Imaging in the Operating Room

An appraisal of mobile imaging systems.

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With the introduction of aortic endografting by Parodi in 1991,[1] 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.

OEC 9800 PLUS

The OEC 9800 Digital Mobile C-arm (GE Healthcare Technologies, Surgery, Salt Lake City, UT) is the standard portable fluoroscopic imaging device currently used in most operating rooms (Figure 1). The previous generation OEC Series 9600, although capable of live fluoroscopy and diagnostic runs, does not offer the functionality and resolution of the OEC 9800. As a result, endovascular procedures should be performed only with the OEC 9800. The device includes a mobile C-arm and a 1k X 1k workstation.

During use, the C-arm is draped with a sterile covering and then positioned over the patient. Using a mobile radiolucent fluoroscopy bed simplifies repositioning. Thus, the bed can be controlled by the interventionist and moved in three planes (cephalo-caudal, left-right, and up-down). If preferred, the C-arm can also be moved in these dimensions. Most modalities can be controlled through the C-arm and control of fluoroscopy is through the interventionist and a foot pedal. The C-arms are fixed with a 9-inch or a 12-inch image intensifier. For peripheral interventions, the 12-inch image intensifier is optimal because it allows for a larger visual field. All C-arms have orbital (obliquities) and radial (cranio-caudal) rotational capabilities. Naturally, all of these positions can be locked in place to allow for diagnostic runs and subsequent interventions. We also prefer

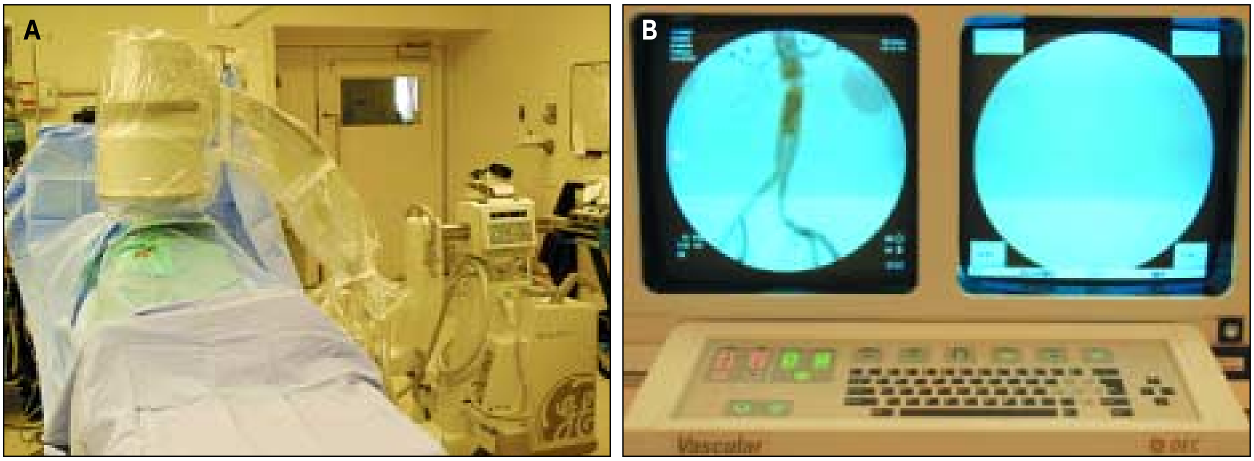


Figure 1. The OEC mobile series 9800 C-arm (12-inch image intensifier) (A) and workstation (B).

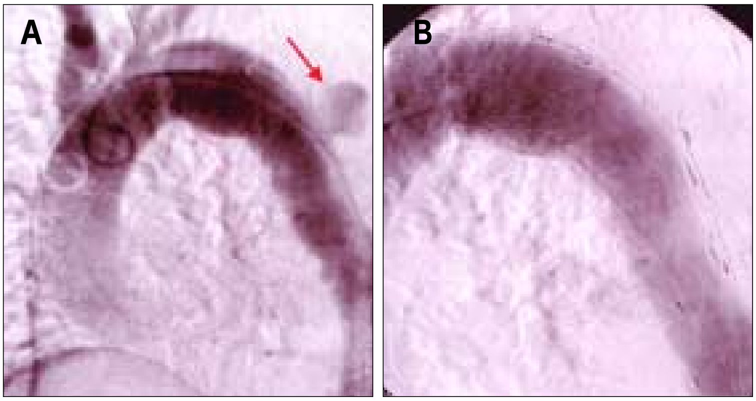


Figure 2. A saccular thoracic aortic aneurysm is shown arising from the distal arch (A). Exclusion of the aneurysm after stent graft deployment (B).

the use of collimation to reduce the amount of x-ray scatter.

