Comparative Study of Ultrasound Doppler and 128-Multi-Detector CT in Assessment of Upper Extremity Ischemia in High-Risk Patients

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Article History:
Received on: 18 Jul 2020
Revised on: 31 Aug 2020
Accepted on: 01 Sep 2020

Keywords:
Upper extremity, ischemia, CT angiography, Stenosis grading

ABSTRACT
Ischemia at the upper extremity is considered one of the disabling and frequent causes of blind medical care failure. Non-invasive techniques as CTA and Doppler could effectively determine stenosis grades up to occlusion of the upper extremity, particularly if they impact the vessels proximal to the wrist also they can characterise the thrombus characters and recanalisation. The study was a prospective study carried out on 30 patients with upper extremity ischemia during the period from April 2019 to April 2020 at the Radiology department of Zagazig University hospitals. All patients presented with signs of ischemia as claudication, colour changes, pulselessness and their age ranged between 45 to 70 years. All patients underwent complete history taking and clinical examination, the results were correlated to conventional angiography. Overall, in the present study, Doppler US has a sensitivity of 86.6%, a specificity of 100%, PVP of 100% and PVN of 91.3%. CTA has a sensitivity of 93.3%, the specificity of 100%, PVP of 100% and PVN of 95.45%. CTA was more sensitive in milder degrees (Grades I & II) of thromboembolism and stenosis but no significant difference in severe cases (Grades III & IV). Segmental length assessment and collateral circulation were better noted on CT Angiography.

INTRODUCTION
Atherosclerotic disorders have relatively less impact on the upper limbs than the lower limbs. The peripheral embolic disease develops twice as often inside the lower extremities than in the upper ones. Proximal affection of the upper limbs is, however, not uncommon (Hellinger et al., 2010). Risk factors are the same as for other sites of atherosclerotic disease and include diabetes mellitus, hypertension, dyslipidemia, ageing process and smoking (Green et al., 2005) Thromboembolism is the primary aetiology of upper extremity ischemia. Moreover, embolic occlusion may lead to severe complications such as limb loss, organ failure, and death (Foster et al., 2006). Non-invasive techniques as CTA and Doppler can accurately evaluate for Upper extremity stenotic or embolic events, mainly when they affect proximal vessels. Their minimal invasiveness, wide availability, rapid acquisition, and display of both vascular and soft tissue structures (Bozlar et al., 2013). Post-processing techniques as volume rendering (VR), maximum intensity projection (MIP) and
curved planner reformatting (CPR) are widely used for the creation of an accurate overview of the vascular system and to outline areas of abnormality for focused determination of pathologic findings (Kumamaru et al., 2010).

The study aim is to compare the sensitivity and specificity of duplex ultrasonography (DUS), and multi-detector computed tomography angiography (MDCTA) to diagnose upper extremity arterial disease.

PATIENTS AND METHODS

This is an observational cross-sectional study that was performed in the Department of Radio-Diagnosis, Zagazig University Hospital from April 2020 to April 2020 and included thirty (30) patients, ten females and twenty males. Their age ranged from 45 to 70 years.

All were suspected clinically to have vascular insufficiency (positional weakness, paresthesia, cold intolerance, pallor with associated loss of pulse).

Pregnant females, renal insufficiency cases (Serum creatinine above 1.5 mg/dl) and not on dialysis as well as a history of Hypersensitivity to IV contrast were excluded.

After taking informed consent, all patients in the study were submitted to the following:

1. Complete history taking: including previous vascular/cardiovascular surgeries, current medications or therapies, risk factors for an arterial disease is suspected such as Diabetes, Hypertension, Hyperlipidemia, Coronary artery disease, old age, smoking history or connective tissue disease such as Scleroderma

2. Physical assessment of the arms, hands, and fingers for symptoms of limb ischemia, skin changes (including duration, location, and whether it is persistent or episodic), gangrene, and/or ulcers.

3. Color Doppler ultrasound.

4. Multi-slice CT angiography.

Comparison of the results of Doppler and multi-slice CT angiography with conventional angiography if done or clinical follow-up.

INSTRUMENTATION

Doppler ultrasound was produced using the Siemens G40 colour Doppler USG machine (Germany).

A linear high-frequency transducer with usually utilised frequencies varying between 7-15 MHz. Lower frequencies or a low footprint transducer, though, may be used to delineate the chest region’s sources of the subclavian arteries.

