion irrigation system is the roller pump (Fig. 34.2B). This system is more sophisticated than the passive pressure saline bag setup in that a roller pump activated by a foot switch creates a peristaltic infusion of saline, eliminating the need to coordinate saline infusion with an assistant. Furthermore, the flow rate can be preset to a desired level, emitting from 10 to 400 ml per minute from the angioscope tip, and the volume of infused fluid can be continually monitored automatically. A fairly high pressure level is required to transmit fluid down the small-diameter angioscopic working channel over a distance of up to 100 cm. The period of high-pressure infusion is temporary and generally not of great concern, but should be considered when operating within a closed system.

The roller pump, although it provides several automated features, is not without drawbacks. When the foot switch is initially activated, saline is infused at a

![FIGURE 34.2 Various angioscope irrigation systems: (A) simple saline bag irrigation system, (B) peristaltic foot-activated pump, (C) foot-activated pressure vessel pump.](image-url)
low pressure until the roller pump builds up to the desired set speed. This short period of low-pressure infusion is insufficient to displace blood and clear the visual field, yet some volume of saline has been added to the patient's vascular system, increasing fluid load while failing to maximize the time spent visually interrogating the vessel. Also, because the pump is not responsive to fluid buildup and pressure feedback, vessels infused within a closed system (i.e., distally clamped vessels with occluded side branches) may undergo a dramatic increase in intra-arterial pressure that has the potential to damage the vessel wall among other vascular complications. Currently, there is no effective means to compensate for the potential pressure buildup using the roller pumps because they are not pressure sensitive. Consequently, care should be taken to monitor fluid induction with this system.

The third irrigation system combines the advantages of the two previously described systems (Fig. 34.2C). The release of irrigation fluid (contained in a saline-filled bag housed within a pressure vessel) is controlled by pressure changes initiated when an on/off foot switch is activated. A bolus of fluid in the range of 250 to 350 ml per minute may be infused to quickly clear the visual field when backflow is encountered, while low-flow infusion at 60 to 80 ml per minute is usually adequate to maintain a constant, unobstructed field of view. In addition to having an external pressure regulator, this irrigation system is pressure dependent, thereby overcoming the problems associated with intra-arterial pressure buildup and minimizing the risk of fluid overload. Usually, 25 to 30 psi is sufficient to procure a clear visual field in the iliofemoral system and below (14). A pinch valve ensures that the initial infusion of saline will be maintained at the preset pressure, thereby providing rapid clearing of the visual field and saving procedure time and unnecessary fluid administration. Total infused volumes should be carefully monitored to prevent patient fluid overload. Often newer irrigation systems have been designed with an automatic shut-off feature as a safety mechanism in tracking fluid infusion to alert the clinician to fluid administration volumes before reaching a 1000-ml infusion level.

Operative Considerations for Angioscopy-Assisted Thromboembolectomy

A standard method of angioscopic examination should be developed for each angioscopic application and should be varied according to the operative procedure and the nature of the region of interest. Miller describes such procedures in his recent work, “Angioscopy: Introduction and Basic Techniques,” which the interventionalist may find useful as a template for individualizing operative protocols (16). When using angioscopy to assist during thromboembolectomy, choosing the proper size angioscope is of paramount importance. The diameter of the angioscope should be the largest that can be easily introduced into the vessel giving due consideration to luminal tapering as the catheter is advanced. Careful angioscope selection will minimize visualization difficulties such as dark or blanched images and reduce the danger of inducing spasm in a native artery.

New Thrombectomy Devices

A greater understanding of the pathology of peripheral vascular disease was brought about, in part, by improved visualization modalities. This, in turn, has prompted the development of new thrombectomy devices designed to address the various stages of atherosclerotic disease. Two such tools have recently been added to the surgeon’s endovascular instrumentation armamentarium. Both the corkscrew-shaped adherent clot catheter and the open-wire graft thrombectomy catheter (Baxter Healthcare Corp., Vascular Division, Irvine, Calif.) are designed to more completely remove adherent thrombotic material after embolectomy, and their beneficial effects can be easily documented when they are used in conjunction with angioscopy.

Adherent Clot Catheter

Figure 34.3 is a drawing showing the longitudinally collapsed insertion position of the adherent clot catheter tip. The device consists of a flexible catheter with a distal latex-covered coiled cable at its tip. A thumb-activated lever on the instrument handle allows the surgeon to adjust the pitch of the corkscrew membrane from a fully collapsed, small-diameter position, to a tightly spiraled retracted configuration with a diameter of up to 10 mm (14). By advancing the catheter in the
low-profile, collapsed position, then expanding it to its wider-diameter configuration, adherent thrombus is "grasped" by the closing spiral loops of the corkscrew membrane (Fig. 34.4). In the same familiar manner an embolectomy procedure is performed, the adherent clot catheter is withdrawn in its expanded position toward the arteriotomy, and the clot is removed manually. The pitch of the retrieval element may be adjusted by the thumb lever if resistance is encountered during the withdrawal process to adjust the gripping force during withdrawal.

