Deep venous thrombosis
Comparison of indirect multidetector CT venography and sonography of lower extremities in 26 patients

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Abstract

Objective: To compare the accuracy of indirect multidetector row computed tomographic (MDCT) venography with lower extremity venous sonography for the diagnosis of femoropopliteal deep venous thrombosis (DVT), and to determine the frequency and location of DVT at MDCT venography. Materials and methods: Twenty-six consecutive patients suspected of having pulmonary embolism (PE) underwent both combined MDCT venography and MDCT pulmonary angiography and lower extremity venous sonography. Indirect MDCT venography was acquired from the upper calves to the mid-abdomen following MDCT pulmonary angiography. The CT venographic findings were compared with those of sonography for the diagnosis of femoropopliteal DVT. All CT scans were also reviewed for the frequency and location of DVT. Results: Indirect MDCT venography disclosed DVT in 19 patients, and 12 of whom also had PE. Seventeen patients with thrombosis in the femoropopliteal veins were identified in both indirect MDCT venography and sonography. The sensitivity and specificity of indirect MDCT venography as compared with sonography, were both 100%. In one patient DVT in the superficial femoral vein was detected using only indirect MDCT venography. MDCT venography also showed superior extension of femoropopliteal DVT to the inferior vena cava and iliac veins in four patients and thrombosis isolated to the inferior vena cava and common iliac vein thrombosis in one patient. Conclusions: Indirect MDCT venography is as accurate as sonography in the diagnosis of femoropopliteal DVT. MDCT venography can further reveal thrombus in large pelvic veins and the inferior vena cava, an important advantage over sonographic screening for DVT.

Keywords: Lower extremities; Deep vein thrombosis; MDCT venography; Sonography; Pulmonary embolism

1. Introduction

Deep venous thrombosis (DVT) is considered the third most common acute cardiovascular disease after ischemic heart disease and stroke: affecting millions of people worldwide [1,2]. Acute DVT results in many complications including pulmonary embolism (PE), post-thrombotic syndrome, and chronic pulmonary arterial hypertension. In the United States alone, the progression of DVT into PE has resulted in 50,000–100,000 deaths annually [3]. DVT of the lower extremities is believed to be the source of PE in most patients, and the primary risk factor for recurrent PE is the presence of residual proximal venous thrombosis [4,5]. Therefore, prompt and accurate diagnosis of DVT is essential for appropriate treatment.

Conventional venography, widely accepted as the best test for detection of lower extremities DVT, is invasive and therefore is less routinely used. Sonography, a noninvasive test and involving no radiation and contrast material, has replaced conventional venography in the investigation of patients with suspected DVT. Because DVT and PE are different aspects of the same disease, a single study that can accurately evaluate both diseases would be desirable and presumably cost effective. A 1998 study describes...
combined CT venography and pulmonary angiography (using single-detector row CT scanner), a procedure that can be performed for a complete evaluation of both PE and DVT [6]. This test consists of indirect CT venography examination of the pelvis veins and deep veins of the lower extremities after CT pulmonary angiography. Advantages of indirect CT venography are that it requires no additional intravenous contrast material, only one venopuncture is needed, little extra time is required (only 5–7 min), and it is technically simple. Several studies have demonstrated that indirect CT venography using single-detector CT scanner with variable protocols is accurate for detection of femoropopliteal DVT when compared with lower extremity venous sonography (LEVS) [7–10]. More recently, the used of indirect multidetector row computed tomographic (MDCT) venography of the lower extremities was reported [11].

The objective of this study was to compare the accuracy of indirect MDCT venography (using a four-channel multidetector scanner with thinner sectional intervals) with that of LEVS in the diagnosis of femoropopliteal DVT, and to determine the frequency and location of DVT.

2. Materials and methods

Twenty-six consecutive patients (13 men and 13 women aged 28–82 years; mean age 60 years) suspected of having PE underwent both combined CT venography and pulmonary (CTVPA) and LEVS. No patient underwent conventional venography. All the patients had hypoxemia and presented with dyspnea or increasing shortness of breath or chest pain, and 12 patients had leg swelling. No patient had renal insufficiency, history of allergy to contrast material, and unstable hemodynamic status. This study was approved by our institutional review board, and informed consent was obtained from each patient after the nature of the procedure had been explained fully.

