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INTERVENTIONAL RADIOLOGY
ORIGINAL ARTICLE

# Reduction of iodinated contrast load with the renal artery catheterization technique during endovascular aortic repair

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PURPOSE
We aimed to present our clinical experience with the renal artery catheterization (RAC) technique, which reduces the volume of intra-arterial contrast media (ICM) used during endovascular aortic repair (EVAR), and describe the short-term results of this technique.

MATERIALS AND METHODS
We retrospectively evaluated 16 patients (15 males and one female) who underwent EVAR between March 2011 and February 2012 using the RAC technique for an abdominal aortic aneurysm. A Simmons-1 catheter was preferred for renal artery cannulation. The mean age of the patients at the time of treatment was 70 years (range, 61–82 years). Fifteen cases were fusiform aneurysms, and one case was a saccular aneurysm. Creatinine and estimated glomerular filtration rate (eGFR) values were recorded before the procedure and during the first 72 hours postprocedure.

RESULTS
Bifurcated stent grafts were implanted with 100% procedural success using the RAC technique. The inferiorly positioned renal artery was cannulated with a Simmons-1 catheter in the first five patients, and was maintained at the level of the renal artery orifice in the remaining patients. The mean volume of the ICM used was 47 mL (range, 23–83 mL). The creatinine and eGFR values were not significantly different between the pre- and postoperative periods (*P* > 0.05).

CONCLUSION
Reducing the volume of ICM used during EVAR is critical for protecting renal function. The RAC technique is a safe and effective method in appropriate patients when performed by experienced clinicians.

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Although contrast medium induced nephropathy (CIN) is a rare occurrence in patients with serum creatinine levels less than 132 μmol/L (1.5 mg/dL) or a preferred estimated glomerular filtration rate (eGFR) greater than 60 mL/min/1.73 m$^2$ with an incidence less than 2%, it is more prominent in patients with diabetic nephropathy (19.7%) and pre-existing renal impairment (3%–33%) (1). Patients who undergo endovascular aortic repair (EVAR) for abdominal aortic aneurysm (AAA) are often elderly, and diabetes mellitus and/or renal impairment are common in this group of patients (2, 3). Dehydration, congestive heart failure, multiple myeloma, and concurrent use of nephrotoxic drugs as well as larger doses of contrast media and multiple injections within 72 hours are also risk factors for CIN (1, 4). In addition, intra-arterial contrast media (ICM), especially when given into the renal arteries or the aorta at the origins of the renal artery, as in EVAR, is more nephrotoxic than intravenous administration (1, 4). Furthermore, pre- and postoperative computed tomography (CT) angiographies as well as EVAR can also cumulatively increase the risk of CIN.

Although strategies used for solving contrast related problems have improved over the years as a result of the development of contrast agents, contrast-related morbidity is still a serious issue. To avoid the adverse effect of contrast media, carbon dioxide angiography and intravascular ultrasonography (IVUS) have been assessed as an alternative strategy in EVAR (5, 6). Intravenous hydration with saline, low-, or iso-osmolar nonionic contrast media as well as lower doses of contrast media can minimize CIN (4). However, drugs such as N-acetylcysteine and bicarbonate have not been shown to provide consistent protection against CIN to date (1, 4). Therefore, other strategies, such as renal artery catheterization (RAC), which is used by our team, must be considered for reducing morbidity and possibly mortality secondary to contrast use.

The RAC technique involves catheterization of the inferiorly positioned renal artery using the Simmons-1 catheter. The inferior border of the renal artery is then determined using the lowest possible contrast medium dose during placement of the main body of the stent-graft. This is followed by placement of the ipsi- and contralateral legs with or without the lowest contrast media dose using retrograde iliac angiography through femoral sheaths. Finally, aortography is performed after stent graft placement with the flush catheter to assess for an endoleak.

In this study, we aimed to describe the RAC technique as a viable option for minimizing the volume of ICM, and as a consequence, reduction of contrast-related morbidity. We also described the short-term results of this technique.

