Re-Evaluation of Body Weight as an Indicator for Contrast Material Dosage for Indirect CT Venography

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Objective: We evaluated body weight as an accurate indicator for determining contrast load using nonionic monomeric contrast material in indirect CT venography.
Materials and Methods: One hundred and thirty-two patients (mean age 51 years) underwent indirect CT venography to exclude the possibility of DVT. We used 150 ml of isohexol (iodine, 300 mgI/ml) administered at a rate of 3.0 ml/s. Scanning delay was 180 s from the time of initiation of contrast injection. Scans were obtained in a caudal-to-cranial direction starting from the ankle. Hounsfield unit (HU) measurements were recorded at the common femoral and popliteal veins. Using linear regression analysis, we calculated the correlation the coefficient between the CT attenuation and the iodine dose per body weight of each patient. We also recorded the presence of DVT and measured the CT attenuation of the clots.
Results: Average contrast dosage per weight was 765.3 mgI (from 420.5 −1184.2 mgI). Average measurements of HU at the common femoral and popliteal veins were 114.4 ± 17.8 HU and 109.9 ± 21.4 HU, respectively. The regression coefficients were 0.62 and 0.41 for the common femoral and popliteal veins, respectively. DVT was detected in 33 of 132 patients. The average HU of the thrombus was 47.7 ± 13.3 HU.
Conclusion: Indirect CT venography for detecting DVT initiated 180 s after the start of infusion of contrast material (150 ml) and a contrast injection at a rate of 3 ml/s produced high mean levels of venous enhancement. However, correlation between dose of contrast material per patient weight and CT attenuation of veins was fairly low.

Key words: CT venography, deep venous thrombosis, contrast material

INTRODUCTION

Pulmonary embolism and deep venous thrombosis (DVT) should be considered parts of the same pathologic process [1]. More than 90% of pulmonary emboli arise from deep veins of the leg and pelvis, and the primary risk factor for recurrent pulmonary embolism is the presence of residual proximal venous thrombosis [2]. Combined computed tomography (CT) venography and pulmonary CT angiography is a novel diagnostic strategy in which radiologists can check both the pulmonary arteries for pulmonary embolism as well as the deep veins of the abdomen, pelvis, and lower extremities for thrombosis in a single study [3−7].

Various scanning protocols and contrast materials for indirect CT venography to exclude DVT have been reported [3−9]. Scanning delay and CT attenuation of deep veins for DVT detection in indirect CT venography have been studied [3−4, 7−9]. In previous reports, investigators who used various combinations of quantities and concentrations of contrast material described a range in mean venous attenuation of 91−112 hounsfield units (HU) in indirect CT venography [3−4, 8−9]. To achieve optimal vessel opacification, investigators have reported several techniques to improve diagnostic accuracy. For example, Goodman *et al*. introduced the use of nonionic dimmer contrast material, which was not used in Japan because of many side effects and reported a modest improvement of venous opacification and evaluated the correlation between weight and venous opacification using linear regression [9]. However, estimation of nonionic monomeric contrast material dose per body weight in indirect CT venography was not performed accurately.

The purpose of our study is to evaluate whether body weight is an accurate indicator for determining contrast load using nonionic monomeric contrast material in indirect CT venography.

MATERIALS AND METHODS

Informed consent was not required because this was a retrospective study approved by our institutional review board.

Between May 2003 and October 2005, 132 patients (109 females, 23 males; age range, 14−81 years; mean age, 51 years) underwent indirect CT venography to exclude the possibility of pulmonary thrombosis and/or DVT. Most of the study participants comprised of females because the CT protocol was performed as a part of the preoperative gynecological examination. Patients with heart failure were excluded. Body weight ranged from 37.2−107 kg (mean, 58.8 kg).

