# Feasibility of three-dimensional fusion imaging with multimodality roadmap system during endovascular aortic repair

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## ABSTRACT

**Objective:** Endovascular procedures for aortic aneurysm repair have become widely accepted as safe and effective surgical options. We investigated the efficacy of the multimodality roadmap (MMR) system with biplane fluoroscopy to attempt to reduce the use of contrast medium and exposure to radiation during surgery.

**Methods:** We retrospectively reviewed 263 consecutive cases with elective endovascular aneurysm repair (EVAR) and thoracic endovascular aortic repair (TEVAR). Patients were categorized into two groups, with and without introduction of the MMR system, which was applied in 164 patients (62.4%). The MMR− group included 62 EVAR and 37 TEVAR cases, and the MMR+ group consisted of 81 EVAR and 83 TEVAR cases. Radiation dose, contrast medium use, and complications were compared between the MMR− and MMR+ groups in the respective EVAR and TEVAR groups.

**Results:** There was a significantly lower amount of contrast medium use in the MMR+ group compared with the MMR− group in EVAR (32.9 ± 10.6 g and 28.2 ± 10.2 g; $P = .009$) and TEVAR (31.7 ± 11.5 g and 26.9 ± 7.8 g; $P = .009$). In addition, significantly lower radiation exposure was observed in the MMR+ group of TEVAR (872 ± 623 mGy vs 638 ± 463 mGy; $P = .033$). The operative time of the MMR+ group was significantly shorter for patients with TEVAR compared with the MMR− group (96.4 ± 27.0 minutes vs 86.2 ± 23.9 minutes; $P = .023$). The incidence of access injury and other complications was similar in both EVAR and TEVAR groups.

**Conclusions:** The MMR system with three-dimensional fusion imaging can reduce the contrast medium dose in EVAR and the exposure to contrast medium and radiation in TEVAR. (J Vasc Surg 2018;■:1-8.)

Endovascular aneurysm repair (EVAR) and thoracic endovascular aortic repair (TEVAR) are the commonly established options for treatment of aortic diseases. To perform truly minimally invasive approaches, surgeons need to minimize the contrast medium dose and fluoroscopy time. Image fusion guidance with the multimodality roadmap (MMR) system has been evolving and has recently been introduced in the field of endovascular procedures.[1-3] However, at present, there are still only a limited number of reports on the topic, and the feasibility of this technique remains controversial. As of May 2013, we introduced three-dimensional (3D) fusion computed tomography (CT) in the hybrid operating room, with biplane fluoroscopy. The MMR system (INFX-8000H; Toshiba Medical Systems, Tochigi, Japan) can superimpose the 3D CT volume data on the live fluoroscopic image. The fused image serves to verify the positional relation of the catheter, vessels, and aneurysm. In addition, it aids in deciding the length of device and landing position required without using contrast dye. Based on the reduction of the patient's exposure to both contrast medium and radiation, the aim of this study was to evaluate the efficacy of MMR in EVAR and TEVAR.

## METHODS

From our institutional database, we reviewed 414 EVAR and 219 TEVAR consecutive cases between September 2012 and June 2016. Only elective cases with standard endovascular technique were included in this study. Therefore, patients who underwent emergent surgery and debranching, snorkel, fenestrated, staged operation, and chimney techniques were excluded. In the percutaneous approach, a suture-based vascular closure device was used under fluoroscopy in limited cases with a nondiseased femoral artery. Therefore, the percutaneous approach was excluded from the cohort. To evaluate a change in renal function, dialyzed patients were also excluded, and the remaining 143 EVAR and 120 TEVAR cases were included in the cohort. At our institution, the hybrid operating room with a biplane system (INFX-8000H) has been in use since September 2012; the MMR system has been in use since May 2013. The MMR system was applied in 164 patients (62.4%); the MMR− group included 62 EVAR and 37 TEVAR cases, and the MMR+ group

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consisted of 81 EVAR and 83 TEVAR cases. All procedures were typically performed under general anesthesia. Radiation dose, contrast medium use, and complications were compared between the MMR− and MMR+ groups. The project was approved by the Institutional Review Board, and consent was obtained from all patients.