## Materials and methods

Sixteen patients diagnosed with AAA who underwent an EVAR procedure with the RAC technique between March 2011 and February

2012 were reviewed retrospectively and included in the study. The RAC technique was not used if the length of the secured infrarenal aortic neck was less than 10 mm and/or the aortic neck angulation was more than 60°. As a result, the technique was not used in three patients during the study period. The perioperative data, patients' medical records, and all radiologic images maintained in the electronic database of our hospital were evaluated and registered. Before the procedure was initiated, all patients received an explanation and information regarding the details of the open surgery and EVAR. This study was approved by our hospital's institutional review board.

*Patients*

EVAR was performed on sixteen patients (mean age, 70 years; range, 61–82 years; 15 males, one female) who were approved for endovascular treatment based on the decision of council of interventional radiology and cardiovascular surgery in our hospital. Fourteen of these patients (87.5%) were asymptomatic, while the remaining two patients had severe abdominal pain.

A degenerative fusiform aneurysm was present in 15 patients (93.7%) and a degenerative saccular aneurysm was detected in one patient. Creatinine and eGFR values of all patients were recorded before and within the first 72 hours after the procedure. The patients were evaluated using the classification of The American Society of Anesthesiologists (ASA) by an anesthesiologist. All patients had at least one concomitant disease or comorbid condition (Table 1). In addition, other medical conditions were noted in patients during the patient history assessment, including percutaneous transluminal coronary angioplasty and/or stent placement in five patients, coronary artery bypass grafting in eight patients, smoking in 14 patients, cholecystectomy in two patients, appendectomy in three patients, hernia repair in two patients, and unilateral nephrectomy in one patient.

**Table 1.** The American Society of Anesthesiologists (ASA) physical status classification and comorbidities of the patients

| | n (%) |
|---|---|
| ASA classification for physical status | |
| Class II | 1 (6.2) |
| Class III-IV | 15 (93.7) |
| Comorbidities | |
| Chronic obstructive pulmonary disease | 6 (37.5) |
| Coronary artery disease | 10 (62.5) |
| Hyperlipidemia | 9 (56.2) |
| Hypertension | 16 (100) |
| Diabetes mellitus | 4 (25) |
| Aortic valve insufficiency | 1 (6.2) |
| Goiter | 1 (6.2) |
| Laryngeal carcinoma | 1 (6.2) |

*Preoperative evaluation*

CT angiography was performed to evaluate whether these patients were anatomically appropriate for the endovascular treatment. The scans were carefully evaluated and stent-grafts of appropriate sizes were selected. In three patients, the creatinine levels were ≥1.5 mg/dL and eGFR levels were ≤60 mL/min/1.73 m². Two of the patients had already received a CT angiography examination and therefore were not re-evaluated. Unenhanced CT, magnetic resonance imaging (MRI) and unenhanced magnetic resonance (MR) angiography was performed on the remaining patient who had not had previous CT angiography. Consequently, CT angiography was performed in 13 out of 16 patients for preoperative evaluation in our radiology department.

*Procedure*

All endovascular treatments were performed by a vascular team consisting of interventional radiologists and cardiovascular surgeons. EVAR procedures were performed in the angiography suite. In all patients, both femoral arteries were exposed surgically. In eight patients (50%), Gore Excluder® AAA endoprostheses (W. L. Gore and Associates, Newark, Delaware, USA) were implanted, and in the other eight patients (50%), Zenith® endovascular grafts (Cook Medical Inc., Bloomington, Indiana, USA) were implanted. Iliac arteries were coil embolized before EVAR in cases where needed.

Firstly, 9 F sheaths were placed in the femoral arteries after surgical exposure. Preoperative cross-sectional scans were evaluated to determine which femoral artery would be preferred for the main body of the stent-graft. Before the main body had been advanced through the previously chosen femoral artery, a Simmons catheter (Simmons-1, 5 F, Terumo, Glidecath, Radiofocus, Tokyo, Japan) was inserted into the contralateral femoral artery in all patients. The Simmons catheter was formed at the level of the aortic arch, and the catheter was then pulled back to the possible level of the renal artery origin. Only the inferiorly positioned renal artery, which was previously detected by CT imaging, was cannulated without using contrast medium, and the catheter tip was delivered distally until the fulcrum abutted the origin of the artery (Fig. 1a). The location of the catheter was then assessed by injecting 3–5 mL of low-osmolar contrast medium (Omnipaque 300 mg iodine/mL, Nycomed, Princeton, New Jersey, USA) because iso-osmolar contrast medium was not available in our hospital.