Examinations were conducted with an intravenous injection of 150 ml isohexol of nonionic monomeric

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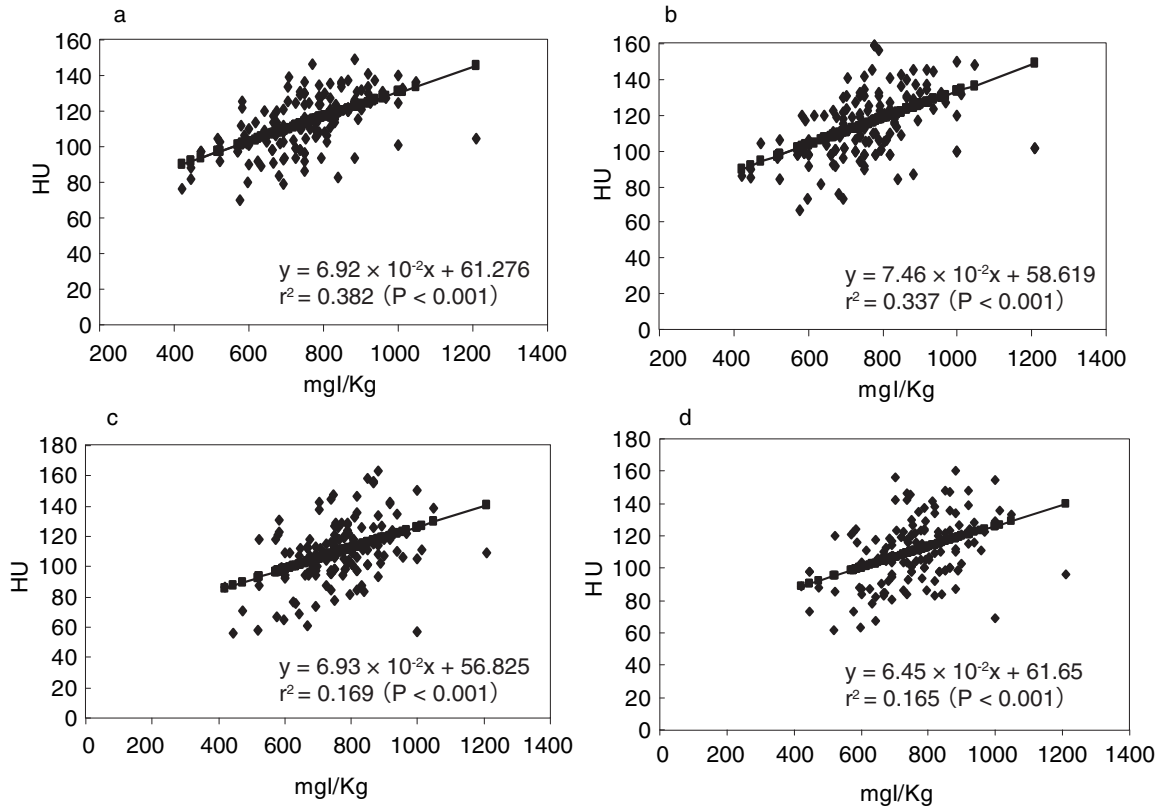

Fig. 1 Graphs of venous attenuation and iodine dose
a: right femoral veins b: left femoral veins c: right popliteal veins d: left popliteal veins

contrast material (Omnipapue 300, Dai-ichi-Sankyo, Tokyo) at a rate of 3.0 ml/s using a power injector. Scanning delay was 25 s and 180 s. The first set of scans was performed in the chest area to exclude pulmonary embolism and the second set of scans was performed to exclude DVT in the lower extremity. Second scans were performed in caudal-to-cranial direction from the ankle joints. Examinations were carried out using a 16-slice multi-detector row CT (MDCT) scanner (Somatom Cardiac Sensation 16, Siemens, Germany) and a 64-slice MDCT scanner (Somatom Cardiac Sensation 64, Siemens, Germany) with collimation less than 1 mm and reconstruction interval of 5 mm.

A radiologist (J.K), with more than 20 years of experience in interpreting vascular CT images, reviewed the CT images. Regions of interest (ROI) were set to measure CT attenuation at representative points in bilateral common femoral and popliteal veins. The ROIs were observed on a workstation using an oval area, approximately two-third of the target vessel in cross-sectional images. When a clot occupied the vein, CT attenuation of the vein was not measured; however, HU of the thrombus was recorded. Location of DVT was recorded in all patients. Criteria for the diagnosis of DVT were an intraluminal filling defect or localized nonopacification of a venous segment.

