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관절 성형술 후 다중 검출 CT를 이용한 심부 정맥 혈전 평가 : 도플러 초음파와의 전향적 비교 연구

Evaluation of deep vein thrombosis after orthopedic arthroplasty with multidetector row CT : a prospective study in comparison with Doppler sonography

2007년 8월

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이 논문을 변성수의 석사학위논문으로 인정함

2007년 8월

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Evaluation of deep vein thrombosis after orthopedic arthroplasty with multidetector row CT: a prospective study in comparison with Doppler sonography

by

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A THESIS

Submitted to the faculty of
IN-HA UNIVERSITY
in the requirements for the master’s degree of
MEDICINE

Department of Radiology
August 2007
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요 약

목적: 이 전향적 연구는 고관절 혹은 슬관절 치환술 후 발생하는 하지 심부 정맥 혈전증을 발견하는 간접적인지 16시관절 CT 정맥 조영술의 진단능을 도플러 초음파와 비교하여 평가하였다.

재료 및 방법: 62명의 환자들이 총 30개의 고관절과 54개의 슬관절에 대하여 정형외과적 관절치환술을 시행받았다. 수술 후 8에서 40일 후 CT 정맥 조영술 (스캔 지연 시간, 160초 척관 두께/증가, 2/1.5mm)과 도플러 초음파가 시행되었다. 우리는 영상 절을 지하시켜 축상 CT 영상에서 하지 심부 정맥 혈전증의 여부를 평가 할 수 없게 하는 범 경화 인공물의 z축 길이를 측정 하였다. 하지 심부 정맥 혈전증의 발생률과 위치가 분석되었다. CT 정맥 조영술의 진단적 효율이 도플러 초음파를 표준 참고 및 비교 대상으로 하여 평가 되었다.

결과: 범 경화 인공물의 z축 길이 (평균 ± 표준 편차)는 술후 슬관절에서 4.5 ± 0.8 cm이었고 고관절에서 3.9 ± 2.9 cm 이었다. 하지 심부 정맥 혈전증은 도플러 초음파상 62명의 환자 중 30명(48%)에서 슬관정맥과 비복정맥에서 관찰되었다. CT 정맥 조영술의 민감도, 특이도, 양성 예측치, 음성 예측치 그리고 정확도는 각각 90%, 97%, 96%, 91% 그리고 94%이었다.
결론: CT 정맥 조영술의 진단능은 범 경화 인공물에도 불구하고 도플러 초음파와 대등하였다. 그러므로 CT 정맥 조영술은 관절 성형술 후 환자를 평가할 때 대체 기법으로 사용하기에 적합하다.

핵심어: 정맥, 혈전증

 컴퓨터 단층 촬영, 혈관 조영술

초음파, 도플러 연구
ABSTRACT

Purpose: This prospective study evaluated the ability of indirect 16-row multidetector CT venography to detect deep vein thrombosis after total hip or knee replacement in comparison with Doppler sonography.

Materials and Methods: Sixty-two patients had undergone orthopedic replacement surgery on total of 30 hip and 54 knee joints. Eight to 40 days after surgery, the CT venography (scan delay time, 180 seconds; slice thickness/increment, 2/1.5 mm) and Doppler sonography were performed. We measured the z-axis length of beam hardening artifact that degraded the image quality so that the presence of deep vein thrombosis couldn’t be evaluated on the axial CT images. The incidence and location of deep vein thrombosis was analyzed. The diagnostic performance of the CT venograms were evaluated and compared with that of Doppler sonography as a standard of reference.

Results: The z-axis length (mean ± standard deviation) of beam hardening artifact was 4.5 ± 0.8 cm in arthroplastic knees and 3.9 ±
2.9 cm in arthroplastic hips. Deep vein thrombosis was found in the popliteal or calf veins on Doppler sonography in 30 (48%) of the 62 patients. The CT venography has a sensitivity, specificity, positive predictive value, negative predictive value and accuracy of 90%, 97%, 96%, 91%, and 94%, respectively.

**Conclusions:** The diagnostic ability of CT venography was comparable to that of Doppler sonography despite of beam hardening artifact. Therefore, CT venography is feasible to use an alternative modality for evaluating post–arthroplasty patients.

**KEYWORDS:** Veins, thrombosis

Computed tomography (CT), angiography

Ultrasound (US), Doppler studies
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Figure 3. Doppler USG and coronal CT image of 54-year-old female underwent left total hip and knee arthroplasty simultaneously.