The main body was subsequently advanced up to the level of the Simmons catheter for the Gore Excluder AAA endoprosthesis. When the tip of the main body and the fulcrum of the Simmons catheter were in contact with each other, the Simmons catheter was pulled back and the main body was deployed (Fig. 1b).

The tip of the Simmons catheter was kept at the level of the renal artery orifice (not advanced distally into the renal artery) within the aorta if one of the following situations occurred: 1) the existence of stenosis in the inferior renal artery, 2) a requirement of im-

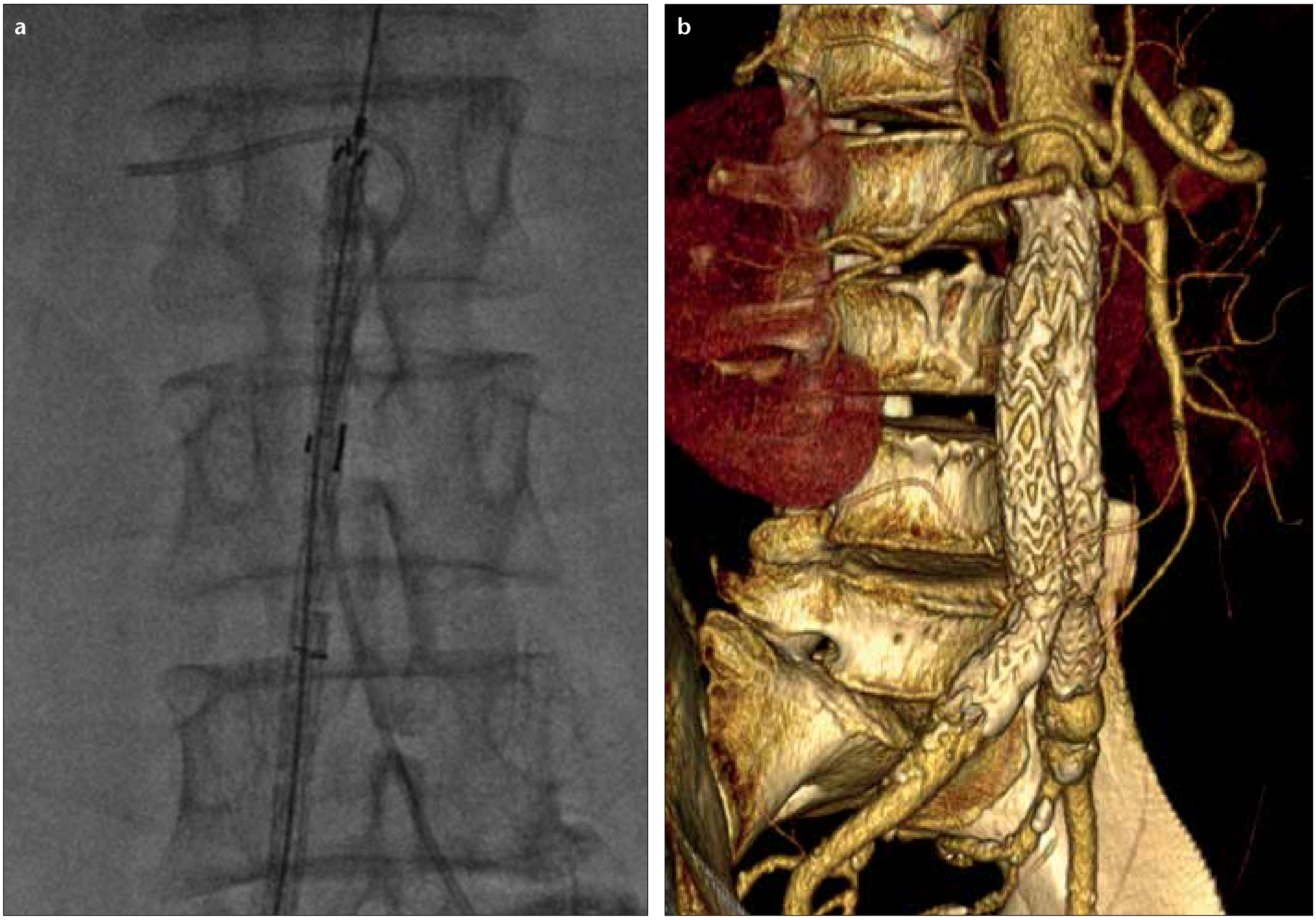


**Figure 1. a, b.** A fluoroscopic image **(a)** showing cannulation of the inferiorly positioned right renal artery with a Simmons-1 catheter. The main body of the Gore Excluder stent graft is advanced to the level of the catheter's fulcrum, which contacts the inferior border of the renal artery at the level of its orifice. At this point, the tip of the main body and the Simmons catheter are in contact with each other **(a)**. Volume rendered CT image obtained on the 3rd day after the procedure **(b)** shows that the proximal tip of the stent graft is at the same level as the inferior border of the right renal artery.

aging of the renal artery orifices, or 3) the use of a stent graft with suprarenal fixation, such as the Cook Zenith endovascular graft (Fig. 2a). The relationship between the main body and the inferior border of the renal artery was checked with a puff injection of contrast medium. The Simmons catheter was subsequently pulled back and the stent-graft was deployed following the confirmation of the desired position of main body (Fig. 2b).