We analyzed the correlation between CT attenuation and iodine dose per body weight by linear regression analysis and recorded DVT and measured CT attenuation. A was good correlation between CT attenuation and iodine dose per body weight of each patient by linear regression analysis was determined by the amount of iodine dosage required to achieve venous CT attenuation of 90 HU or greater, a number that is reported as optimal for venous enhancement. A p value of < 0.05 was considered significant in all statistical analyses.

RESULTS

Average contrast dosage per weight was 765.3 mgI/kg (range from 420.5 to 1184.2 mgI/kg). Average HU measurements at the common femoral and the popliteal veins were 114.4 ± 17.8 HU (range from 66.8 HU to 159.5 HU) and 109.9 ± 21.4 HU (range from 56.1 to 163.7 HU), respectively. The regression coefficients were 0.62 and 0.41 at the common femoral and popliteal veins, respectively. As shown in Fig. 1, there was a fairly low correlation between the dose of contrast material per body weight and CT attenuation on bilateral common femoral and popliteal veins. Because of the poor correlation between dose of contrast material per weight and CT attenuation, per unit weight dosage of contrast material necessary to achieve 90 HU venous CT attenuation could not be determined. DVT was detected in 33 of 132 patients included 58 points of femoral and popliteal veins in indirect CT venography. The average CT attenuation of DVT was 47.7 ± 13.3 HU (range from 39 HU to 78 HU). The highest CT attenuation of DVT (78 HU) was seen in patient with acute thrombophlebitis of left femoral vein (Fig. 2).

DISCUSSION

Pulmonary embolism and DVT have been described as different manifestations of the same disease process

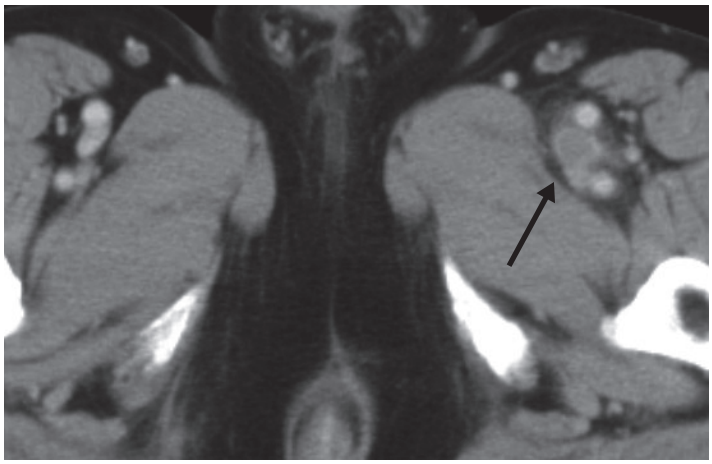

Fig. 2 A 65 year-female with acute thrombophlebitis. CT image showed dilatation of femoral vein with wall enhancement and dirty fat around the vein. CT attenuation of thrombus (arrow) was 78 HU.

[1, 10]. DVT is often asymptomatic and is associated with recurrent DVT and pulmonary embolism when treated inadequately [11-12]. Therefore, accurate detection of DVT is necessary for prompt treatment. CT has now become the initial diagnostic examination of choice for pulmonary embolism in many institutions. Technical advances in pulmonary CT angiography have enabled the accurate detection of pulmonary embolism down to the segmental pulmonary arteries [13-14]. Direct CT venography of the lower extremities has been used to detect DVT and has a sensitivity and specificity of 100% and 96%, respectively as compared to conventional venography. Moreover, it is superior in detecting thrombus extension into the pelvic veins and the inferior vena cava [15], but requires additional injection of the contrast material.

Combined indirect CT venography and pulmonary CT angiography was first reported by Loud *et al.* in 1998 [5]. Among patients undergoing pulmonary CT angiography for suspected pulmonary embolism, addition of indirect CT venography provides considerable benefits. Only 3 min are added to the scanning time for pulmonary CT angiography and additional contrast material is not required [8]. Combined indirect CT venography and pulmonary CT angiography can be used to evaluate pulmonary embolism and DVT in a single examination, providing the radiologist with a useful road map for planning interventional procedures (e.g. placement of vena caval filter and thrombolysis).

