Upper limb DVT after hemodialysis AVF creation: Role of CT venography

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Abstract Objective: The aim of this study was to assess the role of CT venography (CTV) in diagnosis of upper limb deep venous thrombosis (DVT) after arterio-venous fistula (AVF) creation for patients with chronic renal failure (CRF) under regular hemodialysis. Patients and methods: During two years duration 22 patients with upper limb hemodialysis arterio-venous fistulas suspected to have deep venous thrombosis were prospectively evaluated. All patients underwent CTV examinations following a preset protocol. The images obtained were reconstructed using dedicated software and workstations. Results of CTV examinations were compared with those of Color Doppler (CD) examinations. Results: Out of 22 examined cases, 20 cases (90.9%) had autogenous AVF and 2 cases (9.1%) had synthetic grafts. Diagnosis of proximal upper limb segment DVT including brachial, axillary and subclavian veins recorded 12 TP (54.5%), 8 TN (36.4%), 2 FP (9.1%) and no FN cases. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were 100%, 80%, 85.7% and 100% respectively. Diagnosis of central venous segment DVT including innominate veins and SVC recorded 14 TP (63.6%), 8 TN (36.4%) and neither FP nor FN cases. Sensitivity, specificity, PPV and NPV were 100%, 100%, 100% and 100% respectively. Conclusion: CTV has a major role in diagnosis of deep venous thrombosis particularly the central innominate veins/SVC segment after upper limb AVF creation for patients with CRF under hemodialysis.

1. Introduction

A well functioning access is integral to the delivery of adequate hemodialysis. The most preferred vascular access is the arterio-venous fistula (AVF) followed by the arterio-venous graft (AVG). Deep venous thrombosis is a commonly recognized complication. It leads to devastating long-term consequences including poor dialysis delivery caused by recirculation and superior vena cava (SVC) syndrome (1).

The incidence of central venous steno-occlusive disease in hemodialysis patients is a common and significant problem,
which has been reported in the literature to be in the range of 25–40% (2).

This can result in the loss of the access site, increased venous pressure on the dialysis machine and arm swelling due to venous hypertension (3).

Upper extremity deep vein thrombosis has the potential for considerable morbidity in the form of pulmonary embolism (4).

Conventional venography (CV) still remains the gold standard for the diagnosis of upper extremity deep venous thrombosis/occlusion. However, owing to its invasive nature, risk and complication profile, as well as operational costs, CV is not well suited to be a screening procedure. Hence, various non-invasive methods such as ultrasonography and Color Doppler are still being used to detect upper limb DVT. Demonstration of the role and value of another noninvasive method such as CTV as an alternative diagnostic imaging tool is must. Multidetector spiral CTV with reconstructions (3D coronal MPR, 3D-MIP and 3D-SSD) is an ideal minimally invasive technique allowing rapid and accurate assessment with venous mapping in reference to adjacent skeletal anatomy (5).

Advantages of CTV include non-invasiveness, time and cost-efficiency, lower complication profile, demonstration of extra luminal anatomical structures that could be the cause of extrinsic venous compression and the visualization of not only the lumen but also the wall of the vein (5).

Interventional radiologic measures are the primary treatments of choice in benign central venous obstruction e.g. venous catheters and high-flow states associated with hemodialysis access fistulas, while the primary treatment for SVC in patients with malignant disease is radiation therapy. The presence or absence of venous obstruction, and its cause, location, degree, and extent are thus important for the planning of treatment (6).

2. Patients and methods

2.1. Patients

A prospective study of 22 patients aged 25 to 67 years (with mean age of 43 years) on regular hemodialysis using upper limb surgically created arterio-venous fistulas (AVF) presenting to a private specialized medical center with an initial diagnosis of deep venous thrombosis (DVT) after performing Color Doppler study coming for confirmation between January 2014 and January 2016 was performed.

