Using Image Fusion During EVAR

Experience from a high-volume aortic center shows a reduction in radiation exposure when image fusion is utilized.

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Endovascular aneurysm repair (EVAR) was developed to provide a treatment option for patients with abdominal aortic aneurysms who are not eligible for surgery. To increase the number of patients eligible for this minimally invasive procedure, there has been recent development of complex devices such as fenestrated and branched endografts. These have required concomitant advances in intraoperative imaging applications.

Traditionally, EVAR is performed in the operating room with standard intraoperative two-dimensional (2D) fluoroscopy imaging, which can be inadequate in complex procedures requiring prolonged radiation exposure. As a result, a growing number of centers have invested in hybrid rooms that combine an optimal open surgical environment with the advanced imaging capabilities of a fixed system. These capabilities include more tube power (without overheating issues), flat-panel detectors with excellent image quality, and customizable x-ray dose levels. Additionally, latest-generation hybrid rooms have the ability to acquire three-dimensional (3D) images through a C-arm rotation around the patient, also called *cone-beam computed tomography* (CBCT). The 3D images of the anatomy generated at the time of the procedure can then be fused with live fluoroscopy to be used as a 3D road map and facilitate endovascular navigation.[1] Preoperative CT angiography (CTA) images can also be fused with live fluoroscopy.[2]

Depending on the room manufacturer, imaging protocols can differ slightly.[3-6] When following good practices and the As Low As Reasonably Achievable (ALARA) principles, it is possible to achieve excellent clinical outcomes with a simple workflow and low x-ray exposure levels.[7,8]

Figure 1. Discovery IGS730 (GE Healthcare, Chalfont St. Giles, UK) hybrid room in Lille, France.

In this article, we report our experience of image fusion during EVAR in a high-volume center dedicated to aortic repairs, performed by operators focusing on minimizing radiation exposure.

METHODS

Definitions

Image registration consists of spatially aligning two imaging datasets with each other. Image fusion is when several imaging datasets are overlaid and combined as one display. Three-dimensional fusion is used to describe the overlay of a 3D model on top of a C-arm x-ray image. Two techniques of 3D fusion can be used. The 3D

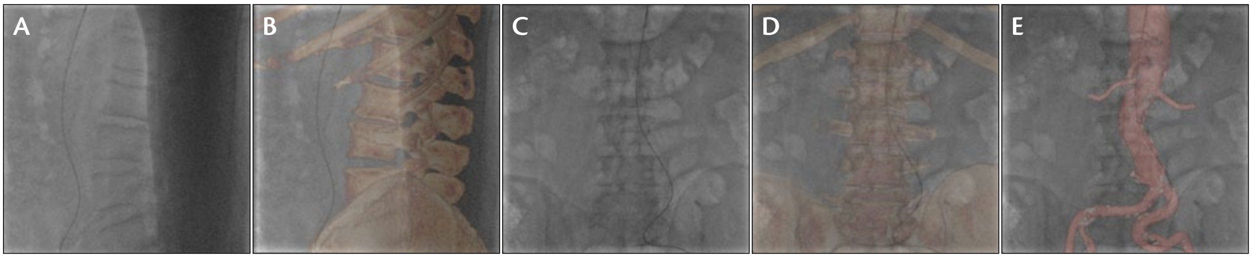

Figure 2. Registration is performed with two fluoroscopic orthogonal (AP and lateral) shots. On the lateral view (A), the vertebral bodies from the bone 3D volume-rendering (3D VR) model reconstructed from the preoperative CTA are moved to perfectly match (B) the vertebral bodies from the fluoroscopic image. The same maneuver is performed on the AP view (C, D). The bone 3D VR model is then replaced by the aortic (E) 3D VR model reconstructed from the preoperative CTA.

model may be created from an intraoperative contrast-enhanced CBCT volume (referred to as *CBCT fusion*), or a preoperative dataset, such as CTA or MRA, may be used for the 3D model (referred to as *CTA fusion*).

Workflow

In our center, every patient undergoing EVAR benefits from the following imaging protocol. Before each procedure, a bone and an aortic 3D VR model is reconstructed from the preoperative CTA on a workstation (Advantage Windows, GE Healthcare, Chalfont St. Giles, UK).

The procedures are performed under general anesthesia in our hybrid operating room (Discovery IGS730, GE Healthcare; Figure 1). Open or percutaneous femoral access is obtained through both groins. The aortic preoperative CTA is fused (Innova Vision, GE Healthcare) with the 2D live fluoroscopy. Registration of this preoperative CTA is performed in two steps, first using the bone subvolume and aligning it on bony landmarks visible on two fluoroscopic orthogonal shots (anterioposterior [AP] and lateral) of the spine, then switching to the aortic subvolume (Figure 2).