The workstation allows for image processing such as edge enhancement, noise filtration, zoom, and others. Furthermore, multiple other functions sometimes necessary for certain procedures are allowed as well. For example, calibration and measurements can be performed to determine exact vessel size. All angiographic runs are saved and can be reviewed repeatedly. Furthermore, runs or static images can be downloaded to a disc or printed on filmpaper.

Live imaging, during which standard fluoroscopy can be performed, is controlled by the foot pedal. High-level static images can also be obtained as digital spot images. Furthermore, pulsed or continuous high-level fluoroscopy can be performed that may be especially important in contrast runs. Vascular imaging in terms of creating roadmap masks can also be controlled via the foot pedal. These images can be obtained with or without digital subtraction. Editing and adjusting runs as well as visualizing different runs are done through the workstation.

LIMITATIONS 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 OEC 9800 MD, C-arm positioning, as well as some other features, can be performed via a joystick controlled by the interventionist.

The largest image intensifier available is only 30 cm, which limits the field of view somewhat. Additionally, the resolution is not quite as good as that provided by a fixed imaging platform. Although the newer series OEC 9800 portable C-arms have quicker cooling systems, they still tend to overheat faster than a fixed device, 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.

BENEFITS

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 OEC 9800 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 an OEC 9800 Motorized C-arm (including the imaging table) 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.

PRACTICAL ASSESSMENT

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

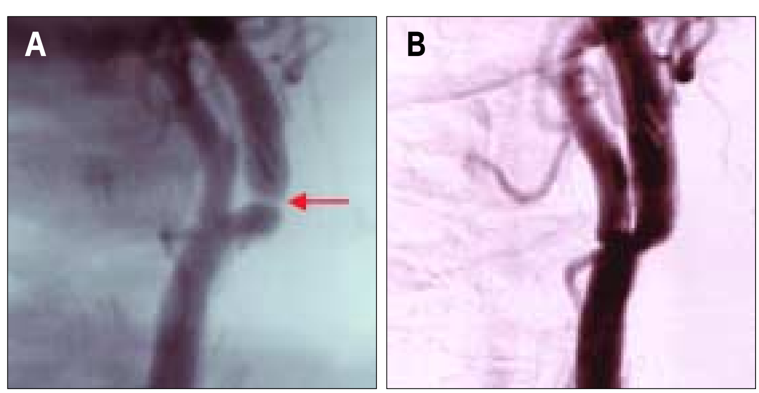
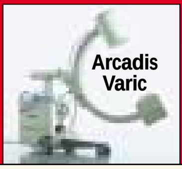
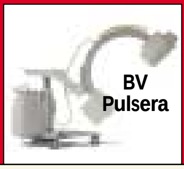


Figure 3. A hemodynamically significant lesion in the internal carotid artery (A). Resolution of this lesion with angioplasty and stenting (B).

AVAILABLE MOBILE C-ARMS





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- High-capacity 15-kW generator for dense anatomy penetration and challenging imaging applications
- Full vascular imaging package for DSA, roadmapping, and vessel measurement package.
- Automatic contrast and brightness adjustments
- DICOM compatible

OEC 9800

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- High-capacity 15-kW generator for dense anatomy penetration and challenging imaging applications
- Full vascular imaging package for DSA, roadmapping, and vessel measurement package.
- Automatic contrast and brightness adjustments
- True point-and-shoot technology
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- Passive heat dissipation eliminates need for noisy cooling fans
- Cost-effective operation with wide range of options, including DICOM