Figure 4. Axial CT image of 32-year-old female underwent right total hip arthroplasty.


**Introduction**

Major orthopedic surgery, such as total hip arthroplasty (THA) and total knee arthroplasty (TKA), is a commonly performed surgical method. However, these procedures have an increased risk of venous thromboembolism with an incidence up to 84% [1-8]. Deep vein thrombosis (DVT) may progress to a potentially fatal pulmonary embolism and secondary complications such as postthrombotic syndrome, recurrent DVT, and chronic pulmonary hypertension [9,10]. Therefore, the early detection and proper management of DVT is important for preventing unexpected complications.

The diagnostic modalities of DVT developed after total joint replacement included conventional venography [11,12], Doppler sonography [1-3,13-26], MR venography [27], and radionuclide venography [28]. Compared with conventional venography, Doppler sonography has the advantage of being portable, painless, noninvasive, without any side effects, and less expensive screening and surveillance tool for managing DVT [13]. It was also reported to be a good examination method with an overall sensitivity and specificity of 85.7% and 97.3% compared with conventional venography, respectively [13].

To our knowledge, CT had not been used to detect DVT after total hip or knee arthroplasty mainly because of beam hardening artifact by arthroplastic joint materials. Therefore, the aim of this prospective
study was to compare the ability of indirect 16-row multidetector row CT venography to detect DVT after TKA or THA with that of Doppler sonography.
Materials and Methods

Patient Population

The institutional review board approved the study protocol. Between June 2004 and February 2005, among whom had undergone total hip or knee arthroplasty in our hospital, the 62 (19 men and 43 women; age range, 28–83 years; mean age, 63 years) patients that performed both CT venography and Doppler sonography after surgery were enrolled in this study. THA was done in 29 patients unilaterally (n = 28) or bilaterally (n = 1). TKA was done in 34 patients unilaterally (n = 14) or bilaterally (n= 20). In only one patient, both THA and TKA were done unilaterally in a single operation. Overall, 30 hips and 54 knees were examined using noninvasive color duplex Doppler ultrasound flow scanning and indirect 16-row multidetector row CT venography after surgery.

CT venography was performed 8–29 days (mean, 12) after surgery to detect DVT. According to Eilas et al [1], most DVT occurred at the 8th to 13th day after major joint surgery. Doppler sonography was carried out within two weeks (mean, 2 days) after CT venography. Only in 8 of 62 patients, the interval between the two examinations was more than 4 days (range, 4 to 11 days). Of the two radiologists who were experienced in vascular imaging, one interpreted the result of CT venography and the other performed Doppler sonography separately. The radiologists who performed CT venography were
unaware of the results of Doppler sonography and vice versa.

Preoperatively, the status of arteries and veins in bilateral lower extremity was evaluated with Doppler sonography in all patients within 35 days (mean, 9). No significant arterial stenosis or DVT was detected in any patient. At our hospital, no pharmaceutical prophylaxis for DVT was administered.

**CT Venography**

The MDCT scans were performed on a Somatom Sensation 16 plus helical CT scanner (Siemens Medical Systems, Erlangen, Germany). After obtaining the topogram from the diaphragm to the feet, CT venography was performed with a detector collimation of 16 x 1.5 mm, a table feed of 24 mm, 120 kV, 200 effective mAs, a rotation time of 0.37 seconds, and with 160 mL of contrast media (Omnipaque; Amersham Health, Cork, Ireland) at a flow of 4 mL/s that was administered by an automated injector (MCT Plus; Medrad, Pittsburgh, Penn) through the antecubital vein. Immediately after the contrast injection, 40 mL of normal saline was pushed with a flow rate of 2 mL/s. The start delay time was determined using bolus tracking software. The region of interest was placed on the abdominal aorta on the level of the second lumbar vertebra. Fifteen seconds after the arrival of 100 Hounsfield units, the CT scan was begun in the craniocaudal direction. One hundred-eighty seconds after the start of the contrast material, indirect CT venography was made from the diaphragm down to the feet. A delay of 180 seconds was chosen
according to the time–density curves of the lower limb veins reported by Szapiro et al [29], who showed that the optimal window for CT venography was obtained between 210 and 240 seconds for the calf level and between 180 and 300 seconds for the above-knee veins. No further contrast material was administered for the venous phase. Care Dose 4D (Siemens Medical Systems, Erlangen, Germany) was also used to further decrease the radiation doses to the patient.