The renal artery was cannulated and visualized during the first five minutes of the procedure in all cases where a Simmons-1 catheter was used; therefore, the RAC technique did not add extra time or cause a delay in the EVAR procedure. When there were two or more ipsilateral renal arteries, both the main and accessory renal arteries were secured if the length of the infrarenal secured aortic neck was greater than 10 mm. If the length of the infrarenal secured aortic neck was less than 10 mm, then we could have sacrificed an accessory renal artery; however, we did not encounter such a case.

The contralateral stump of the main body was cannulated with the appropriate catheters and guide wires. When a hypogastric artery required visualization, 5–10 mL of contrast medium was given quickly through a 9 F sheath after advancement of a marked pigtail catheter over the stiff wire. The distance between the contralateral stump of the main trunk and the origin of the hypogastric artery was then measured using the marked pigtail catheter, followed by placement of the contralateral leg. When needed, extension was performed into the distal part of the contralateral leg. The same procedures were applied for the ipsilateral side when required (Table 2).

The position and the patency of the stent graft and the existence of an endoleak were evaluated with a pigtail catheter, and 20 mL of ICM was used for each aortography. Balloon dilatation was performed before or after aortography if necessary. In patients with significant renal artery stenosis, a stent was deployed after the EVAR procedure.

The patients were followed up in the intensive care unit for one day and routinely received intravenous N-acetylcysteine (a total of 1200 mg/day) and intravenous saline hydration. The follow-up creatinine and eGFR levels were measured daily after the procedure for 72 hours, and the highest creatinine and lowest eGFR levels were recorded. In patients with normal creatinine and eGFR levels, a CT angiography was obtained on the 3rd day postprocedure. If no endoleak was

