

## Multislice CT virtual intravascular endoscopy of aortic dissection: A pictorial essay

Zhonghua Sun, Yan Cao

Zhonghua Sun, Discipline of Medical Imaging, Department of Imaging and Applied Physics, Curtin University of Technology, Perth, Western Australia 6845, Australia

Yan Cao, Department of Medical Imaging, Shandong Medical College, Jinan 5460, Shandong Province, China

Author contributions: All authors contributed equally to this paper.

Correspondence to: Dr. Zhonghua Sun, Discipline of Medical Imaging, Department of Imaging and Applied Physics, Curtin University of Technology, GPO Box, U1987, Perth, Western Australia 6845, Australia. [z.sun@curtin.edu.au](mailto:z.sun@curtin.edu.au)

Telephone: +61-8-92667509 Fax: +61-8-92662377

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### Abstract

**AIM:** To present our experience of using 3D virtual intravascular endoscopy (VIE) to characterize and evaluate the intraluminal appearances of aortic dissection.

**METHODS:** Ten patients with known aortic dissection underwent dual-source computed tomography angiography and were included in the study. In addition to 2D axial and multiplanar reformatted images as well as 3D reconstructions, VIE images were created in each patient to demonstrate intraluminal views of the aorta and its branches, origin of artery branches and artery branch involvement by aortic dissection.

**RESULTS:** Stanford A dissection was found in 8 patients and B dissection in the remaining 2 patients. VIE images were successfully generated in all of the patients with excellent visualization of the normal anatomical structures, intimal flap and intimal entrance tear, communication between true and false lumens, as well as assessment of the extent of aortic dissection.

**CONCLUSION:** Our preliminary experience suggests that

VIE could be used as a complementary tool to assist radiologists accurately evaluate aortic dissection so that better patient management can be achieved.

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**Key words:** Aortic dissection; Computed tomography; 3D visualization; Virtual intravascular endoscopy

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### INTRODUCTION

Aortic dissection is a common vascular disease and it is the most frequent cause of aortic emergency. Aortic dissection can be a life-threatening event which is characterized by splitting of the aortic wall by high blood pressure entering the media through an intimomedial entrance tear. Multislice computed tomography (CT) angiography is the preferred method for diagnosis of aortic dissection with a sensitivity and specificity of nearly 100%<sup>[1,2]</sup>. CT has been shown to be more sensitive than invasive angiography and is comparable to MR imaging and transesophageal echocardiography for diagnosis of aortic dissection<sup>[3,4]</sup>.

Aortic dissection leads to formation of true and false lumens which are separated from each other by a flap of intimal lining and inner layers of media. Outer layers of the aortic media and adventitia form the outer wall of the

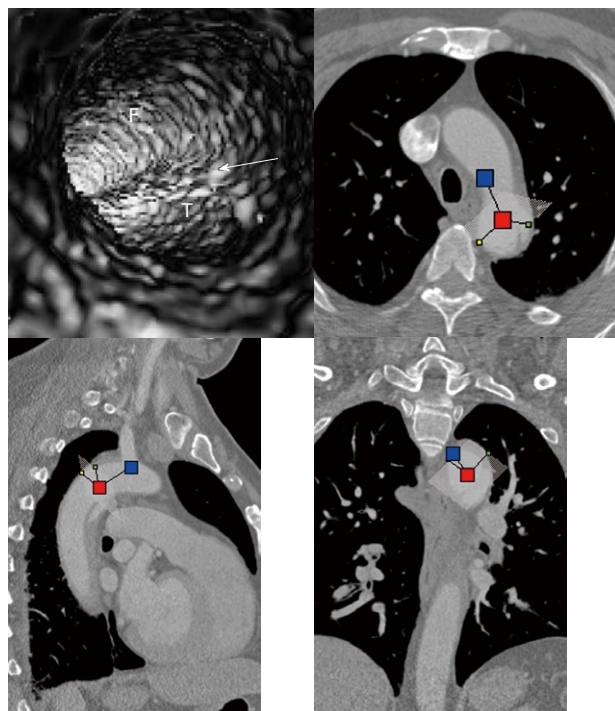
false lumen which is most commonly larger than the true lumen due to lack of outlet of blood flow. Differentiation between true and false lumens is important in the planning of percutaneous treatment with endovascular stent grafts or surgical repair of aortic dissections<sup>[5,6]</sup>. It is crucial to identify the lumen of origin in major branch vessels such as coronary, carotid, renal and mesenteric arteries before treatment because viscera supplied by the false lumen are at risk when the false lumen is spontaneously or surgically occluded<sup>[7]</sup>. The criteria to distinguish true from false lumens by CT have been previously described<sup>[5,8]</sup>. In most of the cases, axial CT imaging supplemented by 2D or 3D reconstructions is able to identify the intimal flap which separates the true lumen from the false lumen and determine the type and extent of dissection; however, this may not be possible in all cases due to variable appearances resulting from different types of aortic dissection<sup>[9,10]</sup>.

3D virtual intravascular endoscopy (VIE) provides unique intraluminal views of the blood vessel and it has been previously reported to be valuable for assessment of aortic aneurysms and endovascular stent grafts<sup>[11-13]</sup>. VIE has been shown to offer better understanding of the abnormalities of the aortic arch after endovascular repair<sup>[14]</sup>; however, investigation of variable imaging appearances of aortic dissection by VIE visualization has not been studied before, to the best of our knowledge. The purpose of this paper is to demonstrate VIE findings in a group of patients diagnosed with aortic dissection. We present our experience of using VIE visualization in the assessment of aortic dissection with the aim of exploring the potential value of VIE for identification of the common and uncommon findings related to the aortic dissection with special focus on the identification of entry site or intimal tears of aortic dissection.

