



## Application of 64-slice spiral computed tomography angiography in extremity vascular injuries

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**ABSTRACT.** The objective of the current study was to assess the utility of 64-row helical computed tomography angiography (CTA) in the evaluation of extremity vascular traumas. The extremities from 17 clinical cases of suspected traumatic vascular damage were evaluated using 64-row helical CTA. To evaluate extremity vascular traumas using CTA, volume rendering, multiple planar reconstruction, and curved planar reconstruction technology were applied to accurately and rapidly indicate the type and extent of blood vessel damage, as well as any relationship with injuries to adjacent bones, joints, soft tissue swelling, or hematomas. The types of extremity vascular traumas evaluated included damaged arteries, artery spasms or block, blood vessels shifted because of pressure, pseudo aneurysms, arteriovenous fistula, and vein occlusion. The results of the study indicated that 64-row helical CTA could be highly efficient and accurate in the evaluation of extremity vascular traumas, and could aid in making clinical assessments.

**Key words:** Computed tomography angiography; Advanced judgment; Extremity vascular trauma

## INTRODUCTION

The 64-slice spiral computed tomography (CT) angiography (CTA) has many advantages, including convenience, speed, and accuracy in the diagnosis of vascular injury following trauma to a limb.

In recent years, the number of traffic and work-related accidents has increased. Consequently, limb fractures and soft tissue injuries are common. Regardless of the nature of an injury, if the trauma is associated with a larger vascular injury, especially an arterial injury, and the diagnosis is not timely, the patient could be faced with the risk of amputation. Rapid assessment of extremity vascular trauma and the determination of an accurate diagnosis are critical for patients with an acute trauma (Mishra and Ehtuish, 2007). Accordingly, CTA has replaced digital subtraction angiography, and become the imaging method of choice for traumas because of its speed, non-invasiveness, accuracy, and availability. With multi-detector computed tomography (MDCT) imaging technology, the fast acquisition speed of 64-slice spiral CTA and its convenient, fast, and accurate advantages provide a suitable screening method for the diagnosis of post-traumatic vascular injury. Further, technological advances make the isotropic multi-planar imaging and high-quality three-dimensional technology possible, which plays a decisive role in diagnosis and surgical planning (Haage et al., 2002; Fishman et al., 2008; Hsu et al., 2008; Peng et al., 2008; Redmond et al., 2008; Foley and Stonely, 2010). Our department reviewed the accuracy of MDCT assessments in determining the conditions of 17 patients with suspected vascular injuries resulting from limb trauma between July 2009 and August 2011, using 64-slice spiral CTA. The details of the evaluation are included in the following report.

## MATERIAL AND METHODS

### General information

Of the 17 cases evaluated in the current study, 14 involved men and three involved women. The patients were aged 23-82 years, with an average age of 47.9 years. Five patients showed suspected upper arterial injuries, while 12 showed suspected lower arterial injuries; two had a weakened radial artery pulse and three had a slightly weakened pulse; two had an indistinct dorsalis pedis pulse and three had a weakened pulse; five had a slight weak pulse, and three showed white distal skin. Some patients were diagnosed with varying degrees of upper or lower extremity fractures, hematomas, and soft-tissue swelling.

### CTA and scanning parameters

All of the patients included in the study underwent limb CTA examination before treatment, using the 64-slice spiral CT machine (GE Medical Systems, Waukesha, WI, USA). During the performance of the upper limb CTA, the patients were required to raise the upper limb up, to allow the scanning range from the aortic arch to the distal finger. The scanning range of the lower limb vasculature was from the fourth lumbar vertebral plane to the remote toe. When positioning the upper or lower extremity CTA image, the aortic arch and the fourth lumbar vertebral abdominal aorta were selected, respectively, as the trigger level positioning line. The trigger threshold was set at 150 Hu. The range of the detector was 64 x 0.625 mm, the

thickness was 0.625 mm, the layer was 0.5 mm, the pitch was 0.516, the pitch reconstruction was 0.625 mm, and one revolution time for collecting information was 0.40 s.