**Graft Thrombectomy Catheter**

The distal working element of the graft thrombectomy catheter is designed much the same as the adherent clot catheter (Fig. 34.5). Both use the principle of a hand-operated, expandable, variable-pitch coil to grasp and remove adherent thrombus. However, two features differentiate the devices. Unlike the adherent clot catheter, which is composed of one membrane-covered wire, the graft thrombectomy catheter is constructed using two helically arranged exposed wires. These two wires are distally mounted on a central retractable wire in an opposing left-handed and right-handed helical arrangement. In both catheter designs thumb-activated retraction of this central wire causes the respective coils to expand in diameter. The lack of a latex membrane covering over the helically arranged wires makes the graft thrombectomy catheter particularly well suited for removal of adherent thrombus or disrupted neointima commonly associated with synthetic grafts.

**Surgical Technique**

**Removal of Adherent Thrombus in Native Vessel**

The following is a description of an angioscopy-assisted thrombectomy of the superficial femoral artery and popliteal artery containing fresh thrombus with underlying adherent clot.

After the angioscopy system is white-balanced and prepared for use, a standard cutdown is made over the femoral triangle. Vascular clamps are applied to the proximal superficial and the deep femoral arteries. An arteriotomy is made just proximal to the branch of the deep femoral artery in the superficial femoral artery. A standard 3 or 4 Fr balloon embolectomy catheter is used to remove soft thrombus in the major vessels of the femoropopliteal system.

It is useful, in fact imperative, to reconstruct the clot with removed clot segments on a towel to provide insight into the anatomic location, structure, dimensions, and character of the clot. Often a meniscus is formed at the distal end of the thrombus at the flow boundary of the distal patent branch. Reconstruction of the clot with
a recognized meniscus may indicate that the distal end of the clot has been removed, and further angioscopic evaluation of the blood vessel may be initiated.

At this point in the procedure, the angioscope is advanced through the arteriotomy and is passed to the distal popliteal region. The walls of the vessel are inspected, and any residual material missed by the balloon catheter (e.g., adherent thrombus, intimal flaps) is noted. Because intimal flaps may appear motionless against the vessel wall under steady-flow irrigation conditions, one may consider using a pulsing irrigation system, which may more accurately mimic arterial blood flow, allowing visualization of rhythmic intimal flap motion. Should adherent clot be detected angioscopically, it can be removed using the adherent clot catheter. This procedure is repeated in the femoropopliteal system until the vessels are angioscopically visualized completely free of soft and adherent thrombus and a therapeutic effect is achieved. Vascular occlusive devices are removed, and the incisions are closed in standard fashion.

**Graft Thrombectomy**

The revascularization procedure using the graft thrombectomy catheter in synthetic grafts is very similar to thrombectomy performed with the adherent clot catheter in native vessels. An incision should be made over the distal anastomotic site and a graftotomy made at the junction of the native vessel and the graft prosthesis. A 5 or 6 Fr balloon catheter is then used to remove soft thrombus. This procedure is repeated until no more residual material is removed. Balloon thrombectomy may occasionally result in weak or even nonexistent flow. In these instances the more aggressive graft thrombectomy catheter should be used to thoroughly remove the obstructive, densely adherent residual thrombus.

In a revascularization procedure involving an aorto-bifemoral graft, a No. 8/14 Fr or No. 8/22 Fr occlusion balloon catheter (Baxter Healthcare Corp., Vascular Division, Irvine, Calif.) is threaded through the helical wires of the graft thrombectomy catheter, advanced to the iliac bifurcation, inflated, and adjusted until the surgeon is satisfied that hemostatic control is achieved.

The graft thrombectomy catheter is guided along the shaft of the occlusion balloon catheter to a site immediately distal to the inflated balloon just below the iliac bifurcation. The thumb-activated lever on the handle of the graft thrombectomy catheter is retracted, coiling the distal tip of the catheter to grasp adherent material. The catheter is withdrawn from the artery, and adherent thrombus is removed from the helical wire element (Figure 34.6). Repeated passes with the graft thrombectomy catheter, alternating with angioscopic inspection of the vessel, should be continued until the graft is documented to be clear of thrombotic debris by direct visual assessment.