## MATERIALS AND METHODS

Ten patients (7 men and 3 women, age range: 39-77 years, mean age: 55 years) with known aortic dissection were retrospectively included in this study. All patients underwent spiral CT angiography (CTA) which was performed with a dual-source CT scanner (Siemens, Definition, Forchheim, Germany). The scanning protocol was as follows: beam collimation 64 mm × 0.6 mm with slice thickness between 0.5-1.0 mm, pitch 1.0 with reconstruction interval of 50% overlap. Non-ionic contrast medium (Visipaque) with a total volume of 100 mL was injected intravenously *via* the antecubital vein at a flow rate of 4-6 mL/s, followed by 40-60 mL normal saline chasing. A bolus triggering technique was used with the region of interest placed at the proximal descending thoracic aorta and the triggering threshold was set at 120 HU to initiate the scan.

Aortic dissection was characterized based on 2D images as Stanford type A in 8 patients and type B dissection in the remaining 2 patients. In addition to 2D axial views, multiplanar reformation and 3D volume rendering including VIE images were generated in each patient.



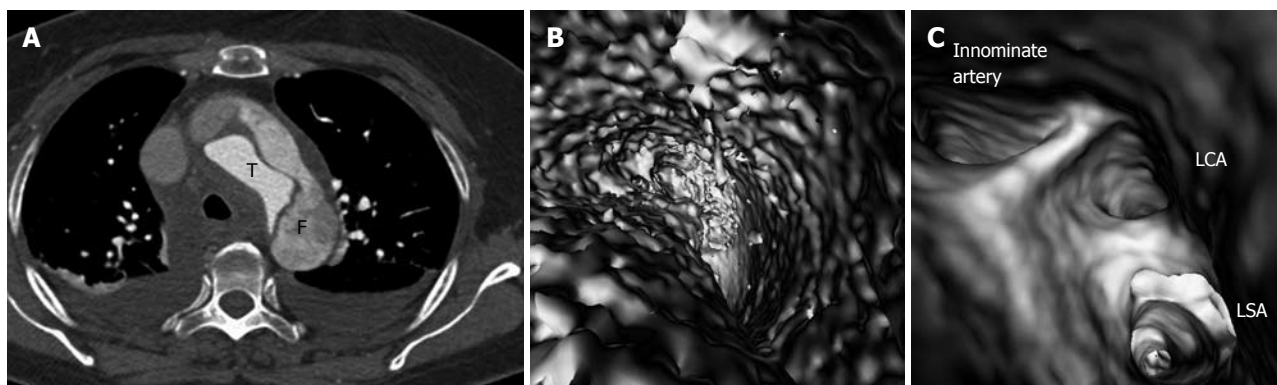
**Figure 1** Virtual intravascular endoscopy visualization of the true lumen, false lumen and intimal flap (arrow) in a Stanford type B aortic dissection. Corresponding orthogonal views (axial, coronal and sagittal) confirm the location of virtual intravascular endoscopy position inside the false lumen (F) looking toward the true lumen (T) and intimal flap.

Since patients' details were removed from the DICOM data, and all of the images were anonymous during post-processing, there was no ethical issue involved so no IRB approval was required for the study.

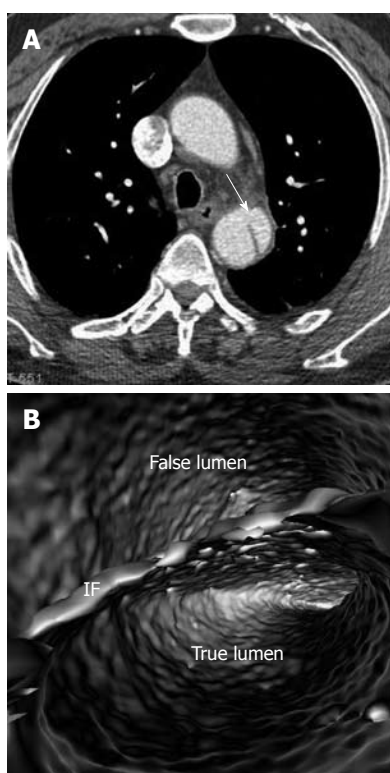
### Generation of VIE views

Multislice CT volume data were converted from original DICOM (Digital Imaging and Communication in Medicine) images using Analyze 7.0 (www.Analyzedirect.com). VIE images were generated based on a CT number thresholding technique to provide intraluminal views of the aorta and its branches as well as abnormal changes<sup>[11,12]</sup>. VIE demonstration of both normal anatomical structures and pathological changes were determined by selecting an appropriate threshold value through measuring the CT attenuation at the aorta (either ascending or descending aorta or abdominal aorta). An upper threshold of 200-300 HU was applied to remove the contrast-enhanced blood from the aorta while keeping the artery wall intact without luminal disruption. Orthogonal views were referenced to assist VIE identification of the true and false lumens as well as intimal flap and entry site of aortic dissection (Figure 1).