AP digital subtraction angiography run with an injection of 7 mL of contrast medium at 30 mL/sec is performed once the endograft is inserted into the aorta over a stiff guidewire. This run is completed to check the accurate position of the renal arteries on the registration, which can be adjusted by the operator from the tableside if required.

Once the endograft has been implanted, a contrast-enhanced CBCT (Figure 3) is acquired to assess technical success. Patency of the endograft, fenestrations, and branches is verified, and endoleaks are depicted. This technique allows for an immediate additional procedure when technical success is not achieved and carries the potential to replace the current postoperative follow-up CTA, reducing cost, hospitalization length, and radiation exposure.

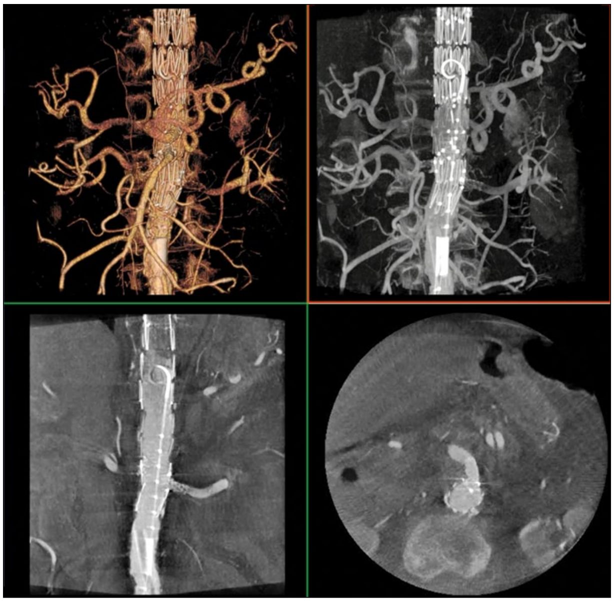

Figure 3. 3D VR, 3D-MIP, and MPR reconstructions of the contrast-enhanced CBCT performed at the end of a 4-fenestration endograft implantation to verify technical success.

DISCUSSION

Clinical Benefit

In our experience, image fusion allows the overlay of a preoperative 3D dataset from CT on live fluoroscopic images through a very simple and fast workflow. This 3D road mapping provides real-time 3D visualization of the vascular anatomy during EVAR procedures (Figure 4). During the procedure, the 3D road mapping is connected to the gantry movement, source-to-image distance, field of view, and table motion. In case of patient motion or vascular deformation upon the introduction of a stiff wire, registration adjustments may be easily performed manually by the tableside operator.[9] The ability to position anatomical landmarks on the 3D model before the procedure allows the operator to select the best working angulation

