

# Evaluation of CT virtual intravascular endoscopy in fenestrated stent grafts: A preliminary study

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## Abstract

We aim in this study to investigate the potential value of CT virtual intravascular endoscopy in patients diagnosed with abdominal aortic aneurysms undergoing fenestrated stent grafts. Both pre-and post-fenestration (within 3 months of implantation) multislice CT data were collected in 8 patients and used for generation of virtual endoscopy images in our preliminary study. Variable fenestrations were deployed in 25 aortic branches with scallop fenestration implanted in 6 aortic ostia, large fenestration in 4 aortic ostia and small fenestration in 15 renal ostia, respectively. Measurements of the aortic ostia diameters both pre-and post-fenestration were successfully performed with virtual intravascular endoscopy visualization, and endovascular stents as well as their relationship to the aortic ostia were clearly demonstrated. Our results showed that there was no significant change of diameter of the aortic ostia following fenestrated stent grafts. Endovascular stents were clearly visualized on virtual endoscopy images, and no apparent deformity or malrotation was observed in this small group. Our preliminary study provides new insights into anatomic configuration/dimension of aortic ostia and endovascular stents, and virtual intravascular endoscopy could be a valuable technique to follow-up patients treated with fenestrated stent grafts.

*Key words:* Three-dimensional imaging; computed tomography; stent graft; aortic aneurysm; fenestration

## 1. Introduction

Rapid development in the technology and application of endovascular devices for the treatment of aneurysmal disease has provided a less-invasive alternative to open surgery (1, 2). However, application of this technology is limited to the suitability of proximal and distal sealing and fixation. Estimates suggest that only 50% of patients with abdominal aortic aneurysms (AAA) will be candidates for endovascular repair with standard stent grafts on the basis of anatomic exclusion criteria (3). Consequently, the advent of endovascular devices capable of incorporating the renal and visceral arteries is a valuable tool to improve patient outcomes. The development and early clinical outcomes of the fenestrated device, manufactured by Cook Australia, have been reported to be an effective alternative to treated patients with complicated aneurysms (4, 5). Fenestrated stent grafting is more complex than conventional endovascular stent grafting because preoperative imaging must provide accurate information on the morphologic structure and quantitative dimensions of the arterial segments involved. The design of each stent graft requires knowledge of ostial diameter of each visceral vessel, relative distances from a fixed landmark, and radial orientation of visceral ostia. Moreover, any angulation of the aortic neck has the potential to induce disparity between the renal ostia. Therefore, a good understanding of the normal anatomic structures as

well as aortic aneurysm will assist vascular surgeons to implant the fenestrated stent graft accurately and assess the post-procedural effect of fenestration. We aimed in this study to investigate the potential value of 3D CT virtual intravascular endoscopy in patients with AAA undergoing fenestrated stent grafts, specifically focusing on the visualisation of aortic ostia, endovascular stents and their intraluminal relationship for assisting fenestration follow-up.

## **2. Materials and Methods**

### *2.1 Patient data selection*

Our preliminary study consisted of 8 patients diagnosed with AAA undergoing endovascular aortic repair. All of the patients' data were recommended by vascular surgeons and provided by Cook R&D (William A Cook Australia), which is responsible for preoperative planning of the fenestrated stent grafts. Prior to the planning of fenestration, original DICOM (digital imaging and communication in medicine) data, multiplanar and 3D reconstructed images were reviewed by the Perth Endovascular Group and a decision about the type of fenestration to be employed in each patient was determined in the planning meeting. Preoperative measurements required for planning of fenestrated stent grafts were performed by a group of graft planners on a separate workstation equipped with Terarecon software ([www.terarecon.com](http://www.terarecon.com)), which allows the user to manipulate DICOM images as well as 3D image reconstruction. The types of fenestration used in our study include scallop fenestration with a minimum width of 10 mm and height range 6-12 mm; large fenestration of 8-12 mm, and small fenestration of 6 x 6 mm<sup>2</sup> or 6 x 8 mm<sup>2</sup>.

### *2.2 VIE images generation and parameters measurements*

All of the DICOM data were transferred to another workstation equipped with Analyze V 6.0 ([www.Analyzedirect.com](http://www.Analyzedirect.com)) for generation of 3D virtual intravascular endoscopy (VIE) images. VIE images were generated by using a CT number thresholding technique to create intraluminal views of the aortic ostia and endovascular stents (6). An optimal VIE image should be free of intraluminal artifacts (including floating shape and pieced surface artifacts) with appropriate demonstration of the aortic ostium without any distortion being observed. This was determined by selecting the appropriate threshold value through measuring the CT attenuation at the level of aortic branches.