Initially, it took about 30 min to produce VIE images for each patient. This includes a series of steps such as the conversion of DICOM images into volume data, image segmentation and generation of various VIE views of the aortic dissection. With experience gathered, the time was shortened to about 10-15 min for each case.



**Figure 2** Stanford type A dissection with the true lumen smaller than the false lumen. The false lumen (F) has lower computed tomography (CT) attenuation than that in the true lumen (T) due to thrombus formation (A), thus a lower CT threshold (90 HU) was applied to view the false lumen intraluminally (B), while a higher CT attenuation (300 HU) was applied to demonstrate the true lumen. Corresponding virtual intravascular endoscopy (C) shows the involvement of three aortic branches by the dissection, namely left subclavian artery (LSA), left common carotid artery (LCA) and innominate artery when the view is positioned inside the false lumen. Bilateral pleural effusion is present on the 2D axial image.



**Figure 3** Stanford type B dissection with similar computed tomography attenuation in both true and false lumens (A). Virtual intravascular endoscopy clearly demonstrates the true and false lumens separated by the intimal flap (IF) in a single image (B). Arrow in A indicates the intimal flap.

## RESULTS

### Identification of true lumen and false lumen

In most cases, the false lumen is larger than the true lumen as once the blood enters the false lumen *via* an intimal tear it accumulates inside the lumen without any outlet. The false lumen then gradually becomes larger and compresses the true lumen which is in contact with the non-dissected portion of the aorta (Figure 2). A thrombus is frequently formed in the false lumen (Figure 2A), and this results in low CT attenuation when compared to the true lumen.

Therefore, for VIE visualization of true and false lumens, different CT thresholds need to be selected for demonstration of individual lumens clearly (Figure 2B).

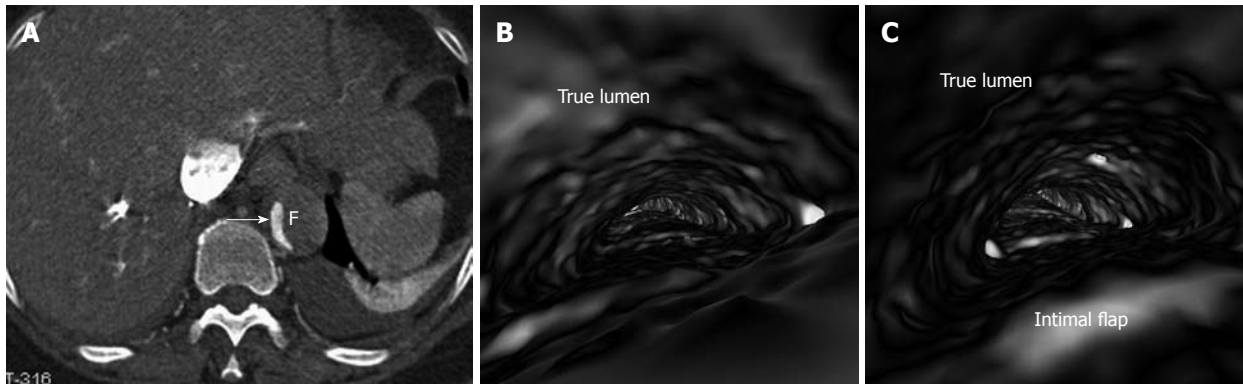
### Identification of intimal flap

The intimal flap is a soft tissue structure that separates the true lumen from the false lumen. The intimal flap can be seen in about 70% of cases in classic dissections<sup>[1]</sup>. If the CT attenuation measured in the true lumen is similar to that measured in the false lumen, VIE is able to demonstrate both lumens separated by the intimal flap in a single image (Figure 3). However, in the majority of cases, contrast enhancement in the true lumen is higher than that in the false lumen, thus VIE visualization of these two lumens is normally presented in separate images as different thresholds are required to demonstrate individual lumens. This indicates that the intimal flap is not usually displayed on a single VIE image since different intraluminal views are generated by showing the individual lumens separately (either true lumen or false lumen) (Figure 2B and C).

