Image fusion performed with noncontrast computed tomography scans during endovascular aneurysm repair

Teresa Martin-Gonzalez, MD, Adrien Hertault, MD, Blandine Maurel, MD, PhD, Marco Midulla, MD, PhD, Mohammad Saeed Kilani, MD, and **Stephan Haulon, MD, PhD,** *Lille, France*

We report two endovascular aneurysm repair procedures achieved under image fusion guidance accomplished with noncontrast injected preoperative computed tomography scans. Such use of this advanced imaging application reduces contrast media injection volume (respectively, 27 and 24 mL throughout the patients' hospital course). No changes in creatinine clearance occurred after the procedures. Contrast-enhanced ultrasound imaging confirmed technical success in both cases. (J Vasc Surg Cases 2015;1:53-6.)

Renal insufficiency after endovascular aneurysm repair (EVAR) is associated with increased morbidity. Iodinated-contrast media injection, required during the implantation procedure and preoperative and postoperative computed tomography (CT), is a major source of renal impairment after EVAR.[1] Renal impairment is observed in up to 24% of patients after EVAR, especially in those with pre-existing renal insufficiency.[2,3]

We report two EVAR cases in patients with chronic renal insufficiency performed under fluoroscopic guidance with three-dimensional (3D) road mapping fusion. In both cases, the 3D overlay was constructed from a noncontrast preoperative CT scan, performed for diagnosis and sizing purposes, to minimize the total volume of contrast media injected to the patients throughout their hospital course. Consent to publish was obtained from both patients.

CASE REPORT

Patient 1 was a 77-year-old man with a 55-mm-wide abdominal aortic aneurysm (AAA). Medical history reported a right lobectomy for a T2 N0 M0 lung adenocarcinoma 6 months earlier and a severe renal insufficiency, noted as stage 3 chronic kidney disease (CKD), with an estimated glomerular filtration rate of 35 mL/min/1.73 m^2 calculated with the Modification of Diet in Renal Disease method. Patient 2 was a 79-year-old man with a 54-mm AAA and a 35-mm right common iliac artery aneurysm. His medical history included two major abdominal surgeries—a subtotal gastrectomy and a radical cystoprostatectomy with ureterostomy—and coronary occlusive disease. In addition, he had a stage 4 CKD (estimated glomerular filtration rate of 21 mL/min/1.73 m^2).

Rapid growth (>5 mm at 6-month interval) was observed in both patients, at the aortic level in patient 1 and at the iliac level in patient 2. We generally perform contrast-enhanced CT for patients with AAA undergoing preoperative workup, but preoperative CTs were performed in both patients without contrast media injection. The CTs were loaded in our Advantage Workstation 4.6, volume share 5 (GE Healthcare, Waukesha, Wisc) and reconstructed in multiplanar reformatted (MPR) views. Adjusting contrast and brightness in various MPR views provides an accurate assessment of the landing zones.[4]

A 3D volume-rendering model of the bone structures was automatically generated. Then, a 3D volume-rendering model of the aorta and its main branches was manually reconstructed (Fig 1, *A*). Schematically, the arterial wall was identified on several consecutive MPR slices (each at least 5 mm) in axial, coronal, and sagittal views, from above the renal arteries to the iliac bifurcations and delimited with contouring software (Fig 1, *B* and *C*). Data inside this segmented area were extracted from the complete CT acquisition and reconstructed separately in 3D. Voxels intensity was adjusted to improve visibility (Fig 1, *D*). This stage required a trained operator and lasted ∼5 minutes.

At the beginning of the procedures, two fluoroscopic orthogonal shots (anteroposterior and lateral) were used to perform a 3D-over-2D registration of the bone subvolume from the noncontrast injected CT scan on the X-ray bone structures. We then switched from the bone 3D model to the vascular model. This second step was performed by a scrubbed physician from tableside and required ∼2 more minutes. After rigid guidewires insertion, fine adjustment was achieved with an injection of 7 mL isosmolar iodixanol contrast media (Visipaque; GE Healthcare, Princeton, NJ) to accurately locate the level of the renal ostia.[5]

Navigation and stent graft deployment were accomplished with a minimum quantity of contrast (27 mL and 24 mL,