**Fusion technique by MMR for endovascular procedures.** Aortic lesions were evaluated by enhanced 1-mm-slice CT using the Aquilion 64 system (Toshiba Medical Systems) at a collimated section width of 1 mm and a gantry rotation time of 0.5 second. To deliver an appropriate amount of iodine, injection rates of 2.5 to 3.0 mL/s and 40 to 60 mL of 370 mg/mL iopamidol (Iopamiron 370; Bayer Pharmacy, Osaka, Japan) were used as standard protocol. The 3D volume rendered, reconstructed image was obtained by using ZIOSTATION 2 PLUS ZWS-2000 (Zio Software Inc, Tokyo, Japan). On preoperative enhanced CT, the arms, body trunk, and legs of a patient are positioned similarly to the expected intraoperative body position. Whereas the operating table is flat, the CT bed is generally rounded. Therefore, the roundness of the CT bed is adjusted by using pads to obtain an accurate fusion image.

**Intraoperative technique.** After introduction of general anesthesia and fixation of body position, the radiographer manually matches the preoperative CT angiogram to the perspective image by using calcified landmarks (iliac bones, vertebrae, and calcification of aorta) as references (Fig 1, *A*). In the frontal and bilateral views, the fused image is checked for 3D matching, and body position is finely adjusted (Fig 1, *B*). The total time of the fusion process is <5 minutes. Draping and exposure of the femoral arteries are then performed. Guided by MMR, the puncture site is determined appropriately, and a guidewire is extended safely to the descending aorta. The fusion overlay is corrected to account for displacement of the native anatomy by stiff guidewires and the delivery system, as needed. After the stiff guidewire is in place, the length of the lesion is measured by a marker pigtail catheter under the fusion image without use of contrast dye, and the length of the device is determined (Fig 2, *A*). The main device is inserted, and contrast imaging is used for a final check just before the deployment of the device. Similarly, the length of the distal component is decided under the fusion image, and contrast dye is used to check the bifurcation of the iliac arteries before deployment of the leg device. The magnified fusion image is useful for proximal deployment of EVAR (Fig 2, *B*). After deployment and adjustment of the device, aortography is performed to evaluate endoleaks. In TEVAR, the level of the artery of Adamkiewicz is identified preoperatively and indicated in the fusion image (Fig 2, *C*).

## ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective, single-center, cohort study
- **Take Home Message:** Intraoperative use of advanced imaging with a multimodality roadmap system in 164 endovascular aneurysm repair (EVAR) and thoracic endovascular aortic repair patients resulted in less contrast agent use, lower radiation exposure, and shorter procedure durations in EVAR patients.
- **Recommendation:** This study suggests that multimodality roadmap systems should be used in EVAR and thoracic endovascular aortic repair to reduce contrast agent use, radiation dosage, and procedural time.

**Radiation dose calculation.** Radiation exposure, including the fusion overlay creation process, was evaluated as cumulative air kerma (kinetic energy released per unit mass), recorded automatically as milligrays. These data were routinely collected in our hybrid operating room. The reference to determine the cumulative air kerma was located at 15 cm from the isocenter toward the X-ray source along the beam axis. Total fluoroscopy time was automatically measured; however, recorded time was not included in the measured fluoroscopy time with the MMR system.

**Definition of acute kidney injury (AKI).** AKI was defined by the RIFLE (Risk, Injury, Failure, Loss of kidney function, End-stage renal disease) criteria using the postoperative maximal increase in serum creatinine (sCrea) concentration within 7 days after surgery and decrease in estimated glomerular filtration rate (eGFR) compared with preoperative values. Because 1.73 $m^2$ was higher compared with mean body surface area (BSA) in this cohort, eGFR adjusted by BSA was estimated with the simplified Modification of Diet in Renal Disease formula: $eGFR\ (mL/min) = 186 \times (sCrea,\ mg/dL)^{-1.154} \times (age)^{-0.203} \times (BSA,\ m^2) \times 1.73^{-1} \times 0.742$ (if female). Urine output criteria were not used in this study, and AKI was defined as an increase of 1.5× baseline sCrea concentration or decline >25% of eGFR according to RIFLE R (risk) class.[4] Also, patients who required renal replacement therapy were included in the AKI group. Renal replacement therapy was defined as intermittent hemodialysis or continuous venovenous hemofiltration.

**Statistical analysis.** Continuous data are presented as mean ± standard deviation and were analyzed using two-tailed *t*-tests or compared with a Mann-Whitney test for independent data, as appropriate. Categorical variables are given as a count and percentage of patients and compared using $\chi^2$ or Fisher exact test. The correlation of contrast medium and radiation exposure with