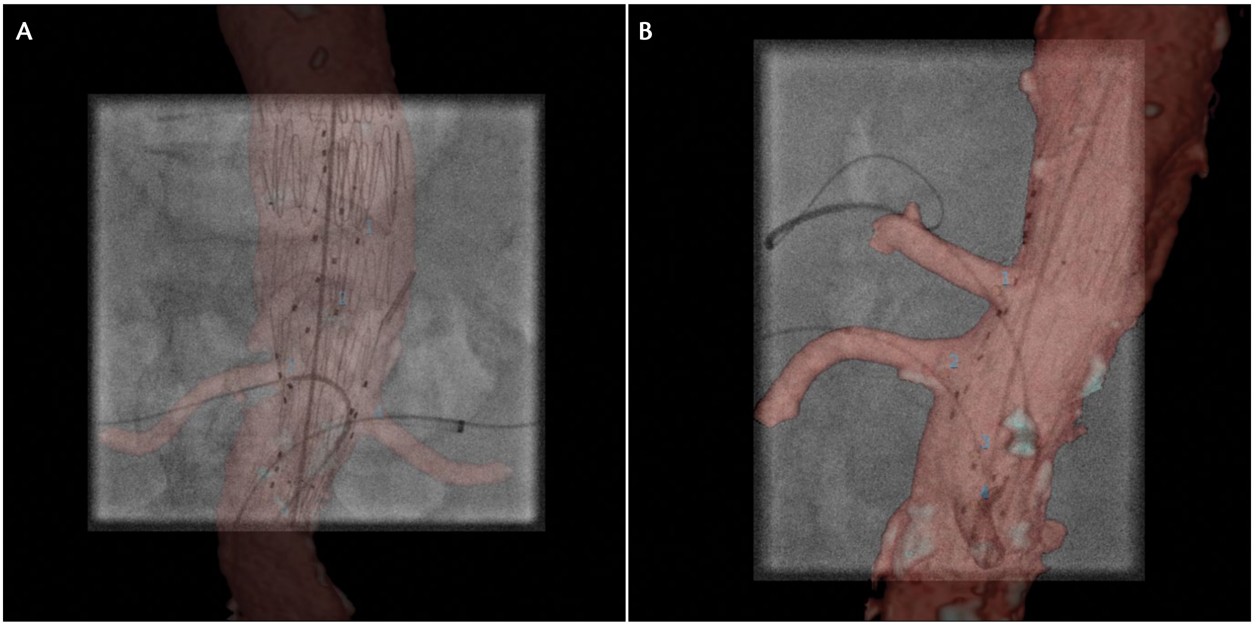

Figure 4. Real-time 3D visualization of the renal (A) and visceral (B) anatomy during a fenestrated endograft implantation.

during the 3D road mapping phase and automatically position the gantry without having to use fluoroscopy. This can be of particular importance in complex and angulated anatomy—for instance, when navigating in the aortic arch.

To be relevant in a real-life setting, we believe image fusion technology needs to remain easy to use and accessible from the operator's working position. In our experience, a variety of tools for enhanced visualization are available. For instance, a single click allows the operator to view the 3D model from the opposite side without losing registration on the fluoroscopy or moving the gantry. This can be of particular interest in viewing the origin of a renal artery, particularly when the superior mesenteric artery is overlaying it. When catheter manipulations are required, the image fusion may be too dense, hiding the device tip. It is then important to adjust the 3D model opacity and brightness, which can easily be done. Finally, the recent introduction of large monitor displays in hybrid rooms increases operator comfort, as it allows them to work within a larger field of view via a digital zoom without requiring additional radiation exposure.

Radiation Reduction

There are a few studies in the literature reporting the results of EVAR performed with image fusion. Most of them report a reduction in contrast media volume[4,10,11] but equivalent or higher radiation exposure when compared to their experience with standard 2D fluoroscopy.[12,13] In our experience, this technique, together with strict adherence to the ALARA principle, also leads to dose reduction. In a recent evaluation of our first 100 aortic endovascular repairs performed with image fusion (A. Hertault, MD, unpublished data, January 2014), we observed significant reduction in radiation exposure for all types of EVAR procedures (including thoracic and fenestrated EVAR) for both patients and physicians, as well as a significant reduction in contrast media volume during complex repairs (fenestrated EVAR).

There are three key explanations for these results. The first is the fusion technique used to overlay 3D images on live fluoroscopy. In our protocol, we use preoperative CTA to generate the 3D model, and fusion registration is performed with two fluoroscopic orthogonal shots (AP and lateral) of the spine to align the bone subvolume of the CTA on bony landmarks. This protocol is fast, easy, and almost radiation free. The other described techniques to overlay the preoperative CTA require a preoperative CBCT, and thus additional radiation.

The second explanation is strict application of the ALARA principle in our current practice. We had previously evaluated our radiation exposure during EVAR performed on a mobile C-arm[14] and had already demonstrated that radiation exposure during EVAR could be considerably minimized by constantly focusing on applying the ALARA principle.[7,8] In our hybrid room, we still apply these principles. In addition, we can now position the table and the C-arm angulation without x-ray, because the 3D mask is connected to the table and gantry movements. Most digital subtraction angiography runs have now been replaced by recorded fluoroscopy runs, including 2D road map runs performed to position the iliac legs of the endograft. Because we have a 56-inch monitor with enhanced image quality, magnification is almost never required. We systematically use collimation to focus radiation on only the area of interest. What is consistent in our practice between our previous setup and the new-generation hybrid setup is that all system settings are set in low autoexposure mode by default. In our new hybrid room, the receptor dose is limited to 25%, and the lowest fluoroscopy frame rate is 7.5 frames/sec (66% of the maximal frame rate). We also have to take into consideration that working on a latest-generation system gives us the opportunity to benefit from the latest technological advances to reduce the radiation emission settings (kilovoltage and ampere) without degradation of the image. Furthermore, a capacitive sensor allows us to estimate the distance from the detector to the patient, and the system automatically minimizes this distance, allowing a reduction of the scattered radiation.

Finally, our imaging system is fully controlled by the operator tableside, which has also proved to reduce radiation exposure when compared to a radiographer-controlled imaging system.[15]

The addition of all the above settings and workflow directly affect the delivered level of radiation, which explains the large data variability observed in the literature.[16]

CONCLUSION

Several advanced imaging solutions are available to help treat complex aortic aneurysms. Routine use of advanced imaging applications in the hybrid room has modified our practice without jeopardizing the overall procedure workflow. Based on our 1-year experience, after a very fast learning curve, we recommend performing all EVAR using image fusion to reduce x-ray dose to the patient and the operators. ■

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