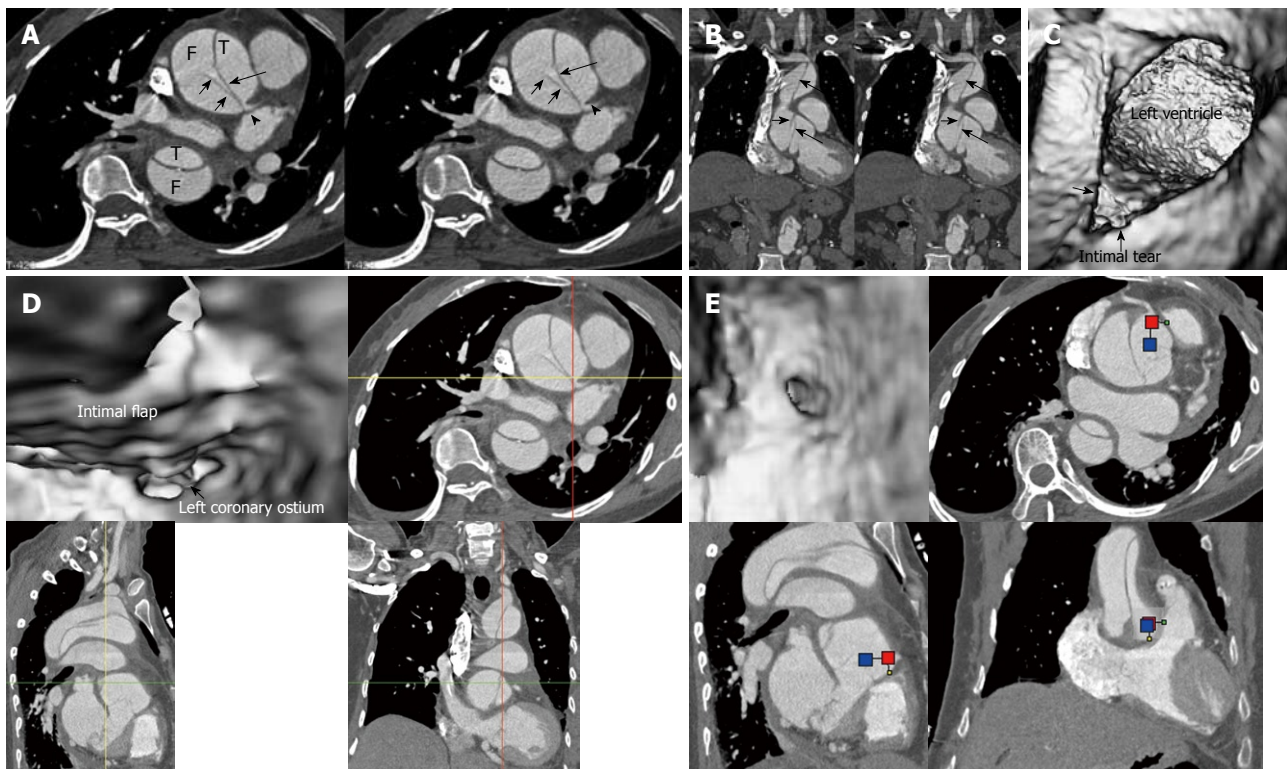
If the false lumen is thrombosed, the intimal flap may be difficult to recognise on CT images; thus it is difficult to distinguish and differentiate acute dissection from mural thrombus or intramural hematoma (Figure 4A). The limitation of conventional visualizations can be overcome with intraluminal endoscopic views, even if in the presence of significantly stenosed lumens (Figure 4B and C).

### Identification of intimal tear (entry site)

Identification of the accurate location of an intimomedial entrance tear is clinically important for diagnostic and therapeutic purposes. VIE is advantageous in this aspect as it enables generation of intraluminal views and clearly shows the communication between true and false lumens (Figure 5). In some complicated cases, VIE is able to confirm the entry site by navigating through the aorta and its branches including coronary branches (Figures 5 and 6). Moreover, VIE is able to determine the extent of the intimal tear which is believed useful for pre-operative evaluation of aortic dissection (Figures 5D and 6C).



**Figure 4** Stanford A dissection with abdominal artery branches involved. The false lumen (F) is thrombosed (A) with the true lumen being compressed to a much narrowed space. Virtual endoscopy views inside the true lumen clearly demonstrate the narrowed true lumen (B) and the intimal flap (C). Arrow in A indicates the true lumen.



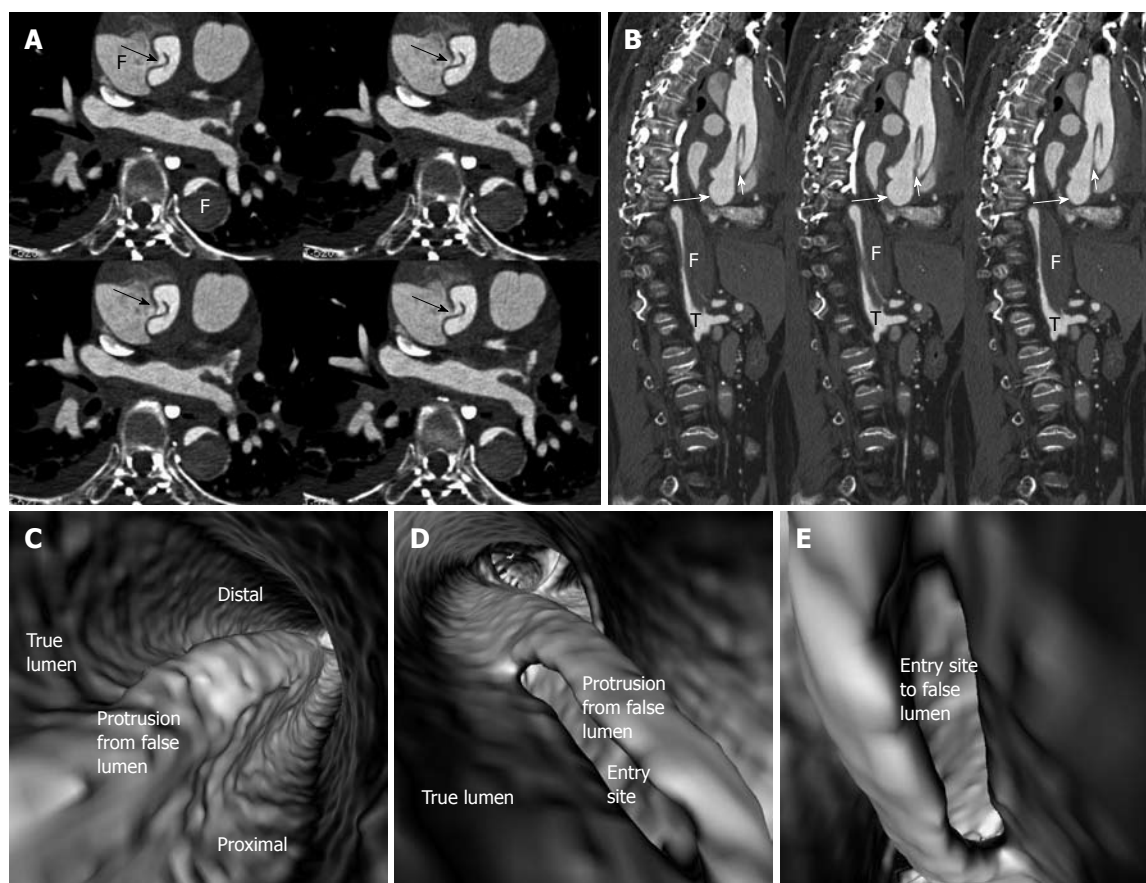
**Figure 5** Stanford type A dissection with the dissection originating at the aortic root. The intimal flap is clearly displayed on 2D axial and coronal reformatted images (long arrows in A and B) with the left coronary artery arising from the true lumen (T) (arrowhead). Virtual intravascular endoscopy shows the intimal tear which is located at the aortic root (arrow in C) proximal to the left ventricle. Both of the coronary ostia arise from the true lumen with the intimal flap extending to the left coronary ostium (D, E). Short arrows in A and B indicate the cobweb sign in the false lumen (F).