Ultravist® (370 mgI/mL; Schering Pharmaceutical Co. Ltd., Guangzhou, China) was injected into the cubital vein using a high-pressure syringe. The contrast agent dose was 100 mL, and the injection rate was 4-5 mL/s. Normal saline (20 mL) was injected at the same rate after injection of Ultravist®. After the arterial phase scan, approximately 120 s after injection of Ultravist®, the patients underwent the venous phase scan. The data collected was put into the processing workstation after the CT scan, and version 4.4 of the AW software (Advantage workstation, AW4.4; GE Medical Systems) was used for redevelopment. The volume rendering and multi-planar and surface reconstruction were used to rotate and cut the three-dimensional image, and to add and subtract structures. Three-dimensional organization using tissue removal technology enabled clarification of the corresponding anatomy of blood vessels and surrounding tissues.

## RESULTS

The CTA of the 17 clinical cases with volume rendering (VR), multiple planar reconstruction (MPR), curved planar reconstruction (CPR) accurately and rapidly revealed the nature and extent of the vascular injury, as well as the relationship between the vascular injury and the adjacent iliac bone, joints, soft tissue swelling, or hematomas. The following types of limb traumas with associated vascular injury were predominant among the clinical cases: 1) five patients showed arterial rupture, three had accompanied active bleeding, and two had vascular thrombosis; 2) four had arterial spasms or occlusions; 3) two exhibited vascular shift because of compression; 4) three had vacation aneurysm; 5) one had an arteriovenous fistula; and 6) one had popliteal vein thrombosis.

## DISCUSSION

There is an increasing trend in extremity vascular injuries in recent years, most of which are caused by traffic accidents, falling from heights, needle penetration, crashing into rocks, and stabbings. Most arterial injuries, especially extremity vascular and trunk damage, cause massive hemorrhage and can be life threatening. Arterial injuries can also cause insufficient blood flow to the distal limbs, and result in necrosis or dysfunction, which in turn causes patient death or disability if handled improperly.

The characteristics of 64-slice spiral CTA include enhanced sharpness, short imaging time, and a clear reflection of vascular changes in the limbs. Also, 64-slice spiral CTA can elucidate the relationship between vascular injury and adjacent structures through VR, MPR, and CPR images (Karcaaltincaba et al., 2004; Willmann and Wildermuth, 2005; Bunger et al., 2006; Gakhal and Sartip, 2009; Ichinose et al., 2009; Pieroni et al., 2009; Shah et al., 2009; Smith et al., 2010; Uyeda et al., 2010; Foster et al., 2011; Halvorson et al., 2011; Sarac et al., 2011). The following are examples of the types of limb trauma with vascular injury included in the analysis: 1) arterial rupture, 2) arterial spasm or occlusion, 3) vascular compression shift, 4) pseudoaneurysm, 5) arteriovenous fistula, and 6) popliteal vein embolism. The classification of the types of limb trauma with vascular injury provides a reliable basis for the assessment of patients with injuries, and helps avoid delays in treatment.