MDCT was performed on a four-channel multidetector row helical CT (MDCT) scanner (LightSpeed QXi; GE Medical systems, Milwaukie, WI) with patients in the supine position, feet elevated to avoid calf compression. A nonmetallic table extender supporting the lower legs was used. Before the administration of contrast material to each patient, a scout CT image for localization of subsequent fast acquisition images was performed. Helical MDCT of the pulmonary arteries was performed from the diaphragm to 2 cm above the aortic arch with the following parameters: collimation of 1.25 mm in fast mode, a table speed of 7.5 mm per gantry rotation, and a pitch of 6.0. All patients received 120 ml of undiluted nonionic contrast material (Optiray [joversol] 350 mg I/ml; Millinckrodt, Pointe-Claire, Quebec, Canada), which was administered by means of a power injector through a 18- or 20-gauge intravenous catheter in the antebrachial vein, at a flow rate of 3 ml/s with a delay of 20–25 s before scanning. The patients were instructed to hyperventilate for three breaths and to hold their breath for the duration of the study. If they were unable to do so, they were instructed to breathe as quietly as possible. Two patients were under mechanical ventilation during scanning and were imaged on quiet respiration. Indirect MDCT venography scanning from the upper calves to the mid-abdomen started 3 min after the beginning of contrast material injection, with a 4×2.5-mm collimation and a 7.5-mm/s table speed, using a pitch of 3. Five-millimeter-thick images were reconstructed with a 5-mm interval. This delay of 3 min was chosen according to the results reported by previous investigators [11–13]. Depending on the height of the patient, approximately 250–300 venous images were typically acquired. Each MDCT venography took approximately 80–90 s. The total MDCT venous examination time (including scanner programming,
image, acquisition, and 3 min delay time) is approximately 5 to 7 min to CTPA.

The axial CT venous images of all patients were retrospectively reviewed by two of three radiologists blinded to sonographic results. They interpreted the CT scans together, and conclusions were reached by consensus. CT images were reviewed on a digital workstation. The deep veins were assessed from the inferior vena cava to the popliteal veins. Criteria for diagnosis of acute DVT are the presence of an intraluminal filling defect in an opacified vein, or a localized nonopacified venous segment on at least two consecutive axial CT images if the vein distal and proximal to the nonopacified segment was opacified. The criterion used to exclude DVT was uniform enhancement in a vein. Additional findings suggestive of DVT are venous dilatation with filling defect, wall enhancement, and perivenous fat stranding. The frequency and location of DVT were also recorded in all patients.

Bilateral LEVS (from the upper calves to the inguinal level), which was used as the standard of reference for diagnosis of femoropopliteal DVT, was performed in all patients before or after indirect MDCT venography but within a 12-h period of CT (mean, 3 h), using standard compression and Doppler techniques. Residents, fellows, and attending cardiologists experienced in evaluating the LEVS performed the examinations. One of the authors experienced in venous sonography reviewed the sonographic reports independently, and findings were correlated with CT scans. For each extremity, the report was reviewed for the presence of acute DVT in the common femoral vein, superficial femoral vein, deep femoral vein, and popliteal vein. The diagnostic criterion for DVT was noncompressibility of the affected deep veins. A lack of flow at Doppler examination was used as a supportive evidence of DVT.

Sensitivity and specificity values from MDCT venography for femoropopliteal DVT evaluation, compared with LEVS, were calculated. Cases with MDCT depicted DVT isolated to the inferior vena cava and/or iliac veins were excluded from these calculations, as sonography of these areas was not performed.

3. Results

The level of enhancement in the deep venous system of helical CT venous phase imaging was adequate to determine the presence or absence of DVT in all patients. No complications arose from the combined indirect MDCT venography and MDCT venography and MDCT of the pulmonary arteries studies.

Among 26 patients examined, indirect MDCT venography disclosed DVT in 19 patients (73%) and no DVT in 7 patients who had PE. Among all patients with DVT, 12 patients also had PE. Seventeen patients had involvement in the femoropopliteal venous system, detected by indirect MDCT venography and confirmed by sonography (Fig. 1). The sensitivity and specificity for femoropopliteal DVT in indirect MDCT venography was 100% when compared with sonography.

One patient had a small nonocclusive thrombus in the left superficial femoral vein that was found by the indirect MDCT venography but was negative at sonography. This patient had received an operation with an internal fixation for femoral shaft fracture one week prior. One patient had isolated inferior vena cava and left common iliac vein thrombosis that was detected by MDCT venography. In four patients, the lower extremity DVT was shown by indirect MDCT venography to extend proximally to the pelvic veins and inferior vena cava. Among these patients, two had extension to the external iliac vein (Fig. 2).