There were no set criteria for referral other than prior history of autogenous or synthetic arterio-venous fistula creation. Patients had clinical evaluation including medical history. Information regarding types of accesses, time of operations and occurrence of complications was obtained from all cases.

2.2. Methods

Multidetector spiral CTV was carried out with an Aquilion One 320 scanner (Toshiba Medical Systems, New York, USA), with tube potential set at 120 kV, current at 300 mA, collimation at 3 mm and table movement at 5 mm/s. Two 20-gauge cannulas were placed one at each limb in a dorsal vein of the hand, with the arms positioned along the patient’s sides. Total amount of 150 ml of 50% diluted (with normal saline) non ionic contrast material (iopromide, 300 mg iodine per ml, Ultravist 300; Schering AG, Berlin, Germany) was injected at each upper limb with an automatic injector at a flow rate of 3 ml/s. An operator initiated (> 120 HU) Smartprep trigger was used to begin scanning from the level of the lower neck down to the hand following visualization of contrast within the superior vena cava (SVC). An extra session of hemodialysis was arranged on the same day few hours after the examination.

2.3. Data analysis and interpretation

The raw data were reconstructed using special software and workstations including interactive viewing of multiplanar

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Deep venous thrombosis in different segments, n (%)</th>
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<tr>
<td>Subgroups</td>
<td>True positives</td>
</tr>
<tr>
<td>1. Proximal upper limb venous segment</td>
<td>12(54.5%)</td>
</tr>
<tr>
<td>2. Central venous segment</td>
<td>14(63.6%)</td>
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Fig. 1 45 years old male patient with past history of right radiocephalic and left brachio-basilic AVFs. 3D VR images showing patent and opacified both deep brachial and axillary veins. Non opacified both subclavian and innominate veins. SVC is not opacified and appears replaced by thread like hypodense line, likely secondary to chronic thrombosis. Multiple irregular venous collaterals are seen along the anterior and lateral chest and abdominal walls drained by inter costal and internal mammary veins. Some collaterals extend caudally to be drained by femoral and iliac veins to opacify the inferior vena cava.
reconstruction images in axial source, 2D coronal maximum intensity projections (MIP), 3D MIP and volume rendering (VR) reconstructions.

All images were performed and evaluated by one staff radiologist with expertise in angiographic imaging.

3. Results

Out of 22 cases examined 20 cases (90.9%) had autogenous AVF and 2 cases (9.1%) had synthetic grafts.

The presence of deep venous thrombosis was subdivided into two subgroups: 1. proximal upper limb venous segment including brachial, axillary and subclavian veins and 2. central venous segment including innominate veins and superior vena cava.

Regarding the first subgroup there were 12 true positives (54.5%), 8 true negatives (36.4%), 2 false positive (9.1%) and no false negative cases (Table 1). Sensitivity, specificity, positive predictive value and negative predictive values were 100%, 80%, 85.7% and 100% respectively.

The true positive patients showed evidence of deep venous thrombosis of the brachial vein (Fig. 5), axillary veins (Figs. 3–5 and 7) and subclavian veins (Figs. 1 and 3–6). One synthetic applied brachio-subclavian graft was occluded (Fig. 5).

The true negative patients had patent and well opacified veins with no evidence of thrombosis (Fig. 2).

The false positive case occurred in 2 patients who showed non opacified segments in CTV interpreted as occluded segments and turned out to be patent on CD examination (Fig. 7).

Regarding the second subgroup there were 14 true positives (63.6%), 8 true negatives (36.4%) and neither false positive nor false negative cases (Table 1). Sensitivity, specificity, positive predictive value and negative predictive values were 100%, 100%, 100% and 100% respectively.

The true positive patients showed evidence of deep venous thrombosis of the innominate veins (Figs. 1–3 and 6) and SVC (Figs. 1–3). One synthetic applied left innominate vein/superior vena cava synthetic graft was occluded (Fig. 6).

The true negative patients had patent and well opacified innominate veins and SVC with no evidence of thrombosis (Figs. 4–7).

The network of venous collaterals created secondary to superior vena cava obstruction included anterior/lateral chest

Fig. 2 52 years old male patient with past history of bilateral brachio-basilic AVFs. 3D VR image showing patent deep venous systems of both upper limbs with opacified brachial, axillary and subclavian veins and no thrombosis. The right innominate vein is markedly attenuated and the left innominate vein is partially opacified with hypodensities partially occluding its lumen. SVC is totally occluded. Multiple irregular collaterals are seen along the lateral and posterior chest walls, more numerous on the left side drained via the para vertebral venous plexuses till the hemi azygos and azygos veins. Both external and common iliac veins are filled via collaterals sharing in the venous drainage of the upper limbs to be finally drained into IVC.

Fig. 3 31 years old female patient with past history of left upper limb brachio-basilic AVF. 3D VR image showing patent both brachial and right axillary veins with no evidence of thrombosis. Non opacified left axillary and bilateral subclavian veins. Non opacification of both innominate veins and SVC. Multiple dilated and tortuous collateral superficial veins are seen along the anterior and lateral chest walls. Hypertrophied epigastric, inter costal and internal mammary veins. Filling of the azygos and hemiazygos veins is noted.
walls in 12 cases (85.7%), internal mammary veins in 6 cases (42.9%), paravertebral/azygos vein in 6 cases (42.9%), iliac veins/IVC in 8 cases (57.1%) and porto-systemic collaterals in 2 cases (14.3%) (Table 2).

4. Discussion

The presence of high blood flow from arterio-venous fistulas and central venous catheter is a major cause of benign thoracic central venous occlusion (7). Central venous stenoses or occlusions in patients undergoing hemodialysis are thought to originate from high-flow states, and occur at sites of turbulence such as valves (7), and injury due to the insertion of a temporary dialysis catheter has also been recognized as a risk factor for central venous obstruction (8).

Color Doppler is non-invasive and does not require nephrotoxic contrast agents. Furthermore, it can be performed at the bed-side and is widely available. This would make it an ideal method for the diagnosis of upper extremity thrombosis. Major advantage of CD is that the distal subclavian vein, axillary vein and the upper arm veins are easily visualized, but a drawback is the lack of visualization of the proximal subclavian vein, the innominate and SVC beyond the clavicle and sternum (9).

Advantages of CTV over US/CD (ultrasound/color Doppler) include less operator dependency, better visualization of extra luminal pathology and ease of referencing to adjacent skeletal anatomy. Given the relative anatomical complexity of the upper limb and axilla, and the inability to demonstrate compression of the large upper limb veins (axillary and subclavian veins) on US/CD, CTV will be superior to US/CD in the diagnosis of upper extremity deep venous thrombosis (UEDVT), and depending on clinical suspicion and circumstance, it may be appropriate as a first-line investigation (5).

The superiority of CTV seems to be related to the ability to evaluate the proximal extent of obstruction or thrombosis, great contrast resolution and ability to provide 3D images at any desired viewing angle (10).

Fig. 4 47 years old male patient with past history of right upper limb brachio-basilic AVF. 3D VR image showing occluded right brachial, axillary and subclavian veins. Multiple irregular collaterals are seen along the anterior and lateral chest walls draining into the internal mammary veins. Patent deep venous system of the left upper limb including brachial, axillary and subclavian veins. Patent SVC with no evidence of thrombosis.

Fig. 5 61 years old female patient with past history of right upper limb brachio-subclavian synthetic graft. 3D VR image showing multiple dilated and tortuous superficial venous collaterals is seen along the forearm as well as anterior aspect of the shoulder, right anterior chest wall and right supraclavicular region. The brachial, axillary and subclavian veins are not opacified. The applied graft (arrows) is completely occluded by hypodense thrombus. The innominate vein is fibrosed and not opacified. SVC is patent with no evidence of thrombosis.
CTV is an excellent, minimally invasive method to diagnose UEDVT, especially in patients with a negative CD result and a high index of clinical suspicion (5).