#### Identification of vessel involvement by aortic dissection

Identification of vessel involvement by aortic dissection can be confirmed by 2D axial images in most situations (Figure 7A). VIE could be used as a complementary tool to 2D images in indeterminate cases, as virtual fly-through allows the viewers to follow the direction of dissection and identify whether the individual aortic branches are involved in the dissection (Figures 2B, 5D, 7B and 8). VIE assessment of vessel involvement is still possible even if in the presence of a severely narrowed true lumen due to compression by the false lumen (Figure 9).

#### Other findings of aortic dissection

In addition to the above-mentioned imaging findings related to the aortic dissection, there are other typical and atypical features which are also observed in aortic dissection. The slender linear areas of low attenuation that occasionally appear in the false lumen on CT images, known as the cobweb sign, are specific to the false lumen and may aid in its recognition (Figures 5 and 10). Another usual indication of the false lumen is the beak sign, which is an imaging manifestation of the wedge of hematoma that cleaves a space for the propagation of the false lumen



**Figure 6** Stanford type A dissection with direct communication between the true lumen and false lumens (arrows in A). The true lumen (T) was obviously narrowed due to compression by the false lumen (F) with thrombus formed in the false lumen as shown on the sagittal reformatted image (B). The intimal flap (short arrows in B) arises from the level of the left ventricle (long arrows in B); C: A protrusion sign was observed on virtual intravascular endoscopy (VIE) images; D, E: The long intimal tear was identified at the ascending aorta posterior to the protrusion from the false lumen on different VIE visualizations. Pleural effusion is present at both sides on 2D axial images.



**Figure 7** Stanford type A dissection with involvement of the three main artery branches on 2D axial image (A). Virtual intravascular endoscopy confirms that these three branches arise from the narrowed true lumen (B). Arrows in A indicate the intimal flap. LSA: Left subclavian artery; LCA: Left common carotid artery; IA: Innominate artery.

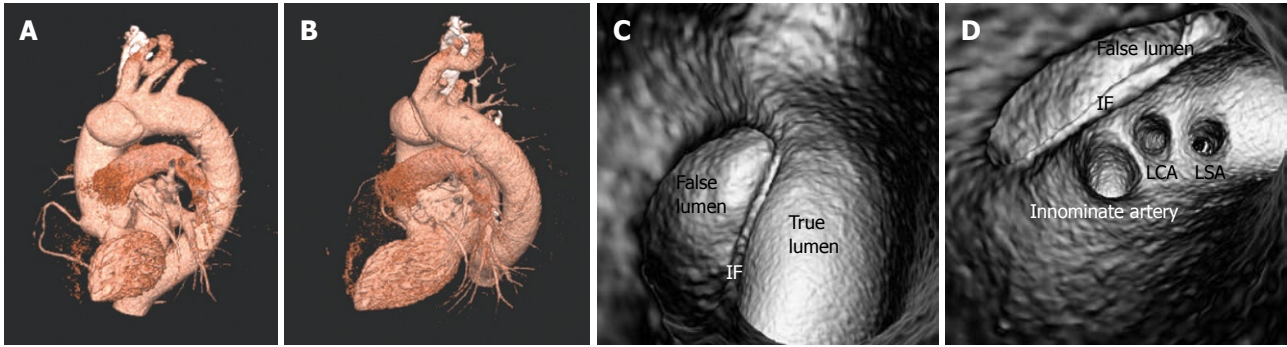
(Figure 11). The beak sign is a characteristic feature of the false lumen. These two findings can be easily identified and confirmed on 2D axial images, while VIE visualization does not present with characteristic features.

