# Effectiveness of an algorithm in reducing the number of unnecessary ultrasound scans for deep vein thrombosis: an evaluation report

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**INTRODUCTION** Patients with suspected deep vein thrombosis (DVT) pose a diagnostic dilemma to the Emergency Department (ED) clinician. This study aimed to implement a known algorithm incorporating the modified Wells criteria and D-dimer testing to guide the ED clinician, thus reducing unnecessary ultrasound scans (USS).

**METHODS** Patients who presented to the ED between August 2008 and April 2009 with suspected DVT underwent Wells scoring. Those with scores < 2 were deemed unlikely to have DVT and underwent D-dimer testing first. Patients with scores ≥ 2 were regarded as likely to have DVT and underwent urgent USS. USS findings were tabulated as positive or negative/indeterminate for DVT. The latter group was followed up for one year to check whether DVT was missed during the initial USS.

**RESULTS** 75 patients presented with suspected DVT and underwent USS. Of these, 14 results were positive and 61 were negative. 37 patients had Wells scores < 2, with three (8.1%) having DVT. Another 38 patients had Wells scores ≥ 2, with 11 (28.9%) having DVT. D-dimer testing was performed on 27 of the 75 patients. Those with DVT had higher average values compared to those without DVT (1.305 vs. 0.595 µg/ml). The majority of patients with raised D-dimer values had cellulitis, although three also had DVT (with values ≥ 0.99 µg/ml).

**CONCLUSION** We managed to reduce the number of unnecessary USS and increase the pick-up rate of DVT. A cut-off score ≥ 2 in our algorithm is suitable for use in the ED setting.

*Keywords: D-dimer, deep vein thrombosis, modified Wells score, ultrasound scan, venous thromboembolism*
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## INTRODUCTION

Venous thromboembolism (VTE) includes deep vein thrombosis (DVT) and pulmonary embolism (PE), both of which may be life-threatening.[1-3] Diagnosing DVT in the Emergency Department (ED) can be difficult given the various differential diagnoses that may mimic this condition, the limited number of diagnostic tools available to narrow the possibilities as well as the inevitable time constraints in a critical care setting.[4] As such, recent ED records reveal a subset of patients with possible DVT who did not have ultrasound scan (USS) done in ED but were instead admitted and had USS done as inpatients. Only a small percentage of them turned up positive for DVT. This has increased the hospital bed occupancy as well as workload at all levels. Hence, a clinical prediction rule was thought to be helpful;[5] the Wells prediction rule being the most popular.[5-8] However, there have been suggestions that this rule may not be adequate for primary care patients.[4,9] Our aim was to evaluate the effectiveness of an algorithm combining a pre-test probability score using the modified Wells criteria with D-dimer testing at the ED level, which would lead to a decrease in unnecessary USS.

## METHODS

This study was conducted at Tan Tock Seng Hospital, Singapore for a period of nine months between August 2008 and April 2009. It was approved by the Domain-Specific Review Board of the hospital's cluster. In mid-July 2008, a consensus algorithm by the ED and Radiology Department was implemented for patients presenting to the ED with suspected DVT (Fig. 1). The screening chart (Table I) was based on the modified Wells criteria[1] with the following exceptions: We did not make a distinction between swelling of the entire leg and localised calf swelling, scoring 1 point if one or both of these were present. By combining these overlapping features, we had nine components instead of ten. In addition, patients with a history of recent long-distance travel were included in the category of being recently bedridden. Finally, those with a past history of DVT and/or PE were scored equally.

In keeping with the modified Wells score,[1,4,9] a score < 2 was considered to be unlikely for DVT and a score ≥ 2, as being likely for DVT.[1] Patients whose score was < 2 were to undergo the D-dimer test first, and if that was found to be elevated, to proceed with urgent USS. Otherwise, they could be safely discharged with USS performed electively. Our institution utilises the Liatest® D-DI (Diagnostica Stago, Asnières sur Seine, France) D-dimer test, and a value < 0.34 µg/ml is considered normal. Urgent USS should be ordered for patients with a score ≥ 2, or < 2 but with a positive D-dimer. A DVT scan would include the proximal veins (common femoral vein to popliteal vein) and calf veins, with a thrombus implying a positive finding. Scanning of

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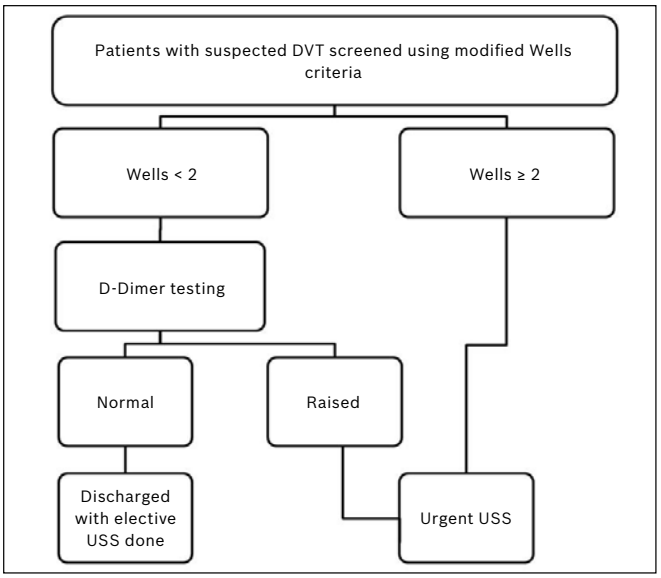


**Fig. 1** Algorithm for patients presenