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Efficacy of Multidetector Computed Angiotomography in the Diagnosis of Limb Arterial Injuries☆,☆☆

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ABSTRACT

Objective: To determine the diagnostic usefulness of multidetector computed angiotomography in the diagnosis limb arterial injuries in patients with suspicion of arterial injury with no indication of immediate surgery.

Methods: Non-invasive 64-channel multidetector computed tomography (MDCT) was performed on 99 limbs suspected of having a traumatic vascular injury over a 44-month period between August 2004 and April 2008. The results were interpreted by the duty radiologist and his findings were compared with those from surgery or clinical follow-up. Interobserver variability was evaluated by comparing the reading of the MDCT by the duty radiologists with the retrospective reading by radiology specialist in trauma.

Results: MDCT as a diagnostic method of vascular injury of the limbs, interpreted by a general radiologist showed a sensitivity of 98% (95% CI: 93–100), a specificity of 88% (5% CI: 77–99), a positive predictive value of 91% (95% CI: 82–99), a negative predictive value of 97% (95% CI: 90–100), a positive likelihood radio of 8.24 (3.6–18.7), and a negative likelihood radio of 0.02 (0–0.15). The inter-observer variability by comparing the interpretation of the MDCT by the duty radiologist with that of the radiology specialist in trauma had a *kappa* of 0.869.

Conclusion: Multidetector computed angiotomography is a high precision diagnostic imaging method in arterial injury of the limbs, offering a suitable and appropriate therapeutic approach, and could be considered as new gold standard for the diagnosis of arterial injuries of the limbs.

Eficacia de la angiotomografía con multidetectores en el diagnóstico del trauma arterial de extremidades

Palabras clave:
Angiotomografía
con multidetectores

RESUMEN

Objetivo: Determinar la eficacia diagnóstica de la angiotomografía multidetectores en el diagnóstico del trauma arterial de las extremidades en pacientes con sospecha de lesión arterial sin indicación de cirugía inmediata.

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Arteriografía
Lesión arterial de extremidades

Métodos: Durante 44 meses, entre agosto del 2004 y abril del 2008, se realizó angiotomografía multidetectores de 64 canales a 99 extremidades con sospecha de lesión vascular traumática. Los estudios fueron interpretados por el radió logo de turno y sus hallazgos se compararon con los de cirugía o los del seguimiento clínico. Se evaluó la variabilidad interobservador comparando la lectura de la angiotomografía realizada por el radiólogo de turno con la lectura retrospectiva de un radió logo experto en trauma.

Resultados: La angiotomografía multidetectores como método diagnó stico del trauma vascular de las extremidades interpretada por el radió logo general demostró una sensibilidad del 98% (IC 95%: 93–100), una especificidad del 88% (IC 95%: 77–99), un valor predictivo positivo del 91% (IC 95%: 82–99), un valor predictivo negativo del 97% (IC 95%: 90–100), una razón de verosimilitud positiva de 8,24 (3,6–18,7) y una razón de verosimilitud negativa de 0,02 (0–0,15). La variabilidad interobservador comparando la interpretación de la angiotomografía del radiólogo de turno con la del radió logo experto en trauma tuvo una kappa de 0,869.

Conclusión: La angiotomografía con multidetectores es un método de imagen con una alta precisión diagnó stica en el trauma arterial de las extremidades permitiendo un adecuado y oportuno enfoque terapé utico. Podría considerarse como nuevo patrón de oro para el diagnóstico del trauma arterial de extremidades.

Introduction

In patients with arterial trauma to the extremities, imaging studies are indicated when signs of vascular damage are present or an ankle-brachial index (ABI) lower than 0.9[1–3] is found. For many years, the diagnostic method of reference has been digital subtraction angiography. However, another fast, non-invasive method is required, and angiography could then be limited to cases in need of endovascular therapy. Doppler ultrasound is operator-dependent and has technical limitations in patients with extensive wounds, hemorrhage and pain[4–7] and resonance angiography in most hospitals is not available 24 h.[8] For these reasons, the use of computed tomography (CT) angiography for evaluating patients with arterial trauma to the limbs has increased.[9,10] The purpose of this present study was to develop an observational study in order to evaluate the efficacy of multidetector computed tomography angiography in the diagnosis of arterial trauma of the extremities, with suspected arterial damage and without indication for immediate surgery. We will also evaluate interobserver variability between a general radiologist and a radiologist specialized in trauma.

Materials and Methods

Patients

A prospective study was designed to evaluate a diagnostic test in patients admitted to the Hospital Universitario San Vicente de Paúl (Medellin, Colombia) with suspected traumatic arterial damage of the extremities without indication for immediate surgery. The study was approved by the Postgraduate Committee of the Radiology Department at the Universidad de Antioquia and the Ethics Committee at the Hospital Universitario San Vicente de Paúl (HUSVP) in Medellin (Colombia). Informed consent was given by the patients or by a family member when the patient's clinical conditions did not allow them to do so.

Included in the study were hemodynamically stable patients over the age of 15 with a clinical suspicion of traumatic arterial damage of the extremities with no indication for immediate surgery, who, after being evaluated by the group of trauma surgeons, underwent multi-detector CT angiography of the affected extremity. Indications for immediate surgery included the presence of ''hard'' or definitive signs of arterial injury: arterial bleeding, hemorrhagic shock, and absence of pulse, thrill/murmur, expanding hematoma or signs of ischemia. Excluded were patients with iodine intravenous contrast allergy, patients whose CT angiogram could not be correctly interpreted because of artifacts due to metallic foreign bodies, and hemodynamically unstable patients.

For 44 months (from August 2004 until April 2008), 96 patients (82 men, 14 women) with suspected arterial trauma in the extremities were admitted to HUSVP and underwent multidetector CT angiography of the injured extremity. Mean age was 31 (SD 13.6, range 15–76).

The indications for computed tomography angiography of the different cases were: diminished pulse in 57 cases, trajectory of the projectile in vascular territory in 15 cases, history of bleeding in 24 cases, small hematoma that did not increase in size in 12 cases, luxation or fracture dislocation in 36 cases, findings suggestive of nerve damage in 11 cases, late diagnosis of arterial injury in 9 cases, other indications (coldness, pulsating mass, growing hematoma, murmur and thrill) in 6 cases and severe closed soft tissue trauma in 3 cases. The majority of the cases presented 2 or more signs suggestive of vascular damage at the time of the initial evaluation. Doppler ultrasound was not used to measure ABI as the device is not available in the Emergency Department.

Computed Tomography Angiography

All the computed tomography angiographies were performed with a GE Prospeed multidetector 64-channel CT. For the study of the upper extremities, the injured extremity was raised above the height of the head and secured with adhesive tape in order to diminish the artifacts caused by chest movements. If the condition of the patient meant that the limbs could not be

raised (due to shoulder fracture, for example), both limbs were secured at the patient's sides. For the computed tomography angiography of the lower extremities, the limbs were affixed to the examination table.

For each study, 100 cc of non-ionic intravenous contrast medium were administered (Iopamidol, 300 mg of iodine per ml) at an injection rate of 4 ml/s. A milliamperage of 350 and 120 kV was used. Images were acquired in the arterial phase with calculated delay using the Smart Prep program. The cuts were taken with a collimation of 2.5 mm, interval 2.5 mm and reconstructions at 1.25 mm. The images were transferred to the workstations AW 3.1 and AW 4.4 GE to generate multiplanar and three-dimensional reconstructions (maximum intensity projection and volumetric reconstructions).

Interpretation of Images and Reference Standards

The computed tomography angiographies were interpreted by the general radiologist at the work station at the time of the study and, later, retrospectively by a radiologist who is a trauma expert and was blinded to the findings of the first reading as well as the result of the angiography when it was performed, surgical findings and follow-up data.

Based on the report of the radiologist on call, the surgeon defined the approach for the patients who were divided into 2 groups: patients who received non-surgical treatment and patients who received surgical treatment. For the non-surgical treatment group, the reference test was the clinical follow-up 2 weeks after the computed tomography angiography that evaluated the presence of distal pulse, murmurs or pulsating mass at the site of the lesion. In the surgical treatment group, the reference test was the surgical description.

Statistical Analysis

Sensitivity, specificity, positive and negative predictive value and likelihood ratios of the multidetector computed tomography angiographies were compared with the surgical findings and clinical follow-up. Interobserver variability was calculated between the reading of the radiologist on call and the expert trauma radiologist.

On the computed tomography angiography, injury was defined as the presence of occlusion, pseudoaneurysm, arteriovenous fistula, intimal flap or active extravasation of the contrast medium. Non-injury was defined as a lack of these findings. In surgery, injury was considered to be the presence of occlusion, pseudoaneurysm or arteriovenous fistula, and non-lesion was an absence of these findings. In the clinical and telephone follow-ups, injury was defined as the presence of clinical signs indicative of vascular damage and non-injury was defined as the absence of these signs.

Operative characteristics were calculated with the EPIDAT 3.0 program.

Results

In total, 99 extremities (cases) with suspected traumatic vascular injury were evaluated with multidetector computed tomography angiography in 96 patients (Table 1). The computed tomography angiographies of 68 cases were available for evaluation by the radiologist specialized in trauma (Table 2).

A total of 43 cases presented contusion trauma, 24 stab wounds, 30 single firearm wounds and 2 multiple gunshot wounds.

The vascular repairs included: 15 cases of saphenous vein graft, 3 synthetic vascular grafts and 7 end-to-end anastomoses. Other procedures included: fasciotomy (11), thrombectomy (15), venorrhaphy (11) and supracondylar amputation (1).

The computed tomography angiography interpreted by the radiologist on duty demonstrated 56 vascular lesions, 42 of which were confirmed by surgery. There were 5 false-positive results. Thirteen patients with injury demonstrated on computed tomography angiography were managed without surgery as the lesions were distal and in well-perfused extremities; none of these cases presented complications during follow-up. The radiologist on duty interpreted 38 CT angiography studies as negative, one of which was a false negative. Mean clinical follow-up was 32 days (range 15–65). No arterial damage was found during clinical follow-up in the patients who had non-surgical treatment. Two patients who did not keep their hospital follow-up appointment were followed up by phone 30 days after computed tomography angiography. They were asked about the presence of pain, mass at the injury site, claudication and about returning to normal activity. Five patients who did not have surgery had no clinical follow-up and were excluded from the analysis.

68 studies were available for interpretation by the radiologist specialized in trauma. There were 36 true positive results, 30 true negatives, 2 false negatives and no false positive results.

Table 3 shows the distribution of the damaged vessels reported in the computed tomography angiography (Fig. 1). The computed tomography angiography revealed distal lesions in 13 patients (4 radial arteries, 1 ulnar artery,

Table 1 – Findings from the Computed Tomography Angiography by the Radiologist on Call.

Radiologist on call	n
Finding	99
Occlusion	33
False aneurysm	17
Arteriovenous fistula	6
Extravasation of the contrast	2
Intimal flap	0
Normal	41

Table 2 – Findings From Computed Tomography Angiography by the Expert Radiologist.

Radiology specialist	n
Finding	68
Occlusion	18
False aneurysm	12
Arteriovenous fistula	5
Extravasation of the contrast	2
Intimal flap	1
Normal	30

Table 3 – Vascular Lesions Reported by Computed Tomography Angiography.

Vessels	n
Upper limb	
Axillary	2
Humeral circumflex	1
Brachial	9
Radial	4
Ulnar	1
Lower limb	
Common femoral	1
Superficial femoral	13
Deep femoral	3
Popliteal	14
Anterior tibial	2
Anterior tibial and peroneal	2
Anterior and posterior tibial	1
Anterior and posterior tibial and peroneal	2
Muscular	2
Posterior tibial arterial	1
None	41
Total	99

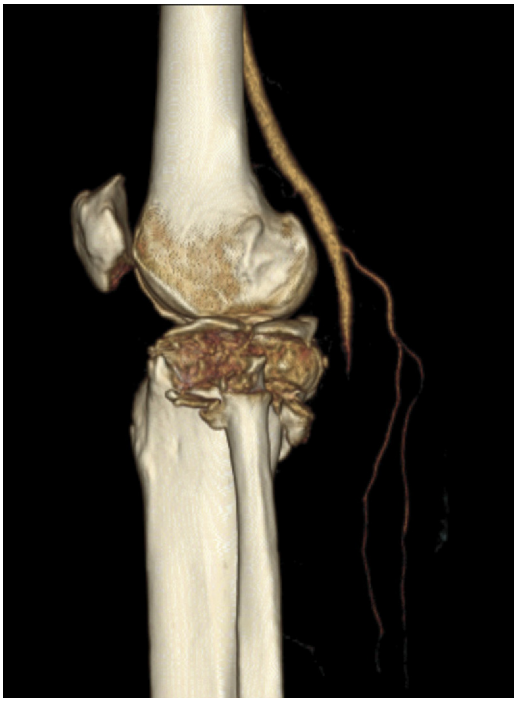

Fig. 1 – Occlusion of the popliteal artery (3-D reconstruction).

8 infrapopliteal vessels). These patients received non-surgical treatment and had a satisfactory clinical course.

The results of the readings done by the radiologist on call are shown in Tables 4 and 5. The operative characteristics of the study done by the radiologist on call were: sensitivity 98% (95% CI: 93–100), specificity 88% (95% CI: 77–99), PPV 91% (95% CI: 82– 99), NPV 97% (95% CI: 90–100), positive likelihood ratio 8.24 (3.62–18.77) and negative likelihood ratio 0.02 (0.00–0.15).

The interpretation of the expert radiologist showed the following results: sensitivity 94% (CI 95%: 86–100), specificity 100% (95% CI: 98–100), PPV 100% (95% CI: 98–100), NPV 93% (95% CI: 83–100), positive likelihood ratio (indeterminate) and negative likelihood ratio 0.05 (0.01–0.20).

The interobserver variability between the radiologist on call and the expert radiologist demonstrated good agreement (kappa: 0.869).