To measure vessel diameter on the VIE views, the user chooses a point along the arterial wall and then draws a line across the lumen to the other side. Because of the complex changes in visual perspective that are present on endoscopic views, however, there are more than one potential line of differing lengths that one might draw across, and it is not apparent to decide which is the true diameter. Our solution to resolve this issue is to correlate endoscopic views/measurements with the orthogonal views, which allows the user to determine the true diameter of the renal ostium.

A series of measurements of the diameter of aortic ostia (both maximal transverse and longitudinal diameters), including celiac axis, superior mesenteric artery and bilateral renal ostia were performed by a radiologist (ZS) who has over 6 year's experience of 3D medical imaging in aortic stent grafts. These measurements were aimed to compare with those measured pre-fenestrated stent grafting, and identify any post-procedural abnormalities or complications related to fenestration.

### *2.3 Statistical analysis*

All data were entered into SPSS (SPSS, V 14.0, Chicago, ILL) for analysis. The relationship between aortic ostial diameters and endovascular stents was evaluated using a statistical model of binary logistic regression. A p value less than 0.05 was considered statistically significant.

### 3. Results

VIE image generation and measurements of the aortic ostial diameters were successfully performed in all cases. The multislice CT scans were performed with a slice thickness of 0.625 mm or 1 mm, and reconstructed images were found to be good quality required for 3D intraluminal visualisation in all cases.

#### 3.1 Implantation details

Fenestrations were deployed in 25 arterial branches, with scallop fenestrations placed in 6 aortic ostia (3 at celiac axis and superior mesenteric artery, respectively); large fenestrations were implanted in 4 arterial branches (all at superior mesenteric artery) and small fenestrations in 15 arterial branches (all at bilateral renal ostia). The height and width for scallop fenestration was 12x10 mm<sup>2</sup> in three cases, double width scallop fenestration in another three cases with 20x20 mm<sup>2</sup> in two and 20x12 mm<sup>2</sup> in one case; for large fenestration, it was 8x8 mm<sup>2</sup> in three cases and 10x10 mm<sup>2</sup> in one case, respectively; for small fenestration, they were all 8x6 mm<sup>2</sup> in terms of the height and width.

#### 3.2 VIE visualisation and measurements

VIE allows clearly demonstration of the intraluminal aortic ostia (both diameter and configuration), endovascular stents and their spatial relationship. It is noted that the diameter of aortic ostia did not demonstrate significant change following fenestrated stent grafts ( $p>0.05$ ), although configuration of the aortic ostia showed changes to some extent in all of the cases (Fig1). Endovascular stents were found to be patent and their relationship to aortic ostia was clearly visualised on VIE images (Fig2). As shown in Fig 2, VIE clearly demonstrated the portion of stents that protruded inside the aortic lumen, as well as the configuration of the protruded component.

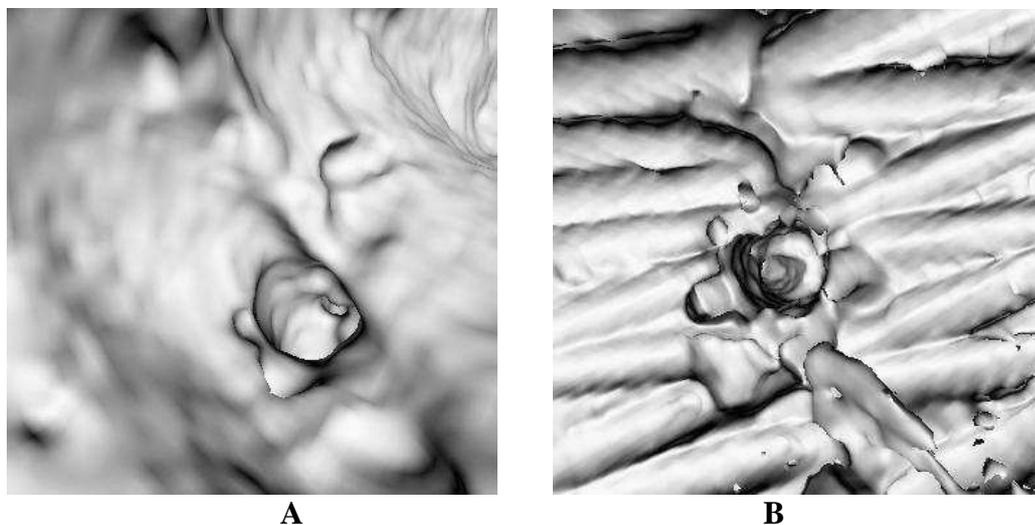


Figure 1 Right renal ostium shows similar configuration following fenestrated stent grafts. The ostial diameter was measured 7.7x6.3 mm<sup>2</sup> pre-fenestration (A) and 8.2x6.8 mm<sup>2</sup> post-fenestration (B).