First, the vessels were examined in the axial and longitudinal planes by greyscale B-mode then by colour doppler to visualise the wall and lumen of the vessel. Then by spectral Doppler at any suspected vessel to view the waveform and velocity.

Doppler spectral analysis is used to detect disease severity. Spectral Doppler waveforms were seen in a longitudinal plane parallel to the direction of the blood flow/vessel walls and at an angle of 60°.

The colour scale was set to a maximum mean velocity of about 30 cm/s. The angle was adjusted, and the least convenient sample volume was centred in the midstream of the luminal flow.

The gain was balanced before colour noise occurred in the neighbouring static tissues of the arterial surface. To accurately identify the arterial colour signal, the transducer was transverse to the arterial section with a 30° angle to the vertical axis.

Longitudinal scanning was then conducted by adjusting the angle pointer parallel to the lumen flow and positioning the Doppler sample gate in the lumen and to achieve the Doppler range and the peak systolic velocity (PSV) measurement.

A vessel documented to be expected when the normal tri-phasic velocity profile was obtained with a late diastolic reversal. Areas with higher blood velocities, biphasic or monophasic waveforms as well as reduced diameter were suspected.

The peak systolic velocity (PSV) was obtained from presumed stenotic areas of the investigated vessel, values were reported directly before, at, and only distal to the stenotic segment.

MDCT angiography

CT angiographic scanning was done by Philips Ingnenuity core 128™ v3.5.7.25001 (Philips healthcare systems) with 128 detector rows.

Parameters used are 16×0.75 mm detector collimation, the pit of 0.2-0.3, 0.39 s rotation time, a reconstruction slice width 0.6mm and increment 0.5 mm. The tube current was 300 + 40 mA at 120-140 kV—scanning direction; craniocaudal. Mean scan time was 12 seconds ± 1.5, and the total time for the examination was less than 10 minutes.
**Patient preparation**

Originally, laboratory reports were updated for patients with special concern in renal function testing.

Patients were advised to fast for four to six hours before the scan. However, they continued sufficient simple fluid intake up to three hours before the exam to ensure adequate hydration.

On the CT table, Patients were supine with the affected arm positioned raised over the head with the hand at the anatomical position, fingers straight and extended. The palm is facing ventrally except in trauma patients with pain and possible fractures where scanning is performed with patients arms by the side.

**Scan protocol**

1. An 18–20 gauge catheter was placed into a superficial vein within the antecubital fossa, forearm, or dorsum of the hand.

2. Saline injections were manually administrated at a high rate of flow before the injector administrated the contrast material.

3. CT angiography was performed following the target injection of about 120 ml of contrast medium at a flow rate of 3–4 ml/s. The contrast medium used was low osmolar nonionic contrast medium (Omnipaque 300 mg I/ml).

4. During the first twenty seconds of the acquisition, patients were required to hold breath and were permitted to breathe softly afterwards.

5. An initial scout image was obtained to determine the scan volume. After placement of a 20-gauge intravenous catheter in a vein in the antecubital fossa of the contralateral arm, a dynamic timing-bolus acquisition was performed.

6. Image acquisition is started when a threshold of 150 HU is reached with the ascending aorta marked as the region of interest.

7. Smart prep software was used to detect the delay time (time to peak of enhancement).

8. No adverse reactions were noted due to contrast material regarding extravasation or reaction. Despite that the procedure is completed within a single breath-hold (about 20 seconds); the total examination time was around 10–15 minutes.

**MDCT image analysis**

1. All images were transferred to the workstation (Philips Extended intellispace™ portal Workstation) for post-processing for the creation of alternative visualisations using curved planar reformations, volume rendering, and maximum intensity projections. Then, the images were subtracted from the original images to get a set of images without any osseous structures.

2. Sections reconstructed at 0.6 mm that is half the average thickness for better delineation of radiological findings.

3. Post-processing techniques as volume rendering (VR), three-dimensional maximum intensity projections (MIP) and curved planer reformations (CPR) were produced from different angles of views, mainly anteroposterior, lateral and both obliques, with a concentration on regions of inconsistent findings. Furthermore, following the radiological observations, more usage of specialised vessel analysis technologies was made.

