

Imaging Modalities for Endovascular Aneurysm Repair

Having multiple options available is essential in providing optimal care.

BY EDWARD Y. WOO, MD, AND RONALD M. FAIRMAN, MD

Essential elements for any vascular center seeking to offer a center-of-excellence level of care for patients with abdominal aortic aneurysms (AAAs) include multidisciplinary collaboration and a concerted effort and commitment among various specialties to efficiently employ state-of-the-art imaging technology. In addition to a team of highly skilled physicians, these elements are necessary to achieve optimal outcomes when treating a large volume of patients. At our institution, this effort primarily involves interaction between the members of the vascular surgery and the radiology departments. In our opinion, no matter how an institution handles the flow of AAA patients, it must have the necessary imaging personnel and the ability to offer open surgical options in addition to endovascular procedures at all times during the day and week. This is essential for treating patients who may or may not be candidates for endovascular aneurysm repair (EVAR), as well as handling emergencies requiring traditional open surgery.

PREOPERATIVE AAA SCREENING AND MONITORING

In our institution all pre-procedural computed

tomography (CT) and magnetic resonance (MR) imaging to evaluate AAAs is performed by the radiology department. If the patient is considered an endovascular candidate, we transmit the CT images to Medical Metrx Systems (MMS; West Lebanon, NH) for three-dimensional reconstruction. Using these reconstructions, we can accurately determine centerline length and diameter measurements, the presence and nature of calcification, thrombus, and other anatomic constraining factors (Figure 1).¹ This information is essential for confirming endovascular candidacy and evaluating anatomical considerations to select the most appropriate

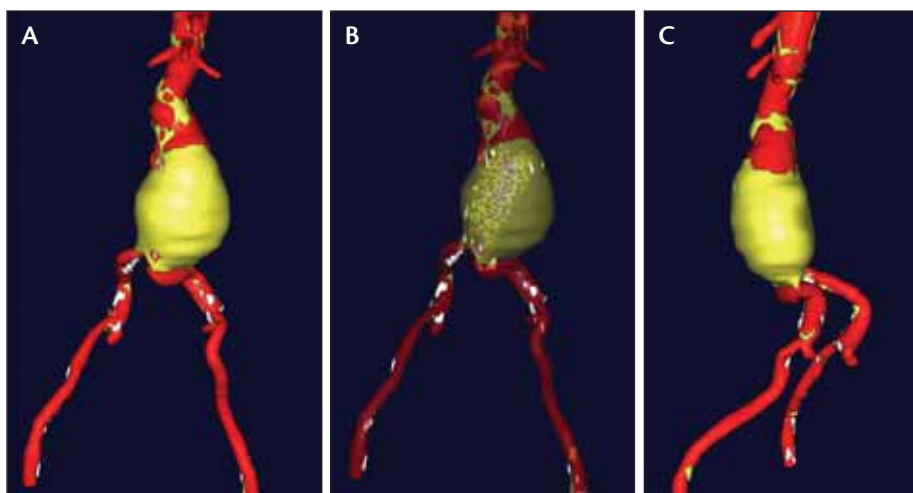


Figure 1. MMS reconstruction of abdominal aortic aneurysm; thrombus is in yellow, calcification is in white (A). Reconstruction demonstrating semitransparent thrombus with centerline measurement (magenta) from the left renal artery to the left hypogastric artery (B). Lateral view of aneurysm demonstrating rotational ability of reconstructions. The reconstructions can be maneuvered in 360° (C).

graft and plan for any possible challenges during placement. Obtaining MMS reconstructions is also reimbursed by Medicare. Preoperative planning contrast arteriograms are rarely performed in our practice since the development of three-dimensional CT reconstructions.

The three imaging modalities most often used in preoperative evaluation are duplex ultrasound (primarily used for detection/confirmation of presence), CT angiography, and MR angiography. Duplex ultrasound does not offer the anatomic detail necessary for EVAR. In our institution, MR has proven effective in imaging the abdominal aorta, as it certainly demonstrates the anatomy of the aorta. However, we have found CT imaging to provide finer anatomic detail. In addition, MMS reconstructions can only be generated from CT images. Although MR offers the benefit of use in people with baseline chronic renal insufficiency, many patients cannot tolerate MR due to claustrophobia or the presence of metal devices such as pacemakers or defibrillators. This is not an insignificant number of patients. Additionally, MR does not demonstrate vessel wall calcification. The benefits of CT are that it is quick and easy to perform, most patients tolerate it well, and it can be reconstructed by MMS. The downside is that CT requires the use of iodinated contrast, which can be detrimental to renal function. In our practice, if the serum creatinine is between 1 mg/dL and 2 mg/dL, we will still obtain a CT angiogram. The patients are given n-acetylcysteine prior to their scan for renal protection. If their serum creatinine is greater than 2 mg/dL, MR is preferred.

Regardless of the imaging modality, every institution should establish a stent graft protocol. This requires timing the contrast bolus through the anatomy of interest and scanning through that area in fine detail (1-mm to 1.5-mm slices). Uncoordinated contrast or gadolinium injections with a CT or MR scanner prevent adequate imaging of the aorta. Furthermore, thin slices are mandatory for evaluating tortuosity, size, and branch vessel origins. Many typical CT scans are performed with either 5-mm or 7-mm slices, making them insufficient in terms of providing the anatomic details necessary to perform an endovascular repair. Thus, MR or CT can be used for preoperative assessment as long as an appropriate imaging protocol is used to fully lay out the aorta. Three-dimensional reconstructions are also helpful, especially in obtaining length measurements. With appropriate MR or CT, a contrast angiogram should rarely be needed. This is an added benefit, as a preoperative interventional procedure is avoided.

