ORIGINAL ARTICLE

Non-compressibility Ratio of Sonography in Deep Venous Thrombosis

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Background: The risk of post-thrombotic syndrome and pulmonary embolism can be increased if there is failure to diagnose deep venous thrombosis (DVT) promptly. Emergency physicians (EPs) need a quick and readily available test to diagnose, treat and help them decide whether to discharge or admit DVT patients in a timely manner. The aim of this study was to investigate the value of the non-compressibility ratio of thrombosed veins in DVT patients, and give EPs an objective value to aid them in their decision-making with regard to DVT patients in the emergency department.

Methods: We reviewed 34 adult patients with DVT diagnosed by sonography in an emergency department. Medical records including demographic data and sonography results were retrospectively reviewed and analyzed.

Results: Mean age was 72.9 ± 16.5 years. Group I comprised 14 patients (41.2%) who had DVT in the popliteal and femoral veins. Group II comprised 8 patients (23.5%) who had DVT isolated to the popliteal vein and 12 patients (35.3%) who had DVT isolated to the femoral vein. Group I had a significantly higher non-compressibility ratio than Group II (93.4 ± 6.2% *vs.* 80.1 ± 19.2%, $p < 0.05$). The area under the receiver operating characteristic curve of the non-compressibility ratio between discriminating groups was 0.711 (95% confidence interval, 0.527–0.854; $p < 0.05$). The clinical prognostic score of Group I was significantly higher than that of Group II (6.2 ± 1.8 *vs.* 4.1 ± 2.6, $p < 0.05$). There was a significant positive correlation between the non-compressibility ratio of the thrombosed vein and the clinical prognostic score ($p = 0.001$).

Conclusion: The non-compressibility ratio of the thrombosed vein provides EPs with an objective test to evaluate the severity of DVT and to admit patients for consideration of adverse outcomes. [*J Chin Med Assoc* 2010;73(11):563–567]

Key Words: deep vein thrombosis, non-compressibility, sonography

Introduction

The risk of post-thrombotic syndrome and pulmonary embolism can be increased if there is failure to diagnose deep venous thrombosis (DVT) promptly. The incidence of DVT in the general population is 5 per 10,000 persons per year.[1] The clinical presentations of DVT, such as swelling, localized pain and tenderness over the calf area, are nonspecific. Homan's sign, calf pain at dorsiflexion of the foot, is present in only 8–30% of symptomatic DVT cases.[2] Approximately 500,000 suspected DVT patients are referred for further evaluation each year in the United States.[3] Emergency physicians (EPs) need a quick and readily available test for correct differential diagnosis of suspected DVT patients, so that they can then go on to treat and decide whether to discharge or admit DVT patients in a timely fashion.

Compression sonography was first suggested as a tool for diagnosis of DVT[4] in 1986; the sensitivity and specificity of diagnosing proximal DVT can reach 97–100% and 98–99%, respectively.[5,6] Compression sonography helps EPs to detect DVT patients quickly[7] and decreases the time to disposition savings (defined as the time to decide on whether to discharge or admit based on ultrasound results).[8] The negative predictive

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value of emergency department (ED) compression sonography has been found to be 95.7%.[9] Negative ED compression sonography reduces the possibility of DVT and helps EPs to discharge patients for outpatient follow-up.[9] However, no study has documented whether the severity of a thrombosed vein recognized by compression sonography can give an objective value for EPs to use when deciding whether to discharge or admit DVT patients. We wanted to investigate the value of the non-compressibility ratio of the thrombosed vein in DVT patients.

Methods

We retrospectively reviewed the emergency medical charts in the ED of Taipei Veterans General Hospital, which has a capacity of around 80,000 visits per year. From January 2005 to August 2006, 155 patients presented to our ED with lower leg edema and were suspected of having DVT. Thirty-four patients were diagnosed and reviewed for the quantitative survey. All patients suffered from lower limb edema, and the final diagnosis was confirmed by Doppler sonography. The method of examination was as follows: a patient was referred to the Department of Radiology and lower-extremity venous sonography was performed by an experienced radiologist to detect the presence of DVT. The transducer was moved distally approximately 1 cm at a time and graded compression was applied during examination. The examination proceeded through the junction of the common femoral, superficial femoral, and deep femoral veins. Firm compression was applied to achieve the collapse of the vein at each point. Veins with thrombosis could not be completely collapsed by compression. The vessel diameter was recorded before and after compression. According to the results of sonography, we collected data for vessel diameter and the involved limbs.