4. All studies were interpreted for soft tissue and bone anatomy, arterial variants and anomalies and the presence of vascular disease. Several criteria were utilised to assess the suitability of CT angiography for routine use in upper extremity imaging such as images clarity and correlation with the intraoperative findings.

**CASES**

**Case (1)**

Hypertensive heavy smoker 60 years old male presented with pallor and numbness of the upper limb Figure 1.

**Case (2)**

Diabetic female 57 years old with acute pain and numbness in hand. Figure 2. Volume Rendering image and Ultrasound Doppler show complete abruption of radial artery at the mid-forearm and ulnar artery attenuation and occlusion just after its origin. DSA confirmed the diagnosis.

**Case (3)**

Hypertensive diabetic 65 years old female with weakness and paraesthesia of the arm Figure 3, showing short segment occlusion of brachial artery 3cm with a distal refill of last 8 mm of brachial artery of right distal brachial artery suggesting grade 4 stenosis. Distal reformation due to collateral formation from profound a brachii (chronic thrombosis).

**Case (4)**
Diabetic 59 years old male with a history of cardiac surgery Figure 4

Figure 1: MIP and volume Rendering images show abrupt filling defect denoting occlusion of the distal axillary artery

Figure 2: Volume Rendering image and Ultrasound Doppler

Figure 3: CT angiography Volume rendering and corresponding MIP image

Figure 4: Volume rendering image shows Complete Radial and Ulnar artery occlusion

Figure 5: Chart denotes that Doppler had a sensitivity of 86.7 %, and CTA has a sensitivity of 93.3 % for the diagnosis of thromboembolic cases

RESULTS

The age of the studied cases ranged from 45-70 years. Twenty were men, and ten were women. Regarding the side of the lesion, the right side was more commonly affected (Table 1)

Hypertension and Diabetes are the most common risk factors. Two patients were multi-factorial (Table 2). Most common sites were subclavian and Axillary arteries. Multiple vessels were affected in three cases (Table 3). CTA gave a better characterisation of stenosis, segmental thrombus length, recanalisation and detection of collateral circulation. However, Doppler sonography was more accurate in the detection of flow in a calcified segment as well as vessels distal to the wrist joint Table 4. Doppler US was able to correctly identify 26 out of 30 patients with thromboembolism (when the comparison is made with the gold-standard test; i.e., angiography). Doppler had a sensitivity of 86.7 % (Figure 5).

CTA was able to correctly identify 28 out of 30 patients with thromboembolism (when the comparison is made with the gold-standard test; i.e., angiography or surgery). CTA has a sensitivity of 93.3 % (Figure 5).

CTA was more sensitive in milder degrees (Grades I & II) of thromboembolism and stenosis but no significant difference in severe cases (Grades III & IV). Segmental length assessment and collateral circulation
Table 1: Data of the studied cases

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n=30</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>45-70</td>
</tr>
<tr>
<td><strong>No. of patients</strong></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>20</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
</tr>
<tr>
<td><strong>Percentage %</strong></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>66%</td>
</tr>
<tr>
<td>Female</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Side of the lesion</strong></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>18</td>
</tr>
<tr>
<td>Left</td>
<td>12</td>
</tr>
<tr>
<td><strong>Percentage %</strong></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>60%</td>
</tr>
<tr>
<td>Left</td>
<td>40%</td>
</tr>
</tbody>
</table>

Table 2: Risk factors of the studied group

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>No.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>12</td>
<td>40 %</td>
</tr>
<tr>
<td>Diabetes</td>
<td>11</td>
<td>36 %</td>
</tr>
<tr>
<td>Obesity</td>
<td>4</td>
<td>13 %</td>
</tr>
<tr>
<td>Smoking</td>
<td>5</td>
<td>16 %</td>
</tr>
</tbody>
</table>

Table 3: Sites of thromboembolism detected by CT angiography in comparison to interventional results

<table>
<thead>
<tr>
<th>Artery</th>
<th>No.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subclavian artery</td>
<td>8</td>
<td>26 %</td>
</tr>
<tr>
<td>Axillary artery</td>
<td>6</td>
<td>20 %</td>
</tr>
<tr>
<td>Brachial artery</td>
<td>9</td>
<td>30 %</td>
</tr>
<tr>
<td>Radial artery</td>
<td>5</td>
<td>16 %</td>
</tr>
<tr>
<td>Ulnar artery</td>
<td>6</td>
<td>20 %</td>
</tr>
</tbody>
</table>