PERIPROCEDURAL IMAGING NEEDS AND OPTIONS

With the introduction of aortic endografting by Parodi in 1991,² the need for appropriate radiographic imaging in the

operating room has rapidly expanded. Traditionally, operative imaging was limited to simple techniques such as completion angiograms after vascular reconstructions or live fluoroscopy during catheter placement. However, as the realm of endovascular techniques has expanded, so too has the need for imaging in the operating room. Although some endovascular procedures are preferentially performed in the operating room due to adjunctive open procedures (eg, cutdowns for stent graft placement), strictly percutaneous procedures are now routinely performed in the operating room as well. The evolution of mobile imaging equipment now allows excellent resolution, a wide range of functionality, and in short, the ability to perform any endovascular intervention in an operating room setting.

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Although many of our endovascular cases have been and continue to be performed using a mobile imaging device, we also recently opened a dedicated angiosuite with a floor-mounted imaging system in a fully functional operating room. A fixed imaging system is ideal, but its absence certainly does not preclude the ability to perform these procedures. Ideally, a center of excellence would be equipped with both options, but this is by no means absolutely necessary. During EVAR, the key to providing optimal care using either system is that each be within a fully functional operating room. If the angiosuite is not prepared for an operative procedure in the event that one becomes necessary, such as a ruptured aneurysm or ruptured iliac artery, significant morbidity can result.

With the use of either a mobile or fixed imaging system, certain functionality is required. The ability to move the bed and C-arm in three dimensions is critical. This allows for appropriate imaging during diagnostic runs and procedures. For example, orbital (obliquities) and radial (cranio-caudal) rotational capabilities allow the C-arm to be directly aligned with the aorta for ideal imaging. In addition, a larger image intensifier is preferred (12 in/30 cm for mobile; 16 in/40 cm for fixed) for maximal visualization. During imaging, we also prefer the use of collimation which reduces radiation exposure.

Ideally, all controls should be available to the interventionalist including post-image processing. This allows the interventionalist to choose and edit runs for optimal viewing. If this is not possible, such as in the case of many mobile systems, a trained x-ray technologist is critical.

LIMITATIONS/BENEFITS TO PORTABLE IMAGING

Several limitations exist with a portable imaging system, none of which preclude performing any endovascular procedures. Certainly, the device is more technician-dependent. If one does not have a mobile fluoroscopy table, the technician needs to move the C-arm to the appropriate positions. Furthermore, fewer controls are readily accessible to the interventionist who is scrubbed in a sterile environment. However, with the recent development of the latest generation of C-arms, including the OEC 9800 MD series (GE Healthcare, Surgery, Salt Lake City, UT), C-arm positioning, as well as some other features, can be performed via a joystick controlled by the interventionist. Another limitation is the size of the image intensifier available, which maximally is 30 cm. Although this limits the field of view, it is not prohibitive to performing these procedures. Additionally, the resolution is not as good as that provided by a fixed imaging platform. Moreover, although the newer-series portable C-arms have quicker cooling systems, they still tend to overheat, especially during procedures involving prolonged magnification or oblique views, as well as on large and obese patients. Finally, there is a small but recognized increased radiation exposure for both the patient and the interventionist when using the portable device.

The primary benefits of using a mobile C-arm are the portability and cost. The choice of a fully functional fixed imaging device requires space, as well as significant financial commitment. In contrast, the mobile C-arm is portable and can be transported to various operating rooms, allowing for procedures to be performed throughout the operating suite. In addition, the cost of one C-arm is approximately \$300,000, as opposed to a fixed imaging platform, the price of which exceeds \$1 million. This cost is in addition to any finances needed to build a compatible room for the fixed device. Cost savings from the purchase of a mobile system can be translated into other equipment needed to perform these procedures (devices, catheters, wires, etc.).

With the advancement of endovascular procedures both in volume and complexity, discussion has arisen as to the best venue for performing these procedures. Criticisms of the portable C-arm have included limited resolution, decreased flexibility and modalities, and somewhat increased radiation exposure. We have found that resolution has not been limiting and that all modalities necessary are available. Furthermore, radiation exposure is minimized with appropriate maneuvers including collimation. The patient should always be positioned as close to the image intensifier as possible to reduce scatter. During diagnostic runs, the interventionist should step back a few feet

away from the C-arm. Finally, appropriate lead aprons should be worn at all times. With careful measures, radiation exposure can be easily limited.³ With that being said, a fixed imaging system within a fully functional operating room offers the ideal situation. Resolution is optimized; radiation is reduced; more control is available; and the most flexibility is offered.

POSTOPERATIVE IMAGING

During the postoperative period, our EVAR patients are typically seen at 1 month, 6 months, and annually thereafter. In addition to a thorough history and physical exam, all patients who do not have renal dysfunction are imaged using CT. We have found this useful for determining migration, endoleak, sac size changes, neck dilatation, limb kinking, or any other important information. Furthermore, we will often obtain an MMS reconstruction for further evaluation. This is especially helpful for sac volume measurements. In the event of patients with renal dysfunction, MR is used for follow-up imaging.

CONCLUSION

Endovascular repair of aortic aneurysms can be challenging. Having the appropriate imaging modalities both preoperatively and perioperatively are essential to obtaining excellent results. In addition to the imaging requirements, specifically trained staff members with the skills required for these procedures (running wires, operating x-ray equipment, etc.), must be available at all times. Thus, optimal care can be delivered at all times. With all of the necessary equipment and personnel, EVAR can be performed at any institution. ■

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