The 34 patients were then divided into 2 categories. Group I patients had DVT in the popliteal and femoral veins, and Group II patients had DVTs in the femoral or popliteal vein alone. The non-compressibility ratio was calculated with the following formula: vessel diameter after compression/vessel diameter before compression (Figure 1). The clinical prognostic score was calculated using the following formula: bilateral DVT (×1 point) + cancer (×4 points) + body weight < 70 kg (×1 point) + immobilization ≥ 4 days (×2 points) + creatinine clearance < 30 mL/min (×4 points) or 30–60 mL/min (×3 points) + chronic heart failure (×1 point).[10] The demographic data, initial clinical presentations, predisposing diseases, laboratory tests, and the findings of Doppler sonography were evaluated.

Statistical analysis was performed using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA). A receiver operating characteristic (ROC) curve was derived for non-compressibility ratio by plotting sensitivity versus specificity. The area under the ROC curve is an indication of the accuracy of a diagnostic test. MedCalc version 9.3 (MedCalc Software, Mariakerke, Belgium) was used to analyze the cut-off point of the non-compressibility ratio between the groups. A p value < 0.05 was considered to be statistically significant.

Results

One hundred and fifty-five suspected DVT patients were referred from the ED for evaluation during the study period. Thirty-four (21.9%) patients were diagnosed with DVT and enrolled into this study. Their mean age was 72.9 ± 16.5 years. Eleven (32.4%) patients had a history of cancer (Table 1). The average length

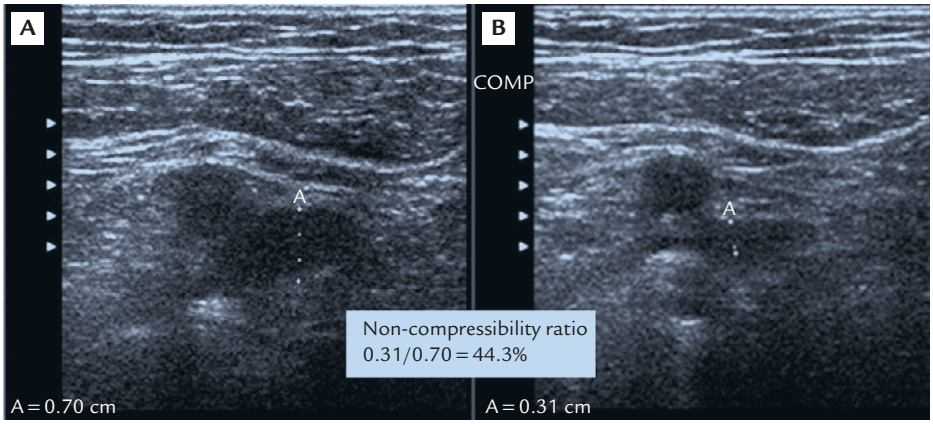

Figure 1. Non-compressibility ratio of thrombosed vein by transverse compression sonography. (A) Vessel diameter before compression. (B) Vessel diameter after compression.

Table 1. Summary of demographic data and tumors*

Age (yr)	72.9 ± 16.5
Male:female	22:12
Hypertension	16 (47.1)
Diabetes mellitus	7 (20.6)
Cerebrovascular accident	6 (17.6)
Cardiovascular disease	6 (17.6)
Tumor	11 (32.4)
Prostate adenocarcinoma	4
Urinary bladder carcinoma	2
Lung adenocarcinoma	1
Hepatocellular carcinoma	1
MEN type 1 + 2	1
Pancreatic adenoma	1
Craniopharyngioma	1