Intimointimal intussusception is an unusual manifestation of aortic dissection caused by circumferential dissection of the intimal layer<sup>[1]</sup>. In intimointimal intussusception, CT scans may show one lumen wrapped around the other lumen in the aortic arch or descending aorta, with the in-

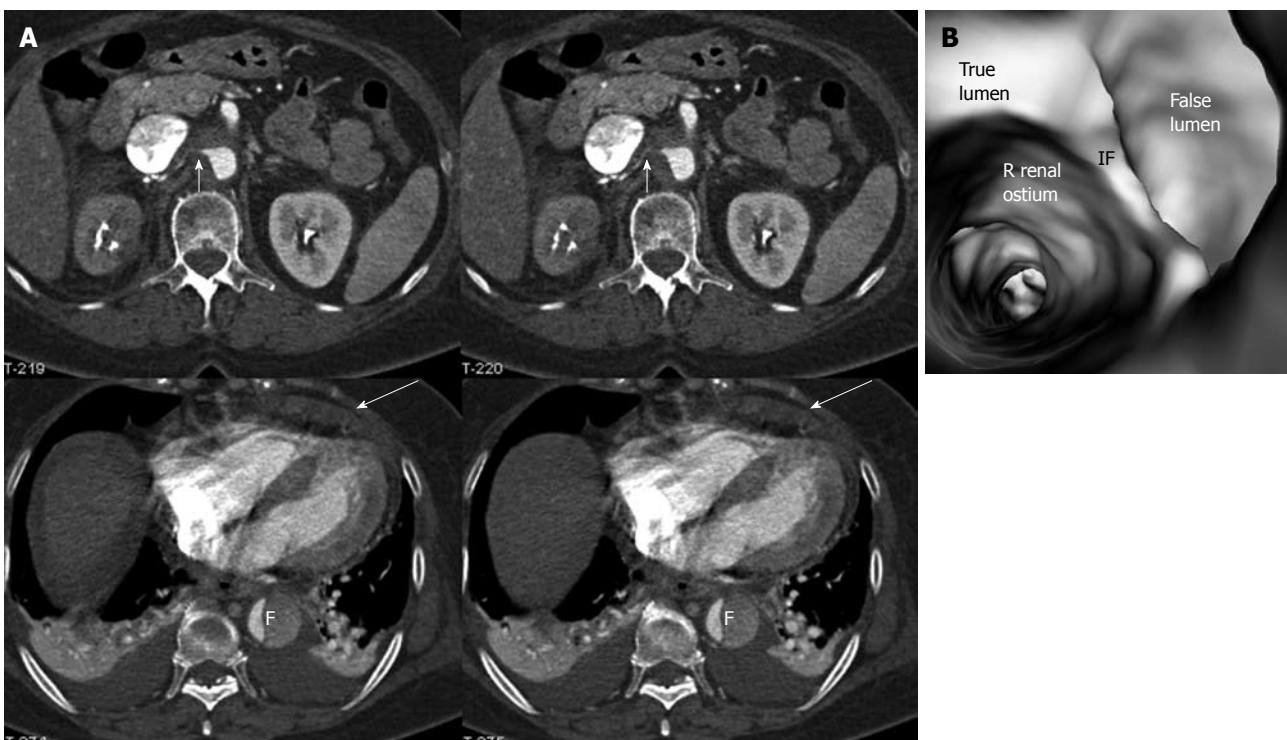
ner lumen always being the true lumen (Figure 12A). VIE clearly shows the central true lumen surrounded by the peripheral false lumen *via* two intimal flaps (Figure 12B), and the intraluminal visualization is enhanced by virtual fly-through viewing.

## DISCUSSION

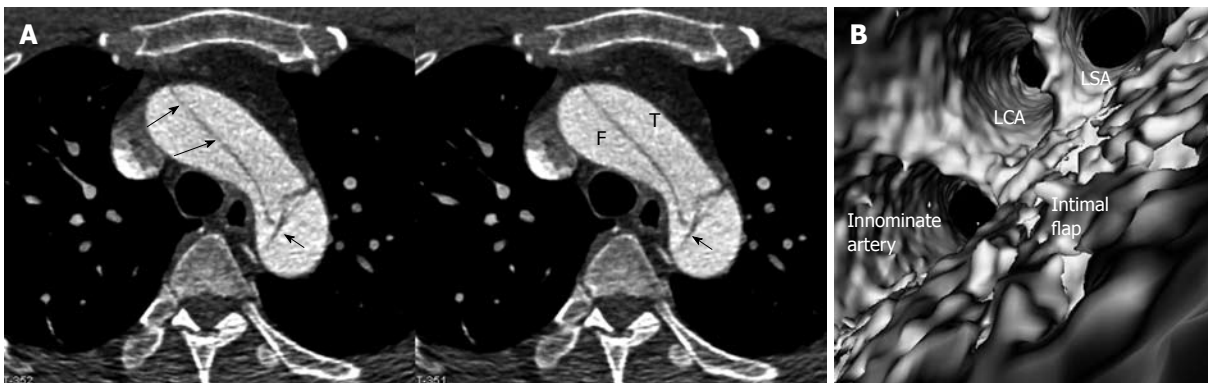
The principal complications of aortic dissection are car-