Various scanning protocols and contrast materials in combined indirect CT venography have been used to exclude DVT [3-9]. To exclude or detect DVT in indirect CT venography, scanning delay of 3 min after injecting the contrast material was chosen to allow time for uniform venous opacification [3, 5, 7]. Concentration of nonionic contrast material in indirect CT venography in previous reports ranged from 240 to 370 mgI/ml and was not standardized [3-9]. Because streak artifact is caused when contrast material of less than 350 mg I/ml is injected by a high injection rate [16-17], high concentration of contrast material is inappropriate without an injection of saline using the bolus chasing technique. Injection rates of contrast material in indirect CT venography were 3-5 ml/s [3-9]; however, injection rate is independent of DVT detection.

The degree of venous enhancement is important in evaluating DVT [3, 6, 8-9]. Arakawa *et al.* reported that patient age, body weight, and the amount of contrast material were important factors associated with vessel enhancement in combined pulmonary CT angiography and indirect CT venography [18]. Venous enhancement may have a close relation to blood volume, and blood volume is not a constant fraction of body weight or surface area [19]. In this study, there was a low correlation between the dose of contrast material per patient weight and CT attenuation of veins. Therefore, we suggest that the dosage of contrast material in indirect CT venography to detect DVT should not be considerably increased. Since there is no consensus about the adequate venous opacification to diagnose DVT in CT, the difference in attenuation between the vein and the clots should be large enough for confident diagnosis. Clot attenuation has been reported to be variable. Loud *et al.* reported an average attenuation of 31 HU [6] and Cham *et al.* reported an average attenuation of 51 HU [8]. If a clot has an attenuation of 31 HU, venous attenuation in the range of 60-70 HU is probably adequate for detection. Moreover, as Cham *et al.* reported [8], if the median attenuation of a clot is 55 HU, half the clots will have an attenuation that is greater than 55 HU. A clot can be possibly diagnosed when the venous attenuation is in the range of 60-70 HU and cannot be completely excluded. Goodman *et al.* reported that a reasonable but unproven attenuation of 80 HU or more would provide adequate contrast differentiation between the clot and opacified vessels. However, CT attenuation of a fresh clot is higher than that of an old clot and the highest CT attenuation of a clot was 78 HU in patient with acute thrombophlebitis in our study (Fig. 2). Clot images obtained within 8 days of disease onset showed an average attenuation of 66 ± 7 HU, whereas those that had been present for more than 8 days showed an average attenuation of 55 ± 11 HU [15]. An average femoral venous attenuation of 93-115 HU in indirect CT venography has been reported [3-4, 8-9].

In our study, the average attenuation of a clot was 47.7 ± 13.3 HU and the average femoral venous attenuation was 114.2 ± 10 HU, which is similar to that reported in the literature [3-4, 8-9]. Based on these data, we suggest that optimal venous attenuation that provides adequate contrast differentiation between

the clot and veins should be more than 90 HU. When Arakawa *et al.* used 100 ml of contrast material (300 mg I/ml) with the same scanning protocol for patients with a body weight less than 50 kg, an average CT attenuation of the popliteal veins was 104 HU [18]. Therefore, a decreased dose of contrast material for low-weight patients may be acceptable. Body weight alone may not be the determining factor in calculating dosage. Other factors such as total blood volume and cardiac output should be considered and further study is required to identify the factors associated with venous enhancement for the diagnosis of DVT.

Because of its safety and speed, ultrasonography has become the most commonly used diagnostic tool for DVT detection of the leg [20]. Goodman *et al.* reported in 2007 that indirect CT venography and sonography showed similar results in diagnosing or excluding DVT [21]. Ultrasonography is more sensitive in detecting DVT in legs as compared to indirect CT venography; however, indirect CT venography is useful in detecting DVT in pelvic veins such as internal or external iliac veins.

In conclusion, indirect CT venography for DVT started 180 s after the start of infusion of contrast material (300 mg I/ml of iodine at an injection rate of 3 ml/s) produced high mean levels of venous enhancement. However, there was a poor correlation between dose of contrast material per body weight and CT attenuation of the veins and further study is required to identify the various factors associated with venous enhancement for the diagnosis of DVT.

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