From the Vascular Surgery and Radiology, Aortic Centre, Centre Hospitalier Régional Universitaire de Lille.
Author conflict of interest: A.H. is a consultant for GE Healthcare. S.H. is a consultant for Cook Medical and GE Healthcare.
Reprint requests: Stephan Haulon, MD, PhD, Aortic Centre, Hôpital Cardiologique, CHRU de Lille, Université Lille 2, INSERM U1008, 59037 Lille Cedex, France (e-mail: stephan.haulon@chru-lille.fr).
The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.
2352-667X

http://dx.doi.org/10.1016/j.jvsc.2014.09.002

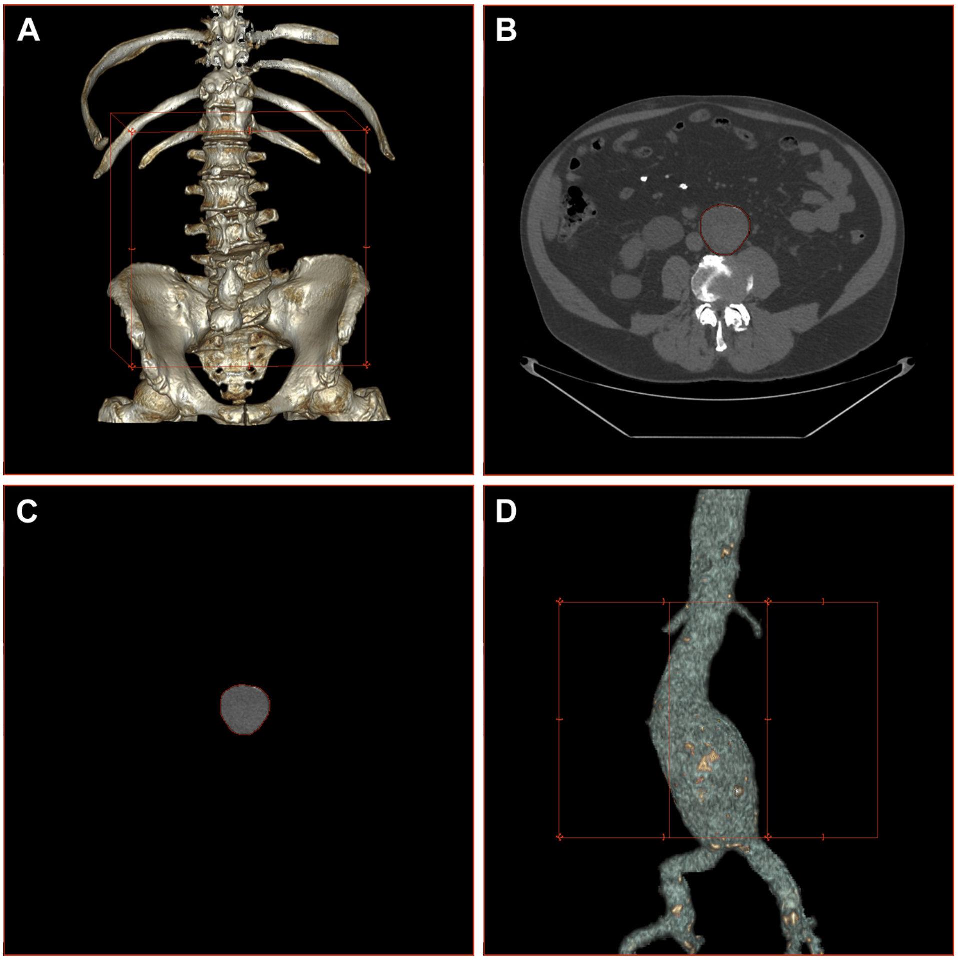

Fig 1. A, Three-dimensional (3D) volume rendering of the bone structures automatically generated by the workstation. **B** and **C**, The arterial wall is identified on several consecutive slices and delimited with contouring software. **D,** Data inside the segmented area are extracted from the complete computed tomography (CT) image and reconstructed separately in 3D. Voxels intensity is adjusted to improve visibility.

respectively). In addition to the 7 mL contrast media to check the accuracy of the 3D-over-2D registration, 10 mL contrast media was injected twice to locate the internal iliac arteries origin in patient 1, and 10 mL to locate the left internal iliac artery origin and 7 mL to perform a right internal iliac artery embolization in patient 2 (Fig 2). The procedure time was 75 minutes in patient 1 and 60 minutes in patient 2, with 7 minutes and 16 minutes of fluoroscopy time, respectively. The radiation dose measured by the dose area product was 1648 $cGy.cm^2$ and 1010 $cGy.cm^2$, respectively.

Postprocedural control was performed with a contrast-free cone-beam CT scan (CBCT; Fig 3) and a contrast-enhanced 3D ultrasound assessment before discharge. No type I or type III endoleaks were observed, and all renal arteries were patent. Occlusion of the origin of the right internal iliac artery after embolization was confirmed. No changes in renal function were noted throughout the hospital course.