Informed consent was obtained from either the patients or their relatives. The CT venography was reconstructed with a slice width of 2 mm with an increment of 1.5 mm. The reconstructions were performed with a soft-tissue reconstruction kernel (B30F medium smooth). The window was adjusted depending on the vessel opacification. The criterion for deep vein thrombosis included non-enhanced, low-attenuated lesions within the deep vein of the lower extremity.

**Doppler Sonography**

In all patients, bilateral leg sonography was performed with a 5 to 10 MHz linear array transducer (VST MASTER, Diasonics, Milpitas, USA; or ATL5000, Philips Medical Systems, Bothell, USA) by an experienced radiologist. The common and superficial femoral veins were assessed with the patient in the supine position. The popliteal vein was examined with the patient turned to either side or with the patient in the prone position. A color Doppler ultrasound examination of the calf veins was then performed in the prone position with a
pillow under the feet. Transverse and longitudinal gray scale images with and without compression as well as transverse and longitudinal color and spectral Doppler sonography including the flow accentuation maneuvers were performed. The main diagnostic criterion used for DVT was the loss of venous compressibility. The findings were compared with the CT venographic results after the examination. If there were any divergent results, further sonographic analysis was carried out immediately by repeating the examination. The typical sonographic examination time was 10 to 20 minutes for each leg.

**Analysis**

Initially the quality of CT venographic image was evaluated both subjectively and objectively. The image quality of the CT venograms was graded as good, sufficient, and insufficient based on visual analysis. ‘Good’ means that the degree of venous enhancement was similar to that of adjacent arterial enhancement. ‘Insufficient’ means that the degree of venous enhancement was similar to that of adjacent muscular enhancement. ‘Sufficient’ means that the degree of venous enhancement was between those of adjacent arterial and muscular enhancement. For objective analysis of image quality, at the mid-femur level, the attenuation of the superficial femoral vessels (artery and vein) and adjacent muscle was measured. For this, we placed a small round region of interest within the selected subject. The differences in the attenuation values of the superficial femoral vein and adjacent muscle were analyzed statistically using Student’s
t-test.

Then, we measured the z-axis length of beam hardening artifact that degraded the image quality so that the presence of DVT couldn’t be evaluated on the axial CT images. We evaluated the mean length and range of beam hardening artifact and compared the results between arthroplastic hips and knees.

The incidence and location of the DVT was then analyzed depending on arthroplasty method (THA vs. TKA) and operated limb (unilateral vs. bilateral). The incidence was counted on the number of the patients who had DVT. The location was divided into 1) inferior vena cava, 2) common and external iliac vein, 3) superficial femoral vein, 4) popliteal vein, and 5) calf vein. However, each thrombus was not matched between Doppler sonography and CT venography by lesion-to-lesion basis. Only, the presence of DVT was recorded within each selected vein.

Finally, the diagnostic performance of CT venography compared with that of Doppler sonography was examined by determining the sensitivity, specificity, positive and negative predictive values and accuracy.
**Results**

In the 62 patients, the image quality of the CT venograms was good (n = 59) or sufficient (n = 3), subjectively. Objectively, at the mid-femur level, the attenuations (mean ± standard deviation) of the superficial femoral vein and artery were 140 ± 23 HU and 161 ± 26 HU, respectively. On the other hand, the attenuation of the adjacent muscle was 65 ± 8 HU (mean ± standard deviation). Therefore, the difference in the attenuation values of the superficial femoral vein and adjacent muscle was significant (p < 0.001).

The z-axis length (mean ± standard deviation) of beam hardening artifact was 4.5 ± 0.8 cm (range, 3.0 – 6.0 cm) in arthroplastic knees and 3.9 ± 2.9 cm (range, 0 – 10.0 cm) in arthroplastic hips. Therefore, the extent of beam hardening artifact in arthroplastic hips was more variable than that in arthroplastic knees.