### 4. Discussion and conclusion

Fenestrated stent grafting is becoming one of the most importantly endovascular fronts that is probably going to be much more widely applied in treatment of patients with complicated aneurysms (7). Fixation of the fenestration to the renal and other visceral arteries can be provided by implantation of bare or covered stents across the graft-ostium interfaces so that a portion of the stents protrudes into the endograft lumen. Therefore, there are concerns about the loss of the target vessel resulting from the fenestrated technique. There are two findings

in our study which we consider important for clinical practice: first, aortic ostial diameter remains relatively unchanged following fenestrated stent grafts, indicating the safety of this technique in our group of patients. Second, endovascular stents in relation to aortic ostia can be clearly demonstrated on VIE -visualisation, and this could be a potential area for VIE to play in the follow-up of patients treated with fenestrated stent grafts. It is difficult to identify the configuration of endovascular stents or any post-procedural abnormality/complication associated with fenestration based on conventional imaging visualisations, however, this is easily overcome with VIE visualisation, as shown in our results. A direct comparison between VIE-measured ostial diameter and the type of fenestration deployed in these arterial branches could not be performed because the preoperative planning of fenestration was not based on VIE measurements, however, our results demonstrated the potential application of VIE visualisation in post-fenestration. We conclude that CT VIE image visualisation is a valuable tool for assessment of patients with AAA undergoing fenestrated stent grafts. Further studies based on a large cohort of patients at regular follow-ups following fenestrated stent grafting deserve to be investigated.

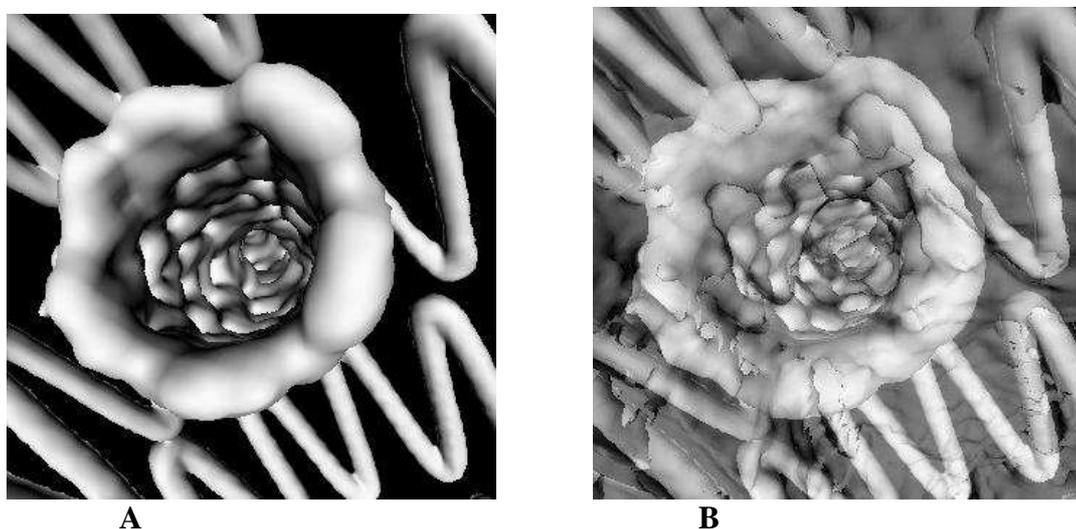


Fig 2. The same patient as observed in Fig 1. VIE shows the endovascular stent only (A) and intraluminal relationship between the stent and right renal ostium by revealing the portion of the stent protruding into the aortic lumen (B).

#### References

1. Zarins CK. The US AneuRx Clinical trial: 6-year clinical update 2002. *J Vasc Surg* 2003; 37: 904-908
2. Zeebregts CJ, Geelkerken RN, van Der PJ, et al. Outcome of abdominal aortic aneurysm repair in the era of endovascular treatment. *Br J Surg* 2004; 91: 563-8
3. Greenberg RK, haulon S, Lyden SP, et al. Endovascular management of juxtarenal aneurysms with fenestrated endovascular grafting. *J Vasc Surg* 2004; 39: 279-287
4. Stanley BM, Semmens JB, Lawrence-Brown MD, et al. Fenestration in endovascular grafts for aortic aneurysm repair: new horizons for preserving blood flow in branch vessels. *J Endovasc Ther* 2001; 8: 16-24
5. Anderson JA, Adam DJ, Berce M, Hartley DE. Repair of thoracoabdominal aortic aneurysms with fenestrated and branched endovascular stent grafts. *J Vasc Surg* 2005; 42: 600-607
6. Sun Z, Winder J, Kelly B, et al. Diagnostic value of CT virtual intravascular endoscopy in aortic stent grafting. *J Endovasc Ther* 2004; 11:13-25
7. Sun Z, B Mwipatayi, J Semmens, et al. Short to mid-term outcomes of fenestrated endovascular grafting of aortic aneurysms: A systematic review. *J Endovasc Ther* 2006; 13: 6: 747-753