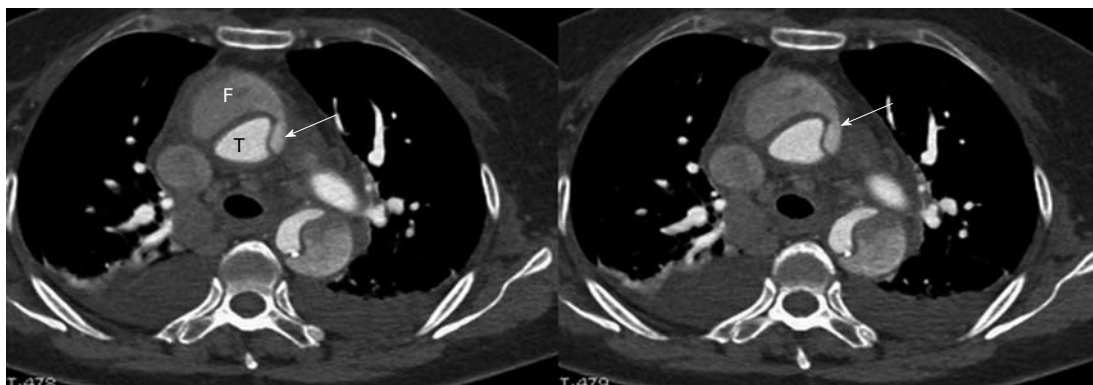
**Figure 8** Stanford type A dissection is restricted to the ascending aorta on 3D volume rendering images (A, B). Both true and false lumens are clearly demonstrated on virtual intravascular endoscopy (VIE) visualization and these two lumens are separated by an intimal flap (IF) (C). The three main artery branches are perfused by the true lumen as shown on VIE view (D). LSA: Left subclavian artery; LCA: Left common carotid artery.



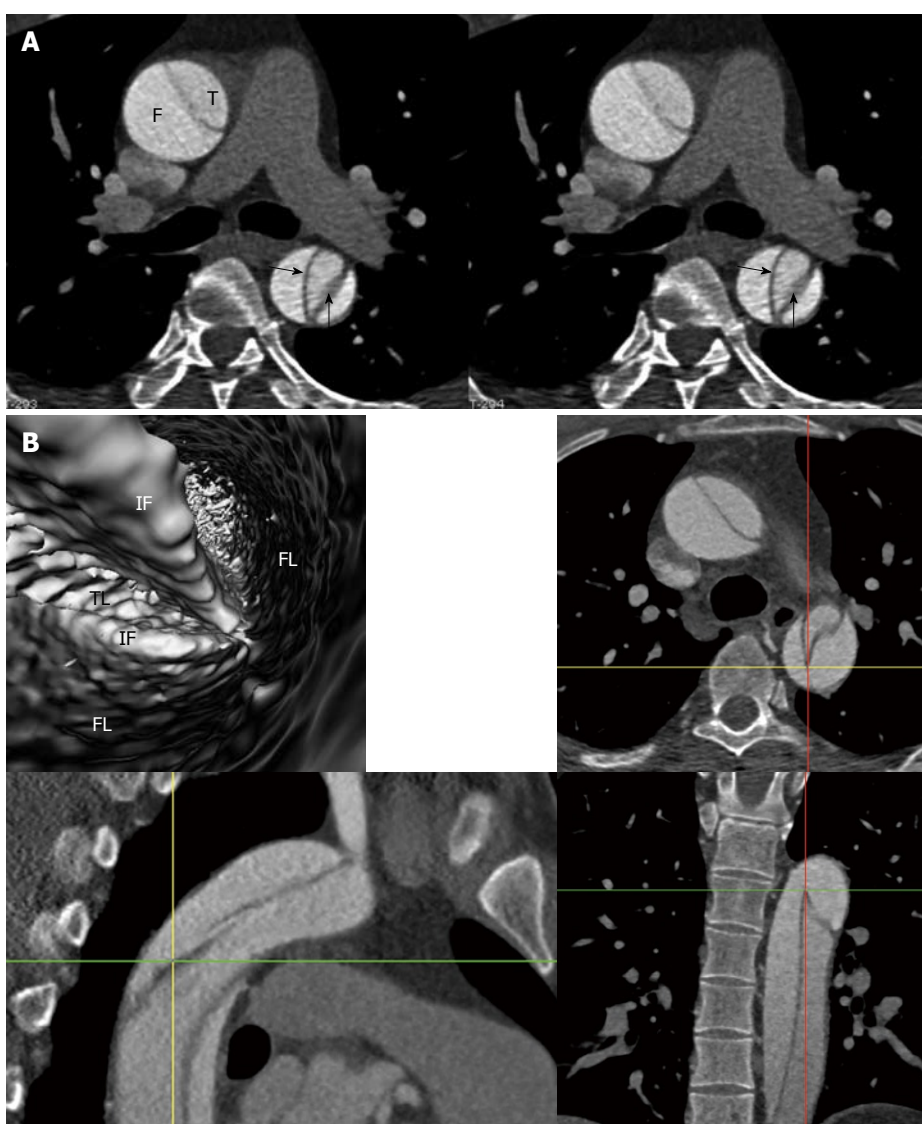
**Figure 9** Stanford type B dissection with the true lumen much smaller than the false lumen. The right renal artery arises from the compressed true lumen resulting in right renal infarction (A). Virtual intravascular endoscopy confirms the origin of the right renal ostium coming from the true lumen which is separated from the false lumen (F) by an intimal flap (IF) (B). Short arrows in A indicate the right renal artery, while long arrows in A refer to pericardial effusion. Pleural effusion is also present at both sides.