DVT was found in the calf veins by Doppler sonography in 30 (48%) of the 62 patients who were enrolled in this study (Table 1). In two patients, the calf vein DVT was extended into the popliteal vein. There was no DVT in the iliofemoral veins in our study. DVT was detected by Doppler sonography in 42 operated extremities and in 1 non-operated extremity (Figs. 1,2). All the DVTs were non-occlusive at the time of the diagnosis and the patients were asymptomatic. In our study, the incidence of DVT was higher after TKA (76%, 25 of 33 patients) than after THA (14%, 4 of 28 patients), which was not analyzed statistically.
**Table 1.** Location and incidence of deep vein thrombosis detected with Doppler sonography

<table>
<thead>
<tr>
<th>Arthroplasty</th>
<th>No of Patients</th>
<th>DVT</th>
<th></th>
<th></th>
<th>Incidence (%)</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>None</td>
<td>IL (UL)</td>
<td>CL</td>
<td>BL</td>
</tr>
<tr>
<td>THA</td>
<td>UL</td>
<td>27</td>
<td>23</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>BL</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>TKA</td>
<td>UL</td>
<td>13</td>
<td>4</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>BL</td>
<td>20</td>
<td>4</td>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>THA + TKA</td>
<td>UL</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Total: 62 patients: 32 with DVT, 16 iliac, 1 contralateral, 13 bilateral. DVT, deep vein thrombosis; THA, total hip arthroplasty; TKA, total knee arthroplasty; IL, ipsilateral; UL, unilateral; CL, contralateral; BL, bilateral; NA, not available
Fig. 1. A 63-year-old female underwent left total knee arthroplasty. (A) Note the degradation of the image quality of the 3.5 cm-long segment (between two arrows) in the popliteal fossa in the three-dimensional volume rendering image. (B) An axial CT image shows non-enhancing, low-attenuated lesions surrounded by contrast material within the left calf veins (asterisks). (C) Color Doppler sonography reveals a hypoechoic lesion partially obstructing the left calf vein. There were blood flow signals surrounding the lesion.
Fig. 2. A 46-year-old female underwent left total hip arthroplasty. (A) Three-dimensional volume rendering image shows the degradation of image quality along the long segment (between two arrows) due to beam hardening artifact by the arthroplastic joint material. However, the entire common and superficial femoral veins except a 2 cm-long segment could be evaluated on whether DVT was present or not. (B) An axial CT image shows beam hardening artifact traversing the adjacent superficial femoral vein (arrow). (C) A coronal image shows non-enhancing, low-attenuated lesions surrounded by contrast material within the left calf veins (arrows). Doppler sonography confirmed DVT (not shown).
Discrepancies between the CT venograms and Doppler sonography were present in 4 patients. In three patients, CT venography did not initially detect the DVT despite the presence of DVT detected by Doppler sonography. However, in these patients, the DVT was found in the CT venography retrospectively (Fig. 3). In one patient, CT venography—showed a suspicious focal DVT in the calf veins (Fig. 4). In the repeated sonographic examination, there was also no DVT in the calf veins. Based on the results of Doppler sonography, the CT venography has a sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 90%, 97%, 96%, 91%, and 94%, respectively, in the diagnosis of DVT after major orthopedic arthroplasty (Table 2).

Table 2. Diagnostic results of MDCT venography for the detection of DVT after arthroplasty compared with those from Doppler sonography.

<table>
<thead>
<tr>
<th></th>
<th>Sonography positive</th>
<th>Sonography negative</th>
</tr>
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<tr>
<td>MDCT positive</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>MDCT negative</td>
<td>3</td>
<td>31</td>
</tr>
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</table>

MDCT, multi-detector row CT; DVT, deep venous thrombosis

* Based on these results, the sensitivity, specificity, positive and negative predictive values, and accuracy were 90%, 97%, 96%, 91%, and 94%, respectively.
Fig. 3. A 54-year-old female underwent left total hip and knee arthroplasty simultaneously. (A-B) Doppler sonography without (A) and with compression (B) revealed DVT in the left calf vein. The blood flow signal means partial occlusion of the left calf veins. After compression, the DVT lesion showed no compressibility. However, DVT was initially undetected in the CT venograms. (C) In retrospective analysis, a coronal CT image showed a small, non-occlusive thrombus (arrows) within the left calf vein.
Fig. 4. A 32-year-old female underwent right total hip arthroplasty. An axial CT image showed non-enhancing, low-attenuated lesions surrounded by high-attenuated tissue in the right calf (arrows). However, there was no definite evidence of DVT in the right calf vein despite the repeated sonographic examinations. This was a false-positive case.
Discussion

Since the advent of MDCT, the diagnostic ability of CT venography to detect DVT in the lower extremities was reported to be comparable to Doppler sonography [30–32]. This was mainly based on the significant difference in attenuation between the deep vein and the perivenous muscle. In this study, the deep vein was easily differentiated from the perivenous muscular tissue after contrast enhancement by visual analysis as well as by measurement of the attenuation.

