Technical Advances in Interventional Radiology

- New robotically controlled C-arm systems are capable of fluoroscopy and 3D imaging (cone-beam CT)
- Accompanying software fuses prior diagnostic 3D images (CT, MRI, or PET) with live fluoroscopic images
- Advantages include superior pre-treatment planning and imaging to ensure treatment is complete, especially for:
  - Neurointerventional procedures such as clot removal and aneurysm treatment
  - Oncology procedures such as chemoembolization
- New navigational tools are under development to aid needle guidance for biopsy and ablation procedures

**Figure 1.** The new interventional radiology suite at Mass General is equipped with a robotically controlled C-arm whose position is adjusted on eight rotating joints. It is used to acquire fluoroscopic and cone-beam CT images during interventional procedures.

Ultrasound, fluoroscopy, CT, and MRI are all used to guide interventional radiology (IR) procedures; however, any individual modality has its limitations. Ultrasound and fluoroscopy provide real-time images, but ultrasound is limited by relatively poor image resolution and is very dependent on operator skill. Fluoroscopy provides high-resolution images that are less affected by natural body surfaces (e.g., air in the lungs) but inherently involves radiation exposure to both patient and practitioner. CT and MRI provide high-resolution three-dimensional (3D) projections, but CT-guidance also requires radiation exposure and presents operational challenges in using a diagnostic machine for interventional purposes. MRI is limited by the challenges of working in a magnetic field (e.g., inability to use traditional metal implements).
Figure 2. 51 year old male with 4.7 cm hepatocellular carcinoma as seen on coronal CT (Figure 2A). Tumor was treated with bland embolization followed by microwave ablation. Targeting precise vessels supplying the tumor allowed for targeted tumor therapy. Identification of the exact vessel was possible by overlaying 3D CT image of the vessels supplying the tumor (arrow) during real time fluoroscopic manipulation of the microcatheter.

Technology has recently been introduced that provides new imaging techniques and improved navigational tools, which have the potential to decrease radiation exposure and procedure time, while increasing the precision of therapy. For example, advanced C-arm devices such as the Artis zeego (Siemens Healthcare) recently installed in a new interventional suite at Mass General can be used to acquire fluoroscopy images as well as 3D cone-beam CT (CBCT) images. This device has a robotically controlled C-arm with eight rotating joints that can be positioned at virtually any angle to acquire fluoroscopic images, providing greater comfort for patients while the interventional radiologist works from any angle. Fluoroscopic imaging can be performed at varying pulse frequencies depending on the clinical need to minimize radiation dose, which is automatically adjusted to the patient’s anatomy.

CBCT images can be acquired by rotating the C-arm in an arc as much as 360 degrees over a period of six seconds. The flat panel detector is 30 x 40 cm, which is large enough to view the entire anatomy of a large tumor and its feeding vessels prior to interventional oncology procedures such as chemoembolization. Although CBCT images do not have as much soft tissue contrast as conventional CT images, images acquired during the procedure are helpful in detecting parenchymal lesions that cannot be adequately depicted by digital subtraction angiography (DSA) and therefore, help the interventional radiologist to select the vessels leading to the tumor(s) prior to treatment.

A second advantage of C-arm CBCT imaging is the ability to acquire a CT image during a procedure without moving the patient to a separate CT scanner. For example, during procedures for clot-removal in stroke patients, it is standard practice to obtain an axial CT to confirm that the clot has been removed and that there is normal blood flow. Using the C-arm for these images without moving the patient reduces procedure time and increases patient safety. When treating tumors, especially hepatocellular carcinoma, CBCT images are helpful for planning treatment and assessing treatment completion.

Image Guidance Software
In addition to the imaging abilities of the new C-arm device, the accompanying software (Interventional Oncology Pro Engine, Siemens Healthcare) offers a comprehensive collection of programs that aid both transcatheter and ablative therapies, including image fusion software and embolization needle guidance. For example, the navigation software can be used to overlay live fluoroscopic images on a corresponding 2D projection of previously acquired 3D images from diagnostic CT, MRI, and/or PET. The combination images offer enhanced guidance during interventional
procedures by providing more information in a single display, with the potential to reduce procedure time and increase user confidence. If there is any patient movement, the registration of the images can be adjusted manually or by automatic algorithms using features seen in both fluoroscopy and the 3D image, such as bony landmarks, or a 2D angiogram corresponding to blood vessels in the 3D image. The intensity of the overlaid images can be adjusted and faded with a joystick.

The additional guidance of fused images helps increase confidence in vessel selection while decreasing the number of image acquisitions as well as the amount of contrast agent needed. For example, in neurointerventional procedures, the software can fade out image data corresponding to an artery not associated with the procedure, simplifying the view for the practitioner. The additional anatomic information is especially helpful in the treatment of cerebral aneurysms because it provides better data on aneurysm morphology and improved optimization of working projections.

**Navigation Aids**

Although not yet in routine clinical practice, a number of navigation aids have been developed to guide procedures such as biopsies and ablations. At present, the skill of the interventional radiologist to judge the position of a needle is critical for success. With CT-guidance, only the depth of the needle is objectively measured and the trajectory is estimated. Thus, repeated scans are necessary to guide the radiologist to the target, which is time consuming and increases radiation dose. When ultrasound is used for guidance, visualization of the lesion as well as the needle can be challenging. Poor visualization, together with problems arising from patient motion or breathing, can result in increased procedure time and the need for deeper sedation.

The new navigation aids owe much to tracking technologies used in, for example, GPS navigation, missile guidance, and video games. In technology similar to GPS, guidance can be achieved with the aid of electromagnetic (EM) fiducial markers placed on the body that can establish the position of internal organs (as seen in a CT image) with a sensor embedded on the tip of a needle. A low magnetic strength field generator positioned next to the patient near a treatment site is then used to detect the relative positions of the fiducial markers and the needle tip. This system creates accurate "mapping" of the organs and allows real-time tracking of the needle as it is advanced into a lesion for a biopsy or ablation.

Guidance can also be achieved with optical tracking using passive reflection or light emitters within view of a camera. The relative position of these light sources provides similar global positioning data to that from EM sensors, which can be integrated with imaging data to determine the treatment trajectory. Optical systems have the advantage of not being affected by metallic components but the disadvantage of requiring a clear line of site.

**Scheduling**

A robotically controlled C-arm device has been installed in the Gray Building on the main campus of Massachusetts General Hospital in Boston. Complex interventional procedures are triaged to that room. All interventional radiology procedures, including complex image-guided interventional procedures supported by this new imaging device, can be scheduled through the Radiology Order Entry system, [http://mghroe](http://mghroe), or by calling 617-726-8314.

**Further Information**

For more information regarding guidance systems in interventional radiology, please contact Raul N. Uppot, MD, Interventional Radiology (617-726-8396) or Joshua A. Hirsch, MD, Vice Chief, Interventional Radiology, Massachusetts General Hospital.

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References


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