Baarslag et al. (11) stated that CD has a sensitivity and specificity of only 82% in the diagnosis of UEDVT a finding that was confirmed by Henk and colleagues (9). The current study recorded a total of 91% true positive and negative cases regarding proximal segment thrombosis and a total of 100% true positive and negative cases regarding central venous segment thrombosis. This matches with results of Qanadli et al. (12) who reported that 21 out 23 cases (91.3%) were technically optimal with a total of 91.3%.

The present study included 2 out of 22 cases (9.1%) that were reported as axillary vein thrombosis and proved to be patent by CD examination findings that were considered as false positive cases. This percentage was higher than that of Qanadli et al. (12) who reported that 1 out 23 cases (4.3%) had flow artifacts and was misinterpreted as intra luminal thrombus. This could be related to amount and rate of contrast injection used throughout the study as the protocol of this study was settled on an amount of 150 ml and rate of 3 ml/s while they used 120 ml of contrast injected with a rate of 2 ml/s.

CTV venography suffers certain technical limitations. In patients with central venous obstruction and severe edema of the upper extremities venous puncture may be difficult. Fur-

### Table 2

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<thead>
<tr>
<th>Types of collaterals</th>
<th>n</th>
<th>%</th>
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<tr>
<td>Anterior/lateral chest walls</td>
<td>12</td>
<td>85.7</td>
</tr>
<tr>
<td>Internal mammary veins</td>
<td>6</td>
<td>42.9</td>
</tr>
<tr>
<td>Paravertebral/azygos vein</td>
<td>6</td>
<td>42.9</td>
</tr>
<tr>
<td>Iliac veins/IVC</td>
<td>8</td>
<td>57.1</td>
</tr>
<tr>
<td>Porto-systemic collaterals</td>
<td>2</td>
<td>14.3</td>
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### Fig. 6

42 years old male patient with past history of bilateral upper limbs repetitive AVFs. 3D VR image showing patent right brachial, axillary and subclavian veins. Non opacified left brachial vein. Opacified distal part of the axillary vein as well as the subclavian vein showing attenuated caliber. The most distal part of the left subclavian vein is markedly attenuated in caliber. The right innominate vein is not opacified. The applied left innominate vein/superior vena cava synthetic graft (arrow) is faintly opacified. The left innominate vein shows faint opacification. Patent opacified left internal jugular vein. Multiple irregular collaterals are seen along left anterior, bilateral lateral and posterior chest walls filling the para vertebral venous plexus and azygos vein. Refilling of the most distal part of the SVC. Refilling of iliac veins and IVC via anterior abdominal walls venous epigastric collaterals.

### Fig. 7

30 years old male patient with past history of left upper limb brachio-basilic AVF. 3D VR image showing markedly attenuated distal part of the left axillary vein. Patent and normal caliber of the left subclavian vein with no evidence of thrombosis. Patent right upper limb deep venous system including brachial, axillary and subclavian veins. Patent both innominate veins and SVC.

Baarslag et al. (11) stated that CD has a sensitivity and specificity of only 82% in the diagnosis of UEDVT a finding that was confirmed by Henk and colleagues (9). The current study recorded a total of 91% true positive and negative cases regarding proximal segment thrombosis and a total of 100% true positive and negative cases regarding central venous segment thrombosis. This matches with results of Qanadli et al. (12) who reported that 21 out 23 cases were technically optimal with a total of 91.3%.
ther problems which may take place are beam-hardening artifacts due to the inflow of contrast and flow artifact due to the inflow of unopacified blood. In order to overcome these problems, diluted contrast material was used with scan delay time as long as possible.

In conclusion, CTV provides accurate information about the site, cause and extent of upper limb DVT and is thus a useful imaging modality for the diagnosis and treatment of peripheral and particularly central venous thrombosis after AVF creation in CRF patients on regular hemodialysis.

Conflict of interest

We have no conflict of interest to declare.

References