DISCUSSION

Renal impairment is a relative contraindication for EVAR because it is associated with increased morbidity. Renal dysfunction is frequently observed after EVAR[6] and has a multifactorial origin, including embolization from guidewire and catheter manipulation and injection of contrast media.[2] In case of pre-existing renal impairment, contrast media injection during EVAR must be restricted to a minimum to minimize the risk of renal function deterioration.

Modern hybrid operative rooms are equipped with advanced imaging applications such as image fusion. This technology allows superimposition of a 3D volume generated from the preoperative CT angiography on the live operative fluoroscopy.[7-9] This vascular overlay is a helpful tool to assist navigation, catheterization, and graft deployment, particularly in complex cases.[10] In 2011, Kobeiter et al[3] reported the first successful endovascular repair of a thoracic aneurysm with zero-contrast injection during the procedure under fusion guidance using CT angiography.

Since then, image fusion has been widely accepted as having the potential to decrease iodinated-contrast media use[11,12] and, thus, nephrotoxicity. Image fusion is

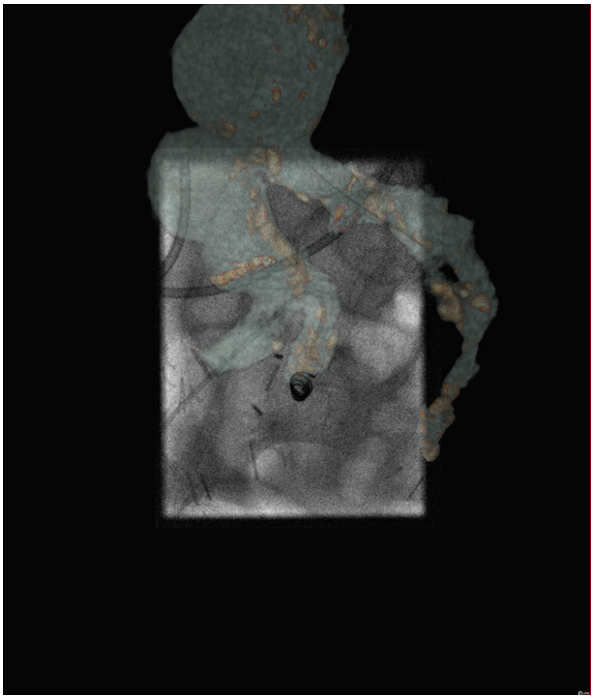

Fig 2. Right internal iliac artery embolization performed with image fusion guidance.

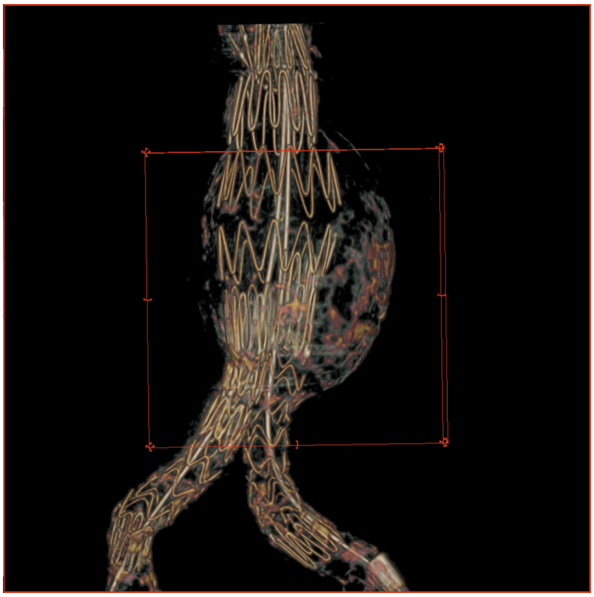

Fig 3. At the end of the procedure, a contrast-free cone-beam computed tomography (CBCT) scan is performed.

traditionally performed from a preoperative contrast-enhanced CT scan or CBCT. We report the first use of fusion based on a preoperative CT scan without contrast. This technique is identical to the previously described fusion technique apart from the fact that we constructed a 3D aortic volume by manual segmentation.

To generate a 3D aortic volume, we had to develop a specific workflow on the 3D workstation. In patients with CKD, the use of image fusion generated from a CT scan without contrast enables EVAR repair with minimum contrast media injection. Postoperative control was also achieved without iodinated contrast media use because it was performed with a noncontrast CBCT associated with a contrast-enhanced 3D ultrasound examination. In patients with a major risk of renal impairment after EVAR, iodinated contrast media injection was restricted to the strict minimum to prevent worsening of the renal disease, new onset of dialysis, and to lower postoperative morbidity.[12] To minimize the risk of contrast-induced nephropathy in patients with CKD, preoperative magnetic resonance angiography-gadolinium registered to an intra-operative rotational system is also an option to perform image fusion. Only one case report[13] has described this technique performed under an experimental protocol. The identification of small branch vessels was not validated.