**Figure 10** Stanford type A dissection with three aortic branches arising from the true lumen. An irregular intimal flap is displayed on virtual intravascular endoscopy visualization (B). A cob-web sign (short arrows) is noticed in the false lumen (F) on 2D axial image (A). Long arrows indicate the intimal flap. T: True lumen; LSA: Left subclavian artery; LCA: Left common carotid artery.



**Figure 11** Stanford type A dissection with appearance of a beak sign (arrows) extending from the false lumen to surround the true lumen. The true lumen (T) is smaller than the false lumen (F). Bilateral pleural effusion is also noticed on 2D images.



**Figure 12** Stanford type A dissection with appearance of intimointimal intussusception (arrows in A). Corresponding virtual intravascular endoscopy shows the centrally narrowed true lumen (TL) was surrounded by the false lumen (FL) and separated by two intimal flaps (IF). The exact position of the VIE view is confirmed by the orthogonal views which are shown in B.

diac rupture, cardiac failure and end-organ ischemia. The aorta gives rise to many important branches that include

coronary arteries, carotid and vertebral arteries, subclavian arteries, lumbar arteries, celiac and mesenteric arteries, re-

nal arteries and iliac arteries. These branch arteries can become poorly perfused due to obstructions at their origin, as would happen if the artery branch was thrombosed during dissection<sup>[15]</sup>. It is imperative to determine whether these major branch arteries originate from true or false lumens before interventional procedures such as placement of endovascular stent grafts or stents<sup>[5,6,8]</sup>, because any branch vessels supplied by the false lumen may be occluded with an intervention unless surgically bypassed. Medical imaging techniques play an important role in this aspect.

High resolution CT imaging is the method of choice for diagnosis of aortic dissection and identification of true and false lumens, as well as determination of the aortic branches in relation to the dissection<sup>[2,10]</sup>. The most reliable direct imaging sign observed by CT for differentiating the true from false lumens is the ability to demonstrate direct continuity between the true lumen and the lumen of the uninvolved aortic lumen distal or proximal to the dissected aortic segment. This may not always be possible because the dissection may extend proximally into the aortic root, or the origin of the intimomedial entrance tear is at the convexity of the aortic arch where the true and false lumens may be difficult to follow<sup>[7,9]</sup>. The limitation of 2D CT imaging is complemented by multiplanar reformation and 3D reconstructions. Our experience of using VIE for assessment of aortic dissection, especially in the identification of intimal tears shows the feasibility of VIE visualization in complex cases of dissection.

In addition to the identification of the entry site, determination of the extent of the entry site can be further explored by VIE and assessment of vessel involvement can be confirmed even if for visualization of the tiny artery branches such as coronary arteries, as shown in Figures 5 and 6. We believe VIE could be used as a complementary tool to conventional CT visualizations for accurate assessment of the aortic dissection.

VIE image quality is determined by an appropriate threshold selection. Demonstration of true and false lumens is dependent on CT attenuation measured in each compartment. The intimal flap has a soft tissue density and presents as a linear structure; thus, it is commonly shown as an irregular linear structure which separates the true lumen from the false lumen (Figure 10B). Detecting full-directional information about the dissection should be assisted with cross-sectional and multiplanar reformatted CT images. Correlation with orthogonal views is necessary to confirm the exact position of anatomic details on VIE visualization, especially to assess the aortic branches with regard to their relationship to the dissection.

With the current multislice CT scanners such as the 64-slice or dual source CT, acquisition of isotropic volume data is possible so that high resolution original data is generated to ensure the image quality of VIE images<sup>[16,17]</sup>. In our small group of patients whose CT scans were performed with a dual source CT scanner, VIE was successfully generated in all of the patients with clear demonstration of anatomical details including the linear

structure of intimal flap. Rapidly technical developments have significantly enhanced the diagnostic value of CT in the detection and evaluation of aortic dissection.

In conclusion, in this pictorial essay, we demonstrated the applications of VIE for visualization of aortic dissection and identification of true and false lumens, intimal flap and intimal entry site. Our preliminary study shows that VIE is a feasible 3D visualization tool which could be used to assist radiologists to accurately evaluate aortic dissection so that better patient management could be achieved.

## COMMENTS

### Background

Aortic dissection is a common vascular disease which carries high mortality if not diagnosed and treated appropriately. Despite high diagnostic value of computed tomography (CT) angiography in the diagnosis of aortic dissection, its accuracy to identify the location of an intimal tear or entry site is limited in some complicated cases. This study presents the advantages of 3D virtual intravascular endoscopy (VIE) for identification of intimal tear and assessment of vessel involvement in aortic dissection.

### Research frontiers

Extended application of 3D VIE to the patients with aortic dissection, thus, improving understanding of the dissection extent and vessel involvement for surgical planning.

### Innovations and breakthroughs

Aortic dissection is routinely diagnosed and evaluated with CT angiography through a combination of 2D and 3D visualizations. This study presents advanced applications of VIE in aortic dissection by demonstrating findings which cannot be achieved with traditional image visualizations.

### Applications

Our preliminary study shows the potential value of VIE in aortic dissection. Further studies based on a large cohort are needed to compare the diagnostic value of VIE with traditional 2D/3D visualizations.

### Terminology

VIE is a method of image data visualization using computer processing of 3D image datasets (such as CT or MR scans). It can provide visualizations of vascular structures similar or equivalent to those produced by standard endoscopic procedures.

### Peer review

It's a well written pictorial essay about 3D VIE in aortic dissection. There are many figures showing aortic dissection and their 3D VIE views.

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