**Data are presented as mean ± standard deviation or n or n (%). MEN = multiple endocrine neoplasia.*

Table 2. Demographic characteristics of Groups I and II*

	Group I (n = 14)	Group II (n = 20)	p
Age (yr)	77.9 ± 12.2	69.5 ± 18.5	NS
Sex (male: female)	10:4	12:8	NS
WBC	8,250 ± 2,923	8,400 ± 3,115	NS
Hemoglobin	13.1 ± 1.85	12.7 ± 1.75	NS
Platelets	208,071 ± 77,604	219,700 ± 103,540	NS
Na	139.64 ± 4.27	139.2 ± 8.9	NS
K	4.16 ± 0.75	3.96 ± 0.6	NS
BUN	29.2 ± 12.8	26.3 ± 16.4	NS
Creatinine	1.85 ± 1.25	1.38 ± 0.5	NS
CRP	3.08 ± 2.3	2.99 ± 3.6	NS
Creatine kinase	18.7 ± 17.0	146.1 ± 247.0	NS
D-dimer	2.9 ± 0.9	1.8 ± 1.1	NS

**Data are presented as mean ± standard deviation or n. NS = not significant; WBC = white blood cell count; BUN = blood urea nitrogen; CRP = C-reactive protein.*

Table 3. Admission, non-compressibility ratio and clinical prognostic score of Groups I and II*

	Group I (n = 14)	Group II (n = 20)	p
Admission	12 (85.7)	11 (55.0)	< 0.05
Non-compressibility ratio	93.4 ± 6.2	80.1 ± 19.2	< 0.05
Clinical prognostic score	6.1 ± 1.8	4.3 ± 2.4	< 0.05
Bilateral DVT	2 (14.3)	0 (0)	NS
Cancer	5 (35.7)	6 (30)	NS
Body weight	62.9 ± 8.1	70.1 ± 13.2	NS
Immobilization ≥ 4 d	1 (7.1)	1 (5.0)	NS
CrCl	32.8 ± 11.5	53.5 ± 33.3	< 0.05
CHF	3 (21.4)	0 (0)	NS

**Data are presented as n (%) or mean ± standard deviation. DVT = deep vein thrombosis; NS = not significant; CrCl = creatinine clearance; CHF = congestive heart failure.*

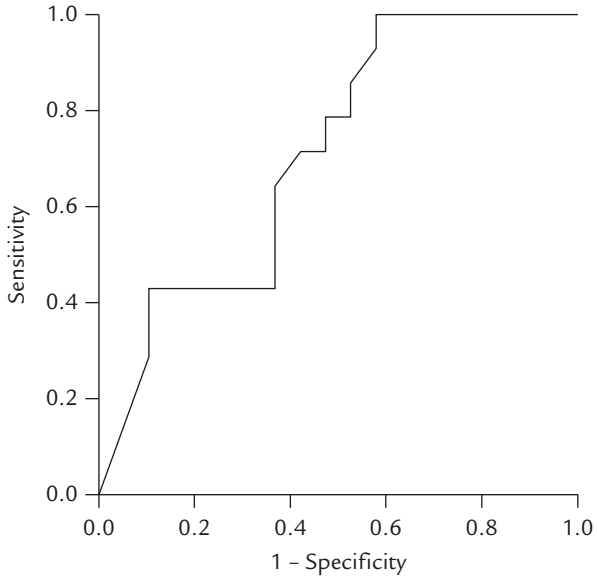

Figure 2. Receiver operating characteristic curve of non-compressibility ratio between Groups I and II. The area under the curve was 0.711 (95% confidence interval, 0.527–0.854; $p < 0.05$).

of hospitalization was 10.3 ± 12.8 days. There were no significant differences in basic chemistry data, age and sex between Groups I and II (Table 2).

Group I comprised 14 patients (41.2%) who had DVT in the popliteal and femoral veins. Group II comprised 8 patients (23.5%) who had DVT isolated to the popliteal vein and 12 patients (35.3%) who had DVT isolated to the femoral vein.

Doppler sonography included compression, color, and spectral sonography. The non-compressibility ratio of the thrombosed vein was 85.8 ± 16.7%. Color flow was absent in 17 (50%) patients and diminished in 17 (50%). The spectrum pattern showed no flow in 17 (50%) patients, was intermittent in 7 (20.6%), and flat in 10 (29.4%). Group I had a significantly higher non-compressibility ratio than Group II (93.4 ± 6.2% *vs.* 80.1 ± 19.2%, $p < 0.05$) (Table 3). ROC curve analysis was performed to show the relative potential of the non-compressibility ratio in the discrimination of groups. The area under the ROC curve between the 2 groups was 0.711 (95% confidence interval, 0.527–0.854; $p < 0.05$) (Figure 2). The best cut-off value for the non-compressibility ratio between the groups was 79.1%.