Periodically, the occlusion balloon catheter may be partially deflated to evaluate flow improvement as an adjunct to angioscopic inspection. When satisfied with the therapeutic result, the occlusion balloon is deflated and removed. The graftotomy closure may then be completed and the incision closed.

**FIGURE 34.5** Graft thrombectomy catheter: (A) fully collapsed (advancing) position; (B) fully retracted and expanded position showing fully retracted thumb lever.

**FIGURE 34.6** Graft thrombectomy catheter threading an occlusion balloon catheter, removing adherent thrombus in an ileobifemoral synthetic graft.
Conclusion

Despite the many benefits afforded vascular surgeons from direct visualization with angioscopy, barriers exist that prevent widespread adoption of the modality (13). Some of the disadvantages associated with use of angioscopy are cost of instrumentation, fragility of equipment, especially optical fibers, inability to use an angioscope concurrently with therapeutic modalities owing to small vessel size relative to the size of the devices, inability to quantitate flow, difficulty navigating tortuous vessels, a steep learning curve, and possible clinical disadvantages such as misinterpretation of data, system fluid overload, traumatic intimal injury, and potential embolization or thrombosis.

To expand upon some of these drawbacks to utilization, one primary obstacle is the cost of angioscopic equipment. The initial monetary investment to procure a dedicated angioscopic system, including the light source, camera, video monitor, pump and irrigation components, can be significant (approximately $60,000 to $65,000). Repair of expensive reusable angioscopes can easily amount to half as much as the original purchase cost and may run approximately $2500 to $3000 per repair. Choosing to utilize less expensive disposable angioscopes interfaced to existing camera and monitor endoscopy or laparoscopy systems will allow a facility to set up an angioscopic service for a fraction of the cost of purchasing a dedicated system (approximate $8000 cost would include purchase of an irrigation pump, two angioscopes, and a camera coupler unit), but the cost of replacing single-use angioscopes is also not insignificant.

A secondary deterrent to adopting this technology has been the learning curve associated with system operation, which requires an understanding not only of device function and application, but also of its maintenance. However, as angioscopy instrumentation usage increases and the full potential of the device is recognized, the technical learning curve should decrease as experienced operators include angioscopic assessment in their surgical repertoire and surgical training programs include this new modality in their course curricula.

In the past ready acceptance of the device was thwarted by the somewhat limited availability of technical support. This situation is changing as the two main suppliers of the devices serving the vascular community have expanded their clinical personnel to offer physicians more opportunities to gain "hands-on" experience evaluating angioscopy systems in clinical settings. The two consistent manufacturers providing angioscopic equipment are Intramed (San Diego, Calif., distributed by Baxter Healthcare Corp., Vascular Division, Irvine, Calif.) and Olympus (Lake Success, N.Y.). Olympus manufactures a broad range of reusable angioscopes for vascular and other medical specialties while Intramed markets, primarily to the vascular community, less-expensive disposable angioscopes or the newly introduced "responsible" (limited reusability) angioscopes. It is likely that other equipment manufacturers will enter the field in the future as the endovascular surgical community recognizes the value of using this technique, which will significantly improve the accessibility to the instrumentation and the technical support services.

Despite some of the obstacles to ready acceptance of this modality, the positive financial impact angioscopy may have on the net cost of surgical interventions should be considered. It is becoming increasingly apparent that cost savings may be realized in several areas, such as decreases in procedure time, operating room time, anesthesia time, often postoperative hospitalization time, and the direct cost savings associated with eliminating the completion angiogram.

Traditionally, thrombectomy was performed as a semiclosed, blind technique. The ability to clearly and completely visualize the intraluminal field with flexible, maneuverable angioscopes has shed new light on thromboendarterectomy and in situ and synthetic bypass grafts procedures, as well as providing the ability to evaluate hemodialysis access shunts.

The growing trend in vascular surgery is toward minimally invasive surgical intervention. Angioscopy provides opportunities to perform these procedures with greater efficacy and safety. Despite some of the current barriers to using angioscopy, this method of visualization has real utility in the thromboendarterectomy process. Angioscopy allows for a thorough intraluminal inspection of blood vessels in three-dimensional, real-time, color images that are a familiar visual modality for surgeons. Pathology often missed by Doppler ultrasound or angiography, such as intimal flaps, can be assessed with greater accuracy and acuity (12).

Technological advances in image quality and resolution, along with an increased ability to interrogate smaller vessels, should significantly improve current angioscopy systems and enhance their acceptance by the surgical community. The use of angioscopy to guide endovascular surgical interventions will become routine in the future. The information direct visualization provides is vital to advancing the development of new endovascular therapeutic modalities.

References