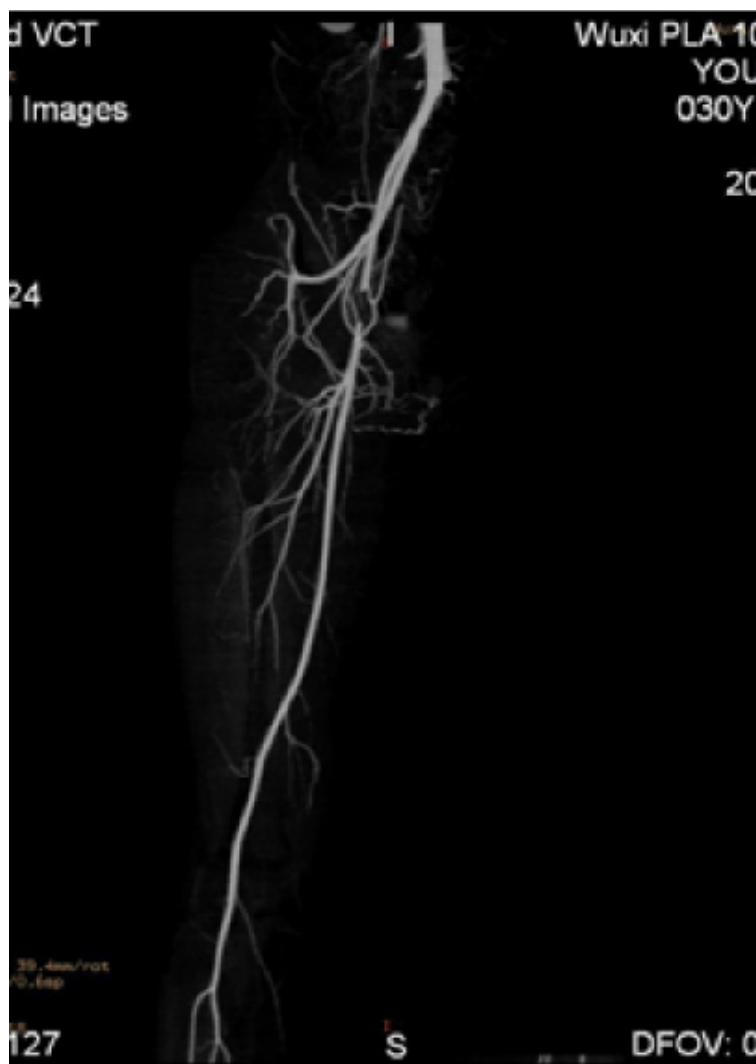
## Arterial rupture

The direct sign of vascular rupture on CTA is interruption of vascular continuity, and the exudation of irregular floc-like high-density contrast agent (Figure 1), which can penetrate into the adjacent soft tissue or muscle, similar to active bleeding of a limb artery, and may lead to hemorrhagic shock or death. Vascular rupture can also lead to thrombosis and occlusion. CTA reveals that part of artery breaks exhibit filling defect. In this study, two cases of vascular rupture which lead to thrombosis and occlusion were detected by CTA, and confirmed during surgery (Figure 2).



**Figure 1.** Increase, thickening, and tortuosity in the peripheral vascular branch of the hypomere in the left femur. It is possible to see high density image in soft tissue, which represent the Ultravist® oozing shadow.

The sign of the filling defect is because the vasculature retracts after complete rupture, and the break point twists inward, which leads to thrombosis. However, bleeding can often stop on its own. Further, the interruption of blood transportation may cause remote acute ischemic or reflux disorder. However, the opening of collateral vessels near damaged vessels can relieve the remote ischemia on the injured side of the limb.



**Figure 2.** In the right side of the iliac artery, there are strips filling the defect shadow, which presents as a vascular occlusion. The range is nearly 2 cm, surrounded by small patches, which represent the Ultravist® oozing shadow.

### Arterial spasm or occlusion

The smooth muscle of the vasculature will forcibly contract for a prolonged period when the vessel wall suffers a blunt trauma. The CTA will show signs of arterial stenosis, and the stricture lumen density will fade. In general, arterial stenosis is considered severe when it is greater than 75% of the artery caliber. Artery spasm is not associated with organic damage to the vascular wall, but a long period of severe spasms can cause vascular thrombosis and occlusion, leading to limb ischemia and even necrosis. There were seven cases of arterial spasm and two cases of occlusion in the current study (Figure 3).



**Figure 3.** We can see the right subclavian artery by curved planar reconstruction. Visible blood vessels of the initial segment of the right subclavian artery (1 cm away from the opening) appeared truncated. The range is about 2 cm, and internal bar-like strips fill the defect shadow. The computer tomography value is about 65 Hu. The diameter of the distal and right axillary artery lumen is unequal, part of which appears as a wavy shape. The range is about 5 cm. There are visible small patches of signal contrast agent leakage in soft tissue, and surrounding soft tissue swelling.