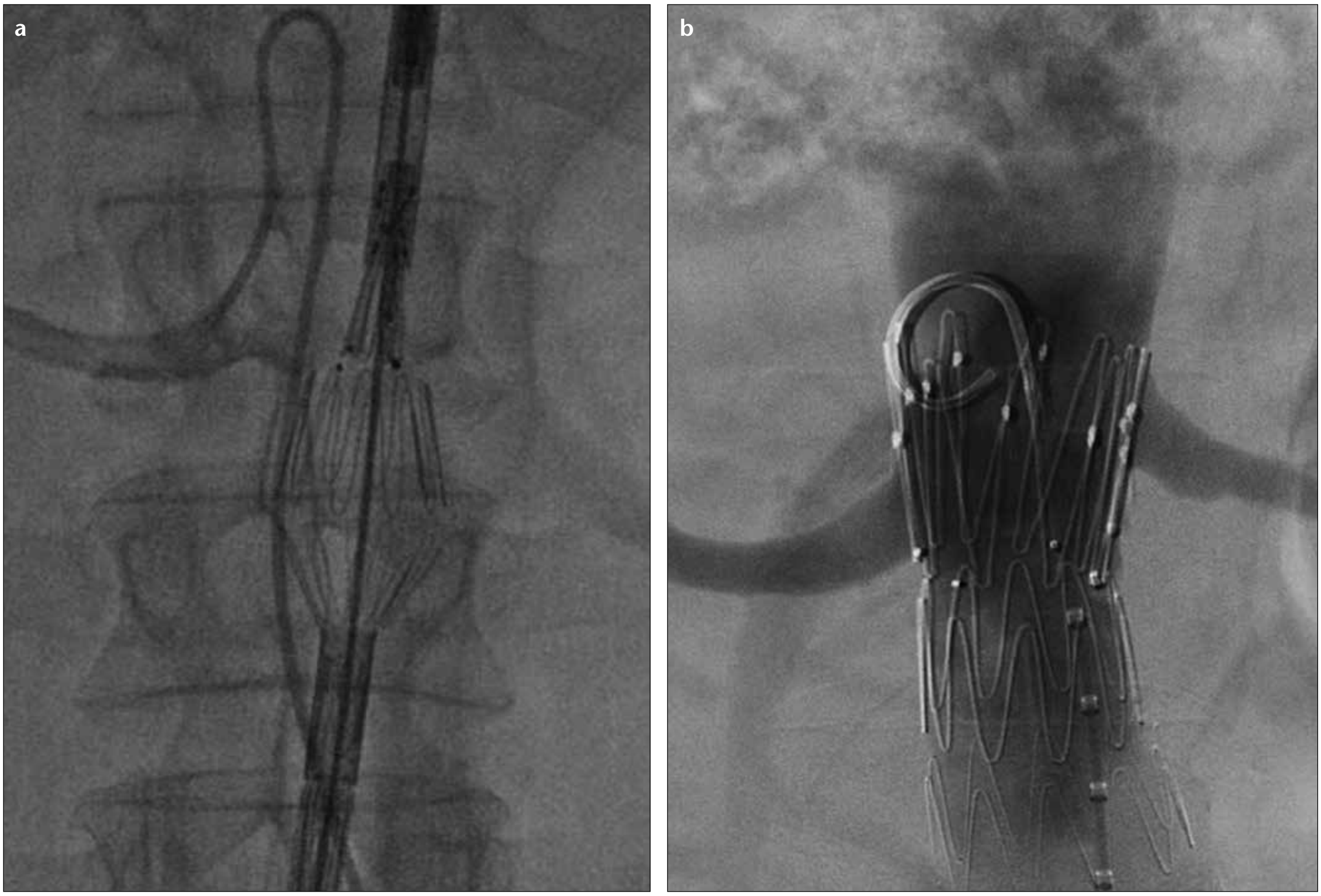


**Figure 2. a, b.** A fluoroscopic image **(a)** showing that the cannulation of the inferiorly positioned right renal artery with a Simmons-1 catheter that is kept at the level of the renal artery orifice within the aorta and the main body of the Zenith stent graft, which is partially deployed. The exact relationship between the main body and the inferior border of the renal artery is clearly observed **(a)**. Digital subtraction image obtained just after placement of the stent graft **(b)** shows that the tip of the proximal covered segment of the stent graft is placed at the same level as the inferior border of the right renal artery.

**Table 2.** Details of the renal artery catheterization technique described in the study

| Parameters | Characteristics |
|---|---|
| Catheter | Simmons-1 |
| Catheter level | Into the inferiorly positioned renal artery<br>-A stent-graft with infrarenal fixation |
| | Into the aorta at the level of inferiorly positioned renal artery orifice<br>-A stent-graft with suprarenal or infrarenal fixation<br>-Inferiorly positioned renal artery stenosis<br>-Requirement of imaging of the renal artery orifice |
| Renal imaging during main body placement | Intermittent or continuously |
| ICM volume per imaging during main body placement, range | 3–5 mL |
| ICM volume for hypogastric artery demonstration, range | Not required<br>or<br>5–10 mL |
| ICM volume per imaging after stent-graft placement | 20 mL |
| Total contrast medium per procedure, mean (range) | 47 mL (23–83 mL) |
| Aortic angulation | Preferably <60° |
| Aortic neck length | Preferably >10 mm |
| Tortuous and angulated iliac arteries | May complicate the manipulation of the catheter |
| A patient with high creatinine level | Preferable (further studies required) |

ICM, intra-arterial contrast media.

detected, then a scan was scheduled six months postprocedure, but if an endoleak was detected, then scanning was repeated one month postprocedure. In patients with creatinine levels ≥1.5 mg/dL and eGFR levels ≤60 mL/min/1.73 $m^2$, cross-sectional imaging was not performed on the third postprocedural day, and contrast-enhanced MR (CE-MR) angiography was obtained one month postprocedure using 7.5 mL Gadobutrol (Gadovist, Schering AG, Berlin, Germany) for follow-up imaging in those patients.