All the false positive results interpreted by the radiologist on call were distal lesions that did not influence patient management. There were 2 false negative readings by the expert radiologist: one false aneurism of the superficial femoral artery, which the radiologist on duty also did not diagnose. This patient was diagnosed by angiography and was treated with coil embolization. The other false negative was a patient in which computed tomography angiography revealed thinning of the posterior tibial artery, without other findings, interpreted as a lesion. The patient developed compartment syndrome that required fasciotomy and the absence of lesions was confirmed during the follow-up.

Table 4 – Correlation of Computed Tomography Angiography and the Reference Test (Operative Findings/Clinical Follow-up) by the General Radiologist on Call.

Tomography angiography	Reference test		No. of patients
	Positive for injury	Negative for injury	
Positive	51	5	56
Negative	1	37	38
Total	52	42	94

Table 5 – Correlation of Computed Tomography Angiography and Reference Test (Operative Findings/Clinical Follow-up) by the Expert Radiologist.

Computed tomography angiography	Reference test		No. of patients
	Positive for injury	Negative for injury	
Positive	36	0	36
Negative	2	30	32
Total	38	30	68

Discussion

The results of this study suggest that multi-cut computed tomography angiography is a highly efficient method for diagnosing arterial lesions of the extremities. Operatively, the study revealed good performance of the interpretation of both the radiologist on call and the expert radiologist, even in distal lesions. Very good interobserver agreement was found between the radiologist on duty and the radiologist specialized in trauma.

The HUSVP in Medellin has accumulated a significant experience with computed tomography angiography for the diagnosis of vascular trauma of the extremities, as shown by 2 studies done at this institution, in which sensitivity and specificity percentages are reported near 100%.[11,12]

The false positive results were distal lesions that did not influence patient management. The artery thinning should correlate with the clinical signs of compartment hypertension and do not necessarily correspond with the presence of damage. We conclude that the false negative results of the expert radiologist were due to an inappropriate arterial phase.

The main limitation of our study was the lack of ABI measurements because there is no Doppler ultrasound in the Emergency Department. In large trauma centers, arteriography/angiography is only ordered in patients with dubious signs and abnormal ABI.

Another limitation was the absence of clinical follow-up for all patients (5 cases were not followed). This may be because many of the patients treated in our institution reside outside the metropolitan area and traveling into the city is difficult, or they might not have come to follow-up appointments after being discharged because of improvement in their disease.

The ideal study for assessing the performance of computed tomography angiography in limb injuries should compare all the patients with surgical intervention or angiography. There are, however, powerful clinical reasons for this not being done, such as non-therapeutic surgical explorations, double exposure to the contrast medium and irradiation of patients who undergo 2 studies.

Likewise, a longer follow-up is recommended in all patients as later lesions may appear that are not evident at the time of the CT angiography. While telephone interviews are not a good follow-up method, it was the only option in 2 patients.

Other published studies have demonstrated similar results,[9,13] so the conclusion is that CT angiography is a safe and reliable procedure for the diagnosis of vascular trauma in the limbs. The main disadvantage of these papers was the exclusion of patients with vascular trauma in the distal segments of the extremities (forearms, hands and feet) and patients with trauma in more than one anatomic segment of the same extremity. This is due to the fact that such studies were done with single-channel helical CT, which does not offer sufficient spatial resolution to be able to evaluate small-sized vessels (such as those of the distal segments) and long anatomical extensions cannot be evaluated in one single acquisition. With the idea of overcoming the disadvantages of single-slice helical CT technology, multi-slice equipment was developed and, consequently, so was multidetector computed tomography angiography. Thanks to their greater space–time resolution, these technologies are able to evaluate small-sized vessels and extensive vascular territories within the same extremity.[14–17]

Some studies compare multi-slice computed tomography angiography with digital subtraction angiography, demonstrating the reliability of CT angiography in the diagnosis of stenosis and occlusion in occlusive arterial disease of the lower limbs.[18–20] The same could be said about its use in arterial injury of the extremities, as concluded by recent studies that present CT angiography as a sensitive and specific imaging method for the arterial evaluation of the lower extremities.[10,21–23] These studies demonstrate a sensitivity and specificity between 90% and 100%, using surgery and angiography as reference tests. More recently, Inaba et al. demonstrated in a prospective evaluation of 73 patients that computed tomography angiography is a highly sensitive and specific diagnostic method and could replace digital subtraction angiography for the evaluation of arterial lesions of the extremities.[24]

In conclusion, with the results obtained we can affirm that multidetector computed tomography angiography is an imaging method with high diagnostic precision in the evaluation of arterial trauma of the extremities. It provides an appropriate therapeutic focus and may be considered the new gold standard for the diagnosis of arterial trauma in the extremities. The evidence is based on several publications from different parts of the world with similar results. Interobserver variability showed good agreement between the general radiologist and the expert radiologist, which indicates that the interpretation by the general radiologist is sufficiently reliable to determine the indicated treatment.

Conflict of Interests

The authors declare having no conflict of interests.

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