CT had not been used as a diagnostic imaging modality for the detection of DVT after major joint arthroplasty because of the general disadvantages such as radiation hazard and contrast-induced nephropathy. In addition, beam-hardening artifacts developed by artificial joint materials strongly hampered its use. Streak or beam-hardening artifacts result in hypodense or hyperdense streaks in the neighboring structures. However, such artifacts can be distinguished from DVT because they extend through the vessel into the perivascular tissue and are in direct contrast to a clot, which is rounded and can be seen on the consecutive images [33]. In the TKA patients, beam-hardening artifacts occurred consistently in a limited area (less than 6.0 cm in our study) in which the artificial joint was present on the axial image. In the THA patients, the artifact involved the very long segment from the femoral head to the middle femur shaft. However, the artifact did not degrade the image quality so
much. The reasons could be inferred that the meaningful length of artifact in arthroplastic hips was rather less than that in arthroplastic knees. First, the area of artificial joint material in the axial CT images was smaller in arthroplastic hips. Second, the distance between the adjacent major vein and the artificial joint material was longer in arthroplastic hips. Therefore, beam hardening artifact did not disturb the image quality along very long segments in arthroplastic hips and knees.

In most of the patients in this study, DVT occurred exclusively at the calf veins. The importance of an isolated calf vein DVT as the cause of a clinically important pulmonary embolism or persistent lower extremity symptoms has been a subject of considerable debate in the literature [30]. According to Wang et al, a calf vein DVT after TKA disappear spontaneously with time [12]. Among the 48 patients, no recurrent DVT, proximal propagation or embolism had developed [12]. However, Delis et al [34] reported that a calf vein thrombosis might propagate to the proximal veins; 50% of calf clots totally lyse in 4 months, yet reflux develops in at least 75% of limbs with DVT.

Most DVT initially occur at calf vein, and then propagate to the femoropopliteal veins. An isolated DVT within the femoral or iliac vein is known to be rare. Therefore, beam-hardening artifacts were not problematic in the diagnosis of DVT, although some portion around the hip or knee joint could not be evaluated due to degradation of image data. Before the beginning of this study in our hospital, the sonographic examination included an evaluation of the deep vein only around the hip and knee joints. At that time, the
incidence of DVT was quite low particularly in the asymptomatic patients.

The incidence of DVT was significantly greater after TKA than THA (Table 1). These results are comparable to those reported by Leutz et al [14]. The main causes might be immobilization, soft tissue swelling, and inflammation after joint surgery.

It is unclear if performing bilateral sonography offers any real advantage over sonography of the operated leg alone. However, the risk of an isolated DVT in the non-operated leg is approximately 4% to 5% [11]. In clinical trials aimed at evaluating the efficacy of thromboprophylaxis in major orthopedic surgery, bilateral venography reduces the risk of undiagnosed DVT in the non-operated leg [11].

In our experience, the sonographic evaluation of the calf vein was time-consuming and dependent to the operator’s experience. In addition, small isolated thrombi confined within the calf vein were easily ignored and extent of deep vein thrombosis can not be evaluated. For those reasons, it was reported that Duplex ultrasound has a low sensitivity [15,18,19]. However, Doppler sonography has been used as primary imaging modality for the detection of DVT after joint arthroplasty because of wide availability and the patient’s safety. The diagnostic performance of CT venography was comparable to that of Doppler sonography in our study. But, several limitations were present. First, the gold standard such as conventional ascending venography was absent. More comparative studies between CT venography and conventional ascending venography may be needed in
the future. Second, the time interval more than 4 days was present between Doppler sonography and CT venography in the several patients. Because the examination findings of the patients did not show discrepancies between the two imaging modalities, it seemed that the results in our study would not be influenced by long time intervals.
Conclusion

In this study, the diagnostic ability of CT venography was comparable to that of Doppler sonography in spite of beam hardening artifact. Therefore, CT venography is feasible to use an alternative modality for evaluating post-arthroplasty patients.
References