*Statistical analysis*

Continuous and discrete variables were expressed by the median (minimum-maximum) values, and categorical variables were expressed by the number and percentage values. Mann-Whitney U test was used to perform comparisons between groups. The percent change of postoperative creatinine and eGFR levels were in correlation with preoperative basal values. Correlations between discrete and continuous variables were evaluated by a correlation analysis, and Pearson and Spearman correlation coefficients were calculated. Statistical analyses were performed using a commercially available software (Statistical Package for Social Sciences, version 13.0, SPSS Inc., Chicago, Illinois, USA), and $P < 0.05$ was considered statistically significant.

## Results

The mean ASA score was 3.4 (range, 2–4) during the preoperative period. The right renal artery originated more inferiorly in half of the patients. The diameter of the aneurysm, duration of the postoperative hospital stay, and type of anesthesia used are summarized in Table 3.

Bifurcated stent-grafts were implanted in all of the patients with 100% procedural success using the RAC technique. The main body was advanced from the right side in 11 patients. Stent-grafts were extended to the external iliac arteries due to an aneurysmal dilatation in both common iliac arteries in one patient and due to an aneurysmal dilatation in the right common iliac artery in one patient. The Simmons catheter was placed into the renal artery in the first five patients, but was kept at the level of renal artery orifice in the remaining 11 patients. In one patient in whom the stenotic renal artery was placed more superiorly, a renal stent was placed after stent-grafting.

The mean ICM volume used during stent placement was approximately 47 mL (range, 23–83 mL). The mean creatinine value of the patients during the preoperative period was 1.08 mg/dL (range, 0.58–1.7 mg/dL), whereas it was 1.14 mg/dL (range, 0.7-2.0 mg/dL) and 1.13 mg/dL (range, 0.6–1.9 mg/dL) during the first 72 hours and one month postprocedure, respectively. The mean eGFR value of the patients at the preoperative period was 75.34 mL/min/1.73 $m^2$ (range, 41.75–110.21 mL/min/1.73 $m^2$), whereas it was 72.62 mL/min/1.73 $m^2$ (range, 35.08–126 mL/min/1.73 $m^2$) and 72.79 mL/min/1.73 $m^2$ (range, 37.22–151.58 mL/min/1.73 $m^2$) during the first 72 hours and one month postprocedure, respectively (Table 4). There was no statistically significant difference in creatinine and eGFR values between pre- and postoperative periods ($P > 0.05$).

CT angiography obtained on the third day identified a type-2 en-

**Table 3.** Aneurysm characteristics, type of anesthesia, and length of postoperative hospital stay of the patients

| Patient number | Aneurysm type | Aneurysm diameter (mm) | Diameter of neck (mm) | Length of neck (mm) | Neck angle | Aneurysm length (mm) | DBASIRA (mm) | Type of anesthesia | PHS (days) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Saccular | 37×46 | 22 | 26 | 46° | 37[a]/74[b] | 3 | Spinal+sedation | 1 |
| 2 | Fusiform | 54 | 23 | 42 | 52° | 60 | 0 | Spinal+sedation | 2 |
| 3 | Fusiform | 60 | 28 | 24 | 60° | 120 | 14 | Spinal+sedation | 2 |
| 4 | Fusiform | 53 | 22 | 15 | 26° | 95 | 2 | Spinal+sedation | 2 |
| 5 | Fusiform | 69 | 24 | 70 | 56° | 90 | 0 | General | 3 |
| 6 | Fusiform | 55 | 22 | 10 | 38° | 80 | 0 | General | 3 |
| 7 | Fusiform | 69 | 18 | 46 | 60° | 70 | 3 | General | 4 |
| 8 | Fusiform | 64 | 21 | 50 | 38° | 60 | 2 | General | 2 |
| 9 | Fusiform | 57 | 24 | 17 | 20° | 78 | 3.5 | General | 2 |
| 10 | Fusiform | 60 | 24 | 50 | 40° | 62 | 0 | General | 4 |
| 11 | Fusiform | 52 | 21 | 10 | 25° | 93 | 0 | General | 3 |
| 12 | Fusiform | 52 | 22 | 42 | 20° | 71 | 1.5 | Spinal+sedation | 2 |
| 13 | Fusiform | 50 | 28 | 22 | 31° | 71 | 3 | General | 3 |
| 14 | Fusiform | 94 | 30 | 15 | 58° | 90 | 0 | General | 3 |
| 15 | Fusiform | 60 | 27 | 14 | 20° | 92 | 0 | Spinal+sedation | 3 |
| 16 | Fusiform | 55 | 32 | 25 | 47° | 100 | 0 | Spinal+sedation | 3 |