The use of carbon dioxide as a contrast agent in patients with CKD or severe allergy to iodinated contrast media has also been suggested.[14] However, the high pressure required to inject carbon dioxide can dislodge mural thrombus and create embolization in the visceral arteries and the lower limbs. Excessive volume injection can also place strain on the right side of the heart.

Finally, precatheterization of renal arteries before stent graft deployment[15] is also an option. This later technique can be challenging and associated with complications such as dissections and embolization.

CONCLUSIONS

Image fusion improves visualization during image-guided procedures and allows a low volume of contrast injection. In patients with pre-existing renal impairment, image fusion can be achieved from a noncontrast injected preoperative CT scan, minimizing the risk of nephrotoxicity without compromising the accuracy of the EVAR.

REFERENCES

1. Solomon R, Dumouchel W. Contrast media and nephropathy: findings from systematic analysis and Food and Drug Administration reports of adverse effects. Invest Radiol 2006;41:651-60.
2. Carpenter JP, Fairman RM, Barker CF, Golden MA, Velazquez OC, Mitchell ME, et al. Endovascular AAA repair in patients with renal insufficiency: strategies for reducing adverse renal events. Cardiovasc Surg 2001;9:559-64.
3. Kobeiter H, Nahum J, Becquemin JP. Zero-contrast thoracic endovascular aortic repair using image fusion. Circulation 2011;124:e280-2.
4. Kurabayashi M, Okishige K, Ueshima D, Yoshimura K, Shimura T, Suzuki H, et al. Diagnostic utility of unenhanced computed tomography for acute aortic syndrome. Circ J 2014;78:1928-34.
5. McCullough PA, Bertrand ME, Brinker JA, Stacul F. A meta-analysis of the renal safety of isosmolar iodixanol compared with low-osmolar contrast media. J Am Coll Cardiol 2006;48:692-9.

6. Greenberg RK, Chuter TA, Sternbergh WC 3rd, Fearnot NE; Zenith Investigators. Zenith AAA endovascular graft: intermediate-term results of the US multicenter trial. J Vasc Surg 2004;39:1209-18.
7. Kaladji A, Lucas A, Cardon A, Haigron P. Computer-aided surgery: concepts and applications in vascular surgery. Perspect Vasc Surg Endovasc Ther 2012;24:23-7.
8. Kaladji A, Dumenil A, Castro M, Haigron P, Heautot JF, Haulon S. Endovascular aortic repair of a postdissecting thoracoabdominal aneurysm using intraoperative fusion imaging. J Vasc Surg 2013;57: 1109-12.
9. Alomran F, Desgranges P, Majewski M, You K, Kobeiter H. Image fusion for hybrid repair of dislocated superior mesenteric branch of a branched endovascular aortic graft. J Vasc Surg 2013;58:798-801.
10. Abi-Jaoudeh N, Kruecker J, Kadoury S, Kobeiter H, Venkatesan AM, Levy E, et al. Multimodality image fusion-guided procedures: technique, accuracy, and applications. Cardiovasc Intervent Radiol 2012;35:986-98.
11. Tacher V, Lin M, Desgranges P, Deux JF, Grünhagen T, Becquemin JP, et al. Image guidance for endovascular repair of complex aortic aneurysms: comparison of two-dimensional and three-dimensional angiography and image fusion. J Vasc Interv Radiol 2013;24:1698-706.
12. Dijkstra ML, Eagleton MJ, Greenberg RK, Mastracci T, Hernandez A. Intraoperative C-arm cone-beam computed tomography in fenestrated/branched aortic endografting. J Vasc Surg 2011;53:583-90.
13. Sadek M, Berland TL, Maldonado TS, Rockman CB, Mussa FF, Adelman MA, et al. Use of preoperative magnetic resonance angiography and the Artis zeego fusion program to minimize contrast during endovascular repair of an iliac artery aneurysm. Ann Vasc Surg 2014;28:261.e1-5.
14. Criado E, Upchurch GR, Young K, Rectenwald JE, Coleman DM, Eliason JL, et al. Endovascular aortic aneurysm repair with carbon dioxide-guided angiography in patients with renal insufficiency. J Vasc Surg 2012;55:1570-5.
15. Canyiğit M, Çetin L, Uğuz E, Algin O, Küçüker A, Arslan H, et al. Reduction of iodinated contrast load with the renal artery catheterization technique during endovascular aortic repair. Diagn Interv Radiol 2013;19:244-50.

Submitted Jul 29, 2014; accepted Sep 24, 2014.