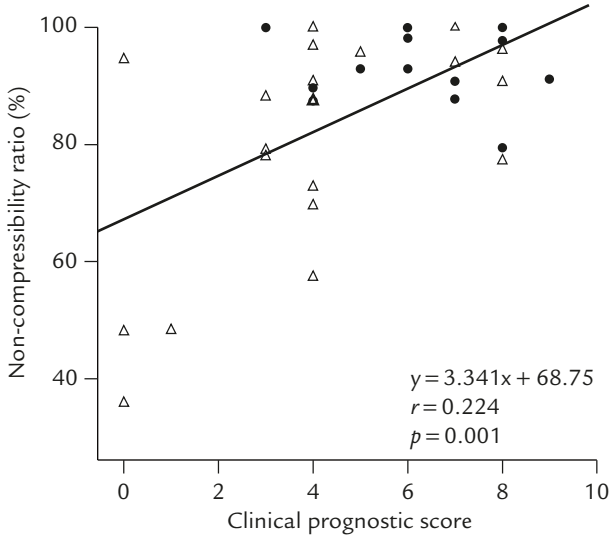

Figure 3. Correlation between non-compressibility ratio and clinical prognostic score in deep vein thrombosis patients. • = Group I, Δ = Group II.

When the non-compressibility ratio was ≥ 79.1%, the sensitivity and specificity were 42.1% and 100%, respectively. The color flow did not differ significantly between the groups. Group I had a significant increase in the spectrum patterns of no flow and intermittent ($p < 0.05$). The clinical prognostic score of Group I was significantly higher than in Group II (6.2 ± 1.8 *vs.* 4.1 ± 2.6, $p < 0.05$). There was a significant positive correlation between the non-compressibility ratio of the thrombosed veins and the clinical prognostic score ($p = 0.001$) (Figure 3).

Discussion

Diagnosis of DVT is a challenge for EPs because a physical examination cannot help to predict the diagnosis, and Homan's sign presents in only 8–30% of symptomatic DVT.[2] Venous Doppler sonography has become the initial test to evaluate the possibility of DVT on the basis of its high sensitivity of 95%, specificity of 99%, and accuracy of 98%.[5,6] While Doppler sonography provides EPs with a noninvasive, quick and reliable test, it is currently not available in many vascular laboratories at night and during the weekend. Real-time compression sonography performed by EPs in EDs could decrease the waiting time for a sonogram and the time to disposition of DVT patients.[8,11]

After successful diagnosis of DVT, the decision as to whether a DVT patient should be treated as an outpatient or inpatient is crucial for EPs. EPs need reliable information to avoid discharging DVT patients at risk for post-thrombotic syndrome. There is a clinical prognostic score that helps EPs to discharge DVT outpatients at low risk for an adverse outcome such as symptomatic pulmonary embolism, recurrent DVT, major bleeding and death.[10] The incidence of adverse events was 1.2% and 6.8% in patients with a score of ≤ 2 and > 3, respectively. Bilateral DVT is included in the clinical prognostic score, but the incidence of bilateral DVT can be as low as 0–9.1%.[12,13] In our study, it was found to be 5.9%. If we take involved thrombosed veins into consideration, DVT in the popliteal and femoral vein accounted for incidences of 61.8%[11] and 41.2% (i.e. Group I in our study). Group I had a significantly higher clinical prognostic score than Group II (DVTs isolated to the femoral vein or popliteal vein). If Doppler sonography shows DVT in the popliteal and femoral veins, EPs should consider admitting patients for prevention of adverse events.