DBASIRA, distance between aortic stent and inferiorly placed renal artery; PHS, postoperative hospital stay.
[a]The length of the aneurysmal orifice.
[b]The length of the aneurysm.

**Table 4.** Volume of iodinated contrast medium during EVAR procedures, and pre- and postoperative creatinine and estimated glomerular filtration rate levels

| Patient number | Volume of ICM (mL) | Preoperative Cr (mg/dL)/eGFR (mL/min/1.73 m$^2$) | Highest Cr (mg/dL)/lowest eGFR after procedure (mL/min/1.73 m$^2$) | Cr (mg/dL)/eGFR (mL/min/1.73 m$^2$) at postoperative 1st month |
|---|---|---|---|---|
| 1 | 23 | 1.7/41.75 | 1.9/36.72 | 1.8/39.08 |
| 2 | 43 | 0.9/88.67 | 0.9/88.67 | 0.9/88.67 |
| 3 | 38 | 1.21/63.01 | 1.2/63.62 | 1.2/60.69 |
| 4 | 48 | 1.1/72.33 | 1.2/65.42 | 1.3/61.65 |
| 5 | 23 | 1.5/49.92 | 1.5/49.92 | 1.3/58.88 |
| 6 | 53 | 0.9/87.2 | 1.2/62.37 | 1.2/62.37 |
| 7 | 63 | 1.22/61.38 | 1.24/60.24 | 1.1/69.17 |
| 8 | 83 | 0.83/104 | 0.7/126 | 0.6/151.58 |
| 9 | 43 | 0.96/83.29 | 1.1/71.18 | 1.1/71.18 |
| 10 | 46 | 0.58/110.21 | 0.7/88.71 | 0.9/66.38 |
| 11 | 46 | 0.99/81.15 | 0.9/90.58 | 1.1/71.86 |
| 12 | 49 | 1.04/73.80 | 1.0/77.22 | 1.0/77.22 |
| 13 | 23 | 1.67/43.2 | 2.0 /35.08 | 1.9/37.22 |
| 14 | 56 | 0.79/103.67 | 0.78/105.21 | 0.81/100.72 |
| 15 | 55 | 1.06/65 | 1.06/65 | 1.1/62 |
| 16 | 55 | 0.98/77 | 0.99/76 | 0.9/86 |

ICM, intra-arterial contrast media; Cr, creatinine; eGFR, estimated glomerular filtration rate.

doleak from lumbar arteries in six patients (38%). During the first month postprocedure scan, the type-2 endoleak disappeared in two of those patients, but remained in the other four patients (25%). In three patients with creatinine levels ≥1.5 mg/dL and eGFR levels ≤60 mL/min/1.73 m$^2$ after the procedure, no control angiographic scan was performed. A CE-MR angiography was performed one month postprocedure in these three patients and did not identify an endoleak.

The mean distance between the proximal tip of the stent-graft and inferior border of the renal artery was 2 mm (range, 0–14 mm) in the angiographic scans (digital subtraction angiography, CT angiography, or CE-MR angiography). While the proximal tip of the stent-grafts was at the same level with the inferior border of the renal artery in eight patients, the distance was 1.5 mm in one patient, 2 mm in two patients, 3 mm in three patients, 3.5 mm in one patient, and 14 mm in one patient. A focal dissection allowing for blood flow occurred in the right common iliac artery in one patient. No additional procedure was planned for this patient. Hip claudication occurred during a 100 m walk in one patient whose internal iliac arteries were blocked bilaterally during stent placement.