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- Bodysmart automatic exposure optimization for noncentered anatomy
- Passive heat dissipation eliminates need for noisy cooling fans
- Entry level system with wide range of options including vascular subtraction and DICOM

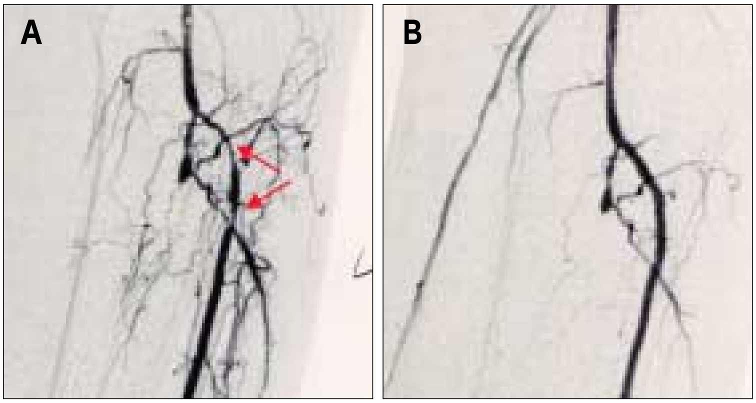

Figure 4. Tandem lesions in the proximal anterior tibial artery (A). Successful angioplasty of these lesions is seen (B).

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.[2]

As previously stated, the necessity of performing certain endovascular procedures in the operating room evolved with the placement of aortic endografts requiring concomitant open procedures. As increasing numbers of endovascular procedures are performed in the operating room, including purely percutaneous techniques, portable imaging devices have been used more extensively. Procedures with varying complexity are performed with the mobile C-arm. Certainly, simple procedures such as inferior vena cava filter placement or iliac angioplasty and stenting can be done on a mobile system. In addition, procedures requiring concomitant open techniques need to be performed in an operating room environment, which may not be available with a fixed imaging unit. We routinely perform our abdominal and thoracic aortic endograft procedures in the operating room with a mobile unit (Figure 2).

In comparison, complex percutaneous procedures, such as carotid angioplasty and stenting, can also be performed with excellent results.[3] We also have not found any limitations with the OEC 9800 in performing carotid interventional procedures. As shown, a significant internal carotid lesion is diagnosed and then treated with angioplasty, stenting, and the use of a protection device (Figure 3). Furthermore, infrainguinal angioplasty including the infrageniculate arteries has been shown to be successful both in terms of technical success and follow-up.[4] Our group has been active in performing the entire gamut of endovascular procedures including carotid angioplasty and stenting, thoracic and aortic endografting, lower extremity angioplasty and stenting including infrageniculate angioplasty (Figure 4), renal artery angioplasty and stenting, and more. All of these procedures have been performed in the operating room with a mobile C-arm, and we have not experienced any limitations in terms of resolution or functionality.

Although an ideal setup would include a fixed imaging system within the confines of a fully functional operating suite, cost constraints can preclude this. Certainly, we have found that state-of-the-art mobile radiographic imaging systems are more than adequate for performing any endovascular procedure. Furthermore, when first establishing an endovascular program, a significant financial expense is required to stock the appropriate disposables (eg, wires, catheters, balloons, etc.). The dollar savings between fixed and mobile devices could thus be used toward many other necessities. In short, an endovascular specialist should not feel constrained by the use of a mobile imaging system. These portable units have evolved into quite sophisticated imaging systems with more attributes and inconsequential limitations. ■

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1. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg*. 1991;5:491-499.
2. Lipsitz EC, Veith FJ, Ohki T, et al. Does the endovascular repair of aortoiliac aneurysms pose a radiation safety hazard to vascular surgeons? *J Vasc Surg*. 2000;32:704-710.
3. Ohki T, Veith FJ, Grenell S, et al. Initial experience with cerebral protection devices to prevent embolization during carotid artery stenting. *J Vasc Surg*. 2002;36:1175-1185.
4. Silva MB, Hobson RW, Jamil Z, et al. A program of operative angioplasty: endovascular intervention and the vascular surgeon. *J Vasc Surg*. 1996;24:963-971; discussion 971-973.