Among all patients with DVT in the lower limbs and pelvic veins, there was unilateral involvement in 18 patients and bilateral involvement in only one patient. The left side was involved in 13 patients, the right side was involved in

Fig. 2. Transverse CT venogram in a 74-year-old man with deep vein thrombosis. (a) CT image at the inguinal level shows thrombus in the left common femoral vein (arrow). (b) CT image at the upper pelvis shows thrombus in the left external iliac vein.
5 patients, and there was bilateral involvement in 1 patient. The distribution of DVT in these patients was as follows: inferior vena cava in 2 patients, iliac veins in 4 patients, deep femoral vein in 7 patients, superficial femoral vein in 15 patients, common femoral vein in 9 patients, and popliteal vein in 6 patients.

4. Discussion

DVT is a common disease and can result in fatal PE. Most pulmonary emboli are due to thrombus arising from the veins of the lower extremities and pelvis, and the primary risk for recurrent PE is believed to be residual DVT in the proximal veins [4,5]. Because of its availability, minimal invasiveness, rapid completion time, technical simplicity, assistance in evaluating other causes of a patient’s thoracic symptoms, helical CT pulmonary angiography has emerged as an initial test in the investigation of patients suspected of having PE, but follow-up assessment of DVT in the extremities is frequently necessary if CT pulmonary angiography does not show PE.

Several imaging modalities are available for diagnosis of lower extremities DVT. Conventional venography has been regarded as the gold standard technique for diagnosing DVT. This technique allows direct imaging of the inferior vena cava and deep veins of the calf, thigh, and pelvis. However, it is invasive and time-consuming, associated with postprocedure phlebitis, does not visualize the deep femoral veins adequately, and may be technically inadequate in 5–10% of the studies [14,15]. Magnetic resonance imaging may also be a promising noninvasive tool in the diagnosis of DVT, but is expensive, has long examination times, and is often difficult in acutely ill patients [16]. Direct CT venography of the lower extremities was a good alternative in the detection of DVT, however, the examination required venous puncture of both feet and an injection of contrast medium through each, and flow artifacts may occur [17,18]. Sonography, owing to its high accuracy, noninvasiveness, speed, portability, and the fact that it does not require radiation or contrast material, has largely supplanted conventional venography in imaging the deep venous system of the thighs for thrombosis. It has high accuracy in symptomatic proximal DVT. It is unreliable for diagnosing small nonocclusive, asymptomatic, and recurrent DVT, as well as thrombus below the knee and above the inguinal ligament. Furthermore, it is an operator-dependent test and may present difficulties in patients with massive edema, wounds, or obesity, or in patients who are intubated.

Indirect CT venography has been compared with LEVS for the diagnosis of femoropopliteal DVT in several studies [7–10,19,20]. The sensitivity and specificity values of indirect CT venography in these studies ranged from 89% to 100% and 94% to 100%, respectively [9,10,19,20]. Cham et al. [10] demonstrated that, of the 116 patients with sonographic correlation, 15 had DVT that was found at both indirect CT venography and sonography, and 4 other patients had thrombus correctly identified in the CT venography that was initially missed by sonography. In Loud et al.’s [9] study of 308 of patient who had sonographic correlation, indirect CT venography was 97% sensitive and 100% specific for DVT in the thighs, and 4 patients had initially negative results from sonography and positive findings from CT venography, but repeated sonography helped to confirm the presence of DVT. More recently, Begemann et al. [11] obtained a sensitivity of 100% and a specificity of 96.6% in detecting DVT using MDCT venography in comparison with Doppler sonography. In our study, the sensitivity and specificity of indirect MDCT venography for diagnosing femoropopliteal DVT were similar to or even better than these previous results. As there was excellent correlation between indirect CT venography and LEVS, LEVS could be replaced by indirect CT venography for the evaluation of DVT in the thigh whenever CT pulmonary angiography is indicated.

In the present study, seven patients with DVT in the absence of PE were detected by indirect MDCT venography. The benefit of indirect CT venography after CT pulmonary angiography is understandable in this aspect, as no additional sonography is required to assess the deep venous system, which can result diagnostic delay. It is possible that subsegmental pulmonary emboli in some of these patients remained undetected in CT pulmonary angiographic studies. Previous studies demonstrated technically suboptimal CT pulmonary angiographic studies, in the range of 3% to 10% [21,22].

The high frequency (73%) of DVT in this study, as opposed to the results in the previously reported literature [9,23,24], may be a consequence of a small sample size and because only those patients with sonographic examinations were recruited. Katz et al. [23] reported an overall rate of 10.5% of DVT in 957 patients in their series, with equal distribution of DVT at the common femoral vein, superficial femoral, popliteal, and deep calf veins. In the present study, the distribution of the thrombus was higher in the superficial femoral vein, with almost equal distribution in the common femoral vein, deep femoral vein, and popliteal vein. Isolated thrombus was seen in two patients, one in the superficial femoral vein, and another in the pelvic vein and inferior vena cava, which may represent fragments of previously larger clots that have migrated cranially from the calf veins.