## Discussion

Radiological imaging with ICM has a risk for the development of CIN due to toxic ischemic injury of the kidney and secretion of vasoconstrictive hormones. CIN is defined as an increase in serum creatinine levels by 25% or more, or by 0.5 mg/dL or more than the baseline level, within the first 48 to 72 hours after administration of ICM (7). Renal dysfunction, the presence of long-standing diabetes mellitus, dehydration, poor renal perfusion (i.e., secondary to congestive heart disease), and the use of nephrotoxic drugs with ICM are all risk factors for CIN (8). Infrarenal AAA usually manifests in the elderly population, whereby comorbid diseases such as diabetes mellitus and renal impairment frequently occur, which was observed in our study group (2, 3). In addition to the risk factors mentioned above, renal atheroembolism, renal artery trauma, stent-induced renal artery stenosis or occlusion, and blood loss that may occur during the EVAR may contribute to further exacerbation of renal dysfunction (9). Several studies have shown that both open aortic repair and EVAR can cause transient or permanent alterations in renal function, but hemodialysis is rarely required (9–12). Thus, the volume of ICM used during the endovascular procedure is very important, especially in patients with long-standing diabetes mellitus and renal dysfunction.

In this study, the feasibility of the RAC technique, which allows for the use of lower volume of ICM during EVAR, was evaluated. During a routine procedure, 20–30 mL of ICM is administered into the aorta with flush catheters each time during the positioning of the stent-graft. The correct positioning of the stent-graft is often not possible during the first attempt, and the volume of contrast medium consumption increases with repetitious aortagraphies.

To the best of our knowledge, there is only one study in the literature that has described the placement of the SOS Omni catheter into the inferiorly positioned renal artery during the EVAR procedure, and it has been used as a landmark to place the stent-graft in an optimal position (13). That study focused on IVUS during stent-graft planning and placement; however, no information was provided on the SOS Omni catheter and the volume of ICM used, which was 127±60 mL per patient. This value is fairly high compared to the ICM load used in our study. We used the catheter not only to visualize the inferiorly positioned renal artery, but also as a landmark when deploying the stent graft. We preferred not to use a Cobra catheter or SOS Omni catheter for this technique because our goal was to cannulate the renal artery and advance the tip distally until the fulcrum abutted the origin of the artery. A Cobra catheter may fall or pop out of the renal artery ostium during the procedure, which is why the Simmons catheter was our catheter of choice.

Based on our clinical experience, AAA patients who have longer infrarenal aortic necks and/or lower aortic neck angles are candidates for the RAC technique. If the technique is used to treat aneurysms with a shorter neck length or higher neck angle, then the Simmons catheter should be kept at the level of the renal artery orifice. However, manipulation of the Simmons catheter and demonstration of the renal artery orifice is not always possible with higher neck angulations. Furthermore, tortuous and angulated iliac arteries may complicate the manipulation of the Simmons catheter. Therefore, placement of a guiding sheath could eliminate these problems.

Carbon dioxide has been used to avoid adverse effects of ICM in diagnostic and EVAR procedures (5, 14). However, since the use of carbon dioxide requires experience and special instruments, it is not widely used in our country, which is similar to the rest of the world. In addition, IVUS have been used to decrease the use of ICM for planning before the placement of an endograft (15–18). In a study by Hoshina et al., (6) IVUS was compared to conventional techniques during EVAR, and it was demonstrated that the volume of contrast medium used was lower in the IVUS group (67±34 mL) than the control group (123±50 mL). The mean volume of ICM used in our study was 47 mL (range, 23–83 mL). A comparison on this value with that from the IVUS group in the study by Hoshina et al. (6) suggests that the RAC technique may be superior to IVUS in relation to the ICM load.

In conclusion, an unintentional consequence of the EVAR procedure is ICM-induced nephropathy, which may shorten life expectancy after treatment. CT angiography is often used during follow-up after EVAR, which could increase the risk of CIN due to consecutive exposure of the kidney to contrast media. Thus, using lower volume of ICM during the EVAR procedure is vital in terms of protecting renal function. The RAC technique was developed for this purpose and is a safe and effective method for the appropriate patients when performed by experienced clinicians. Careful preoperative evaluation of images obtained from cross-sectional imaging methods and the attentive selection of appropriate devices for this technique is crucial.

#### Conflict of interest disclosure

The authors declared no conflicts of interest.

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