Compression sonography has achieved optimal specificity (98%) in the diagnosis of proximal DVT in symptomatic patients.[14] EPs can quickly apply compression sonography for differential diagnosis of suspected DVT patients, and the results of sonography have a high correlation with vascular laboratory results.[11] There are 3 types of compression sonography responses: patency, partial occlusion, and total occlusion. The patency type can be easily established on complete collapse of the venous lumen. Total occlusion type can also be quickly diagnosed by persistently dilated venous lumen after compression sonography. Partial occlusion makes it difficult to establish the severity of the thrombosed vein. The non-compressibility ratio of the thrombosed vein can help EPs realize how severe the thrombosis is. In the present study, Group I was more severe than Group II because the thrombosed vein was noted in more than 1 area. The non-compressibility ratio and prognostic score of Group I were significantly higher than those of Group II. The non-compressibility ratio of the thrombosed vein had a significant positive correlation with the clinical prognostic score ($p = 0.001$). If the non-compressibility ratio is ≥ 79.1%, the specificity to predict patients in Group I is 100%, and further evaluation should be considered for these patients. The non-compressibility ratio could give EPs an objective value to aid in their decision of whether to discharge or admit DVT patients in the ED based on ultrasound results.

In conclusion, compression sonography is a quick and reliable test for EPs to diagnose DVT patients. The non-compressibility ratio of the thrombosed vein provides EPs with an objective test to evaluate the severity of DVT and admit patients for evaluation of potential adverse outcomes.

References

1. Fowkes FJ, Price JF, Fowkes FG. Incidence of diagnosed deep vein thrombosis in the general population: systematic review. *Eur J Vasc Endovasc Surg* 2003;25:1–5.
2. Hamper UM, Dejong MR, Scoutt LM. Ultrasound evaluation of the lower extremity veins. *Radiol Clin North Am* 2007;45: 525–47.
3. Anderson FA Jr, Wheeler HB, Goldberg RJ, Hosmer DW, Patwardhan NA, Jovanovic B, Forcier A, et al. A population-based perspective of the hospital incidence and case-fatality rates of deep vein thrombosis and pulmonary embolism: the Worcester DVT Study. *Arch Intern Med* 1991;151:933–8.
4. Raghavendra BN, Horii SC, Hilton S, Subramanyam BR, Rosen RJ, Lam S. Deep venous thrombosis: detection by probe compression of veins. *J Ultrasound Med* 1986;5:89–95.
5. Cornuz J, Pearson SD, Polak JF. Deep venous thrombosis: complete lower extremity venous US evaluation in patients without known risk factors: outcome study. *Radiology* 1999;211: 637–41.
6. Heijboer H, Büller HR, Lensing AW, Turpie AG, Colly LP, ten Cate JW. A comparison of real-time compression ultrasonography with impedance plethysmography for the diagnosis of DVT in symptomatic outpatients. *N Engl J Med* 1993;329:1365–9.
7. Jang T, Docherty M, Aubin C, Polites G. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: fast and accurate. *Acad Emerg Med* 2004;11: 319–22.
8. Theodoro D, Blaivas M, Duggal S, Snyder G, Lucas M. Real-time B-mode ultrasound in the ED saves time in the diagnosis of deep vein thrombosis (DVT). *Am J Emerg Med* 2004;22:197–200.
9. Frazee BW, Snoey ER, Levitt A. Emergency department compression ultrasound to diagnose proximal deep vein thrombosis. *J Emerg Med* 2001;20:107–12.
10. Trujillo-Santos J, Herrera S, Page MA, Soto MJ, Raventós A, Sánchez R, Monreal M. Predicting adverse outcome in outpatients with acute deep vein thrombosis: findings from the RIETE Registry. *J Vasc Surg* 2006;44:789–93.
11. Blaivas M, Lambert MJ, Harwood RA, Wood JP, Konicki J. Lower-extremity Doppler for deep venous thrombosis: can emergency physicians be accurate and fast? *Acad Emerg Med* 2000;7:120–6.
12. Dryjski M, O'Brien-Irr MS, Harris LM, Hassett J, Janicke D. Evaluation of a screening protocol to exclude the diagnosis of deep venous thrombosis among emergency department patients. *J Vasc Surg* 2001;34:1010–5.
13. Armstrong PA, Peoples JB, Vitello WA, Lemmon GW. Improved selection criteria for ordering stat venous ultrasounds from the emergency department. *Am J Surg* 1998;176:226–8.
14. Goodacre S, Sampson F, Thomas S, van Beek E, Sutton A. Systematic review and meta-analysis of the diagnostic accuracy of ultrasonography for deep vein thrombosis. *BMC Med Imag* 2005;5:6.