Among 26 patients examined, five patients (19%) had pelvic veins and inferior vena cava DVT (four patients had also femoropopliteal DVT and one patient had isolated thrombus in the inferior vena cava and pelvic vein). The incidence of inferior vena cava and pelvic involvement of DVT in our study was comparable with reported rates of incidence, which range from 7% to 30% [25,26]. Although isolated to pelvis vein and inferior vena cava clots are reported in these studies as between 0.5% and 4%, there is potential risk of recurrent PE even when no distal DVT has been found [9,10,27–29]. Consequently, indirect CT
venography not only has high accuracy in the detection of femoropopliteal DVT, it also provides information on the large pelvic veins and inferior vena cava, areas often poorly accessible to sonography. The ability to detect clots in these areas by indirect CT venography is useful for baseline follow-up as well as when inferior vena caval filter placement is considered.

In this study, there were no false-negative CT venograms. This may be because a narrower scan interval of 5 mm was used. In their study, Loud et al. [9] reported two false-negative CT venograms as the result of using 5-cm scan intervals [9]. Although the number of images is increased with narrow scan intervals, there is no much increased in the examination times when a faster MDCT scanner is used. In the present study, a small nonocclusive clot in the superficial femoral vein in one patient was detected with indirect MDCT venography, despite beam hardening artifacts from orthopedic hardware. The reason for negative study at sonography in this case may be because of a small nonocclusive thrombus and compressibility difficult in the leg. Garg et al. [8] reported that the sensitivity of compression sonographic screening for proximal DVT is only 62% in patients with orthopedic hardware, while a tiny nonocclusive clot in the left superficial femoral vein was disclosed only on CT venography. Therefore, in patients with orthopedic hardware, indirect CT venography may be capable of detecting a small nonocclusive clot.

In present study, two of our patients are intubated. Images of MDCT pulmonary angiography in these patients were degraded by breathing artifacts causing difficulty to assess peripheral pulmonary arteries. Although no PE in central pulmonary vessels was shown, indirect MDCT venography nevertheless revealed DVT in the thigh. Garg et al. [8] also reported that indirect CT venography was useful in intensive care unit patients who are intubated for diagnosis of proximal DVT. As it is difficult to evaluate leg symptoms in this subgroup of patients, knowing the condition of deep venous system in their lower extremities and pelvis provided by CT venography may be of help in the assessment of venous thromboembolic disease, even in the presence of undiagnostic CT pulmonary angiography study, because the treatment of either PE or DVT is the same. Performing sonography studies of lower extremities in intubated patients is challenging and time-consuming because of lack of mobility of these patients.

According to previous studies [20,30], indirect CT venography can demonstrate not only DVT but also additional nonvenous pathology in the abdomen, pelvis, and lower extremities. These diagnoses range from very serious to incidental findings, and cannot be obtained by the other currently used screening method for DVT. Thus, this is another advantage of CT venography in these patients. In our series, the most common nonvenous pathology diagnoses included hydrouretrius due to ureteral stone (n = 1), liver cyst (n = 2), right ovarian cyst (n = 1), baker cyst (n = 2), and renal atrophy (n = 1).

This study has several limitations. First, it is a retrospective study and contains a small sample size. Second, the choice of sonography as the reference standard may also be considered as a limitation of our study because sonography is less than 100% accurate [31,32]. However, in clinical practice, conventional venography has been completely replaced by sonography, therefore indirect CT venography for leg vein evaluation still has to be compared with sonography. Also, comparison of indirect CT venography with conventional venography, the gold standard for evaluation of lower-extremity DVT, would provide more complete confirmation of CT venographic results but would require additional venopunctures and contrast material injection.

In conclusion, indirect MDCT venography is as accurate as sonography in detecting femoropopliteal DVT. Additionally, MDCT venography also depicts DVT in the pelvis veins and inferior vena cava, regions where sonography is seldom performed routinely. Indirect CT venography could be widely recommended when CT pulmonary angiography is indicated. Indirect CT venography following CT pulmonary angiography simplifies and expedites the thromboembolism work-up.

5. Summary

The accuracy of indirect MDCT venography with LEVS for the diagnosis of femoropopliteal DVT in 26 patients was compared. The sensitivity and specificity of indirect MDCT venography for femoropopliteal DVT, as compared with sonography, were both 100%. Indirect MDCT venography is as accurate as sonography in the diagnosis of femoropopliteal DVT.

References