### Vascular compression shift

Vascular compression may be caused by fracture, dislocation, hematoma, foreign bodies, or even a splint, bandage, or tourniquet, and the prognosis can be very serious if the pressure lasts for an extended time. Severe artery compression may completely block the blood flow, and thus injure the blood vessel wall, causing thrombosis and distal limb necrosis. Such oppression is common in knees and elbows where the vascular anatomy is fixed, and is close to joints. VR imaging may be better than MPR and CPR in its ability to show the area of vascular injury and bone joints, as well as whether there are any pressurized vessels. However,

where the understanding of the relationship between a hematoma or hematoma intensity secondary to vascular rupture and adjacent vessels is concerned, MPR and CPR perform better than VR, but still require full integration with the original axial images.

### Pseudoaneurysm

There was one case involving a pseudoaneurysm in our study. The patient hurt their right foot in a car accident, and clinical examination revealed a beating mass in the right inward heel. An emergency lower limb CTA (Figures 4-5) revealed a round, uniform intensity shadow in the right inside of the calcaneus with a clear edge.



**Figure 4.** The volume rendering icon shows that there is no image in the middle of the left brachial artery and that the distal edge of the injured vasculature is rough. There is a comminuted fracture in the middle of the left humerus. The sides of the broken bone form an angle, and there is no push to the brachial artery.





**Figure 5.** It is possible to see round uniform abnormal enhancements in the inside of the soft tissue in the right foot, which appear as a clear realm and connect with the inside arteries in the right foot. The right side of the calcaneal has comminuted fractures. The ends of fractures have counterpoints. The fracture line is clear.

In addition, it was connected to the inside artery of the bottom right foot with a comminuted fracture in the right calcaneus. According to the CTA details, there was a pseudoaneurysm in the right inside of the calcaneus. The mechanism behind pseudoaneurysm formation is that the arterial fracture causes the development of a hematoma, the outer layer of which is formed by organizing fibrous tissue. The artery break is still connected with the hematoma cavity. There are no normal vessel wall structures in pseudoaneurysms, and they may rupture at any time. At the same time, pseudoaneurysms may compress adjacent organs such as nerves and bone, and cause additional damage. The intra-capsular blood clots are also a potential source of emboli. Furthermore, fever in the adjacent skin, as well as pain with weak pulsation, may be misdiagnosed as abscesses and be incised, which will cause serious consequences. As a result, the CTA can determine the pseudoaneurysm location in a timely manner, as well as the extent and relationship with adjacent structures, and provide a reliable basis for clinical treatment.

### **Traumatic arteriovenous fistula**

If damage to the adjacent artery and vein occurs at the same time, blood from the artery and vein will mix, and cause the development of a traumatic arteriovenous fistula, due to the pressure gradient between the artery and vein, which may cause a weakened pulse or insufficient blood supply to distal limbs. However, a traumatic arteriovenous fistula can be easily detected using CTA (Figure 6).





**Figure 6.** There is a comminuted fracture on the left side of the lower segment in the tibia and fibula. The capitulum of broken bones appears as a slight dislocation. The posterior tibial artery connects to the vein.

### **Traumatic venous embolism**

There is an increasing trend in traumatic venous embolisms in recent years, which occur more frequently in lower limbs than in the upper limbs. Recent studies show that, at the point when trauma occurs, the blood of the patient immediately exhibits a hypercoagulable state. Local mechanical vein contusions, lacerations, or the stabbing of fracture fragments will easily cause venous thrombosis. Venous thrombosis leads to limb swelling and pain, and may cause superficial varicosis, a series of lesions related to nutritional disorders, or pulmonary embolism if transferred to sequelae. Further, the CTA shows that the popliteal vein exhibits a filling defect in the case of traumatic popliteal vein embolism.

Sixty four-slice spiral CTA offers the advantages of a short examination time, non-invasiveness, and large-scale scanning. In addition, it provides a good evaluation of the different types and extent of limb trauma with accompanying vascular injury, as well as the relationship

with adjacent injuries, which is valuable for the clinical evaluation and determining the appropriate treatment. The post-traumatic vascular lesion location, shape, and its relationship with adjacent muscle and soft tissue, could be clearly determined with the full use of VR, MPR, and CPR reconstruction techniques via rotation to any angle and any position, which will provide reliable image data for clinical use.

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