Table 4: Validity of Doppler and CT in lesion characterisation

<table>
<thead>
<tr>
<th></th>
<th>CD US</th>
<th>CTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stenosis</td>
<td>94%</td>
<td>96%</td>
</tr>
<tr>
<td>Segmental length</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>Recanalisation</td>
<td>100%</td>
<td>92%</td>
</tr>
<tr>
<td>Collateral circulation</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>Flow in a calcified segment</td>
<td>100%</td>
<td>90%</td>
</tr>
<tr>
<td>Distal and hand vessels</td>
<td>100%</td>
<td>90%</td>
</tr>
</tbody>
</table>

was better noted on CT Angiography. Doppler was unable to recognise stenosis in two acute patients because of associated oedema & obesity, resulting in 86.6 % sensitivity. However, Doppler is more appreciated than CTA in the flow-related assessment of calcified segment, plaques, thrombosis and evaluation of recanalisation as well as distal vessels evaluation.

**DISCUSSION**

In this study, we compare two non-invasive modalities which are being readily accessible nowadays. In all patients colour, Doppler sonography and multidetector CT angiography were done. A comparative study of their diagnostic efficacy was undertaken.

After a preliminary physical examination, colour Doppler ultrasonography is mostly indicated as a cost-effective initial diagnostic modality. Ultrasonic studies include details of nature, the intensity of the
disorder, thrombosis, soft tissue plaques, Segmental length, Recanalization, Collateral circulation.

The few constraints being operator dependent as well as time consumption, soft-tissue oedema and obese patients (Kumamaru et al., 2010).

On the other side, CT angiography is minimally invasive and Multiplanar reconstruction aids in the imagining of stenoses segment length, collateral circulation and better arterial tree replication. But often includes the potential possibility of allergic reactions and sensitivity to radiation exposure as well as renal disorders limitation (Mohler and Giri, 2008).

The age of the studied cases ranged from 45–70 years with mean years. Sixteen were men and twenty were women. Regarding the most common side of lesions was the right side (%) relative to the left side (%).

Doppler US was able to correctly identify 26 out of 30 patients with thromboembolism (when the comparison is made with the gold-standard test; i.e. angiography or surgery). Doppler couldn’t recognise stenosis in two acute patients because of soft tissue oedema and patient obesity. Overall, the present study shows that Doppler US has a sensitivity of 86.6%, a specificity of 100%, PVP of 100% and PVN of 91.3%.

Chidambaram et al. (2016) the study reported overall sensitivity, specificity, and accuracy of Doppler USG compared with CTA were 93.36%, 82.44%, and 86.42%, Chidambaram et al. (2016) stated that Doppler could be the first examination in excluding ischemic arterial disease, in particular for assessment from the second portion of the subclavian artery.

Dev et al. (2018) stated sensitivity, specificity and accuracy of colour Doppler US as equated to CTA was 91%, 87% and 89% respectively.

On the other hand, CTA was able to correctly identify 28 out of 30 patients with thromboembolism (when the comparison is made with the gold-standard test; i.e. angiography or surgery). CTA failed to detect thrombosis in one case due to calcification artefact. CTA in the present study has a sensitivity of 93.3%, a specificity of 100%, PVP of 100% and PVN of 95.45%.

In both MIP and VR images, areas of significant wall calcification portentous stenosis observed on CT angiography were hard to determine. This was also reported by Dev et al. (2018) who favoured supplementary imaging in the type of Digital Subtraction angiography, especially when seeking interventional therapy or MR angiography.

On the descriptive correlation of Doppler with CTA, Segmental length assessment and collateral circulation were better noted on CT Angiography.

The explanation for the difference may be that the area of colour flow in the lumen is underestimated in such lesions because flow velocities close to the arterial wall were below the sensitivity of the device as well as low PSV values in the long stenotic segment compared to high values in the short stenosis segment (Huh et al., 2016).

On the contrary, CDUSG scored over CTA in the flow-related assessment of calcified segment, plaques and evaluation of recanalisation and distal vessels evaluation.

CONCLUSION

CTA was more sensitive than Doppler sonography in the diagnosis of milder degrees (Grades I & II) of thromboembolism and stenosis. Still, no significant difference was detected between the two modalities in severe cases (Grades III & IV).

Funding Support

The authors declare that they have no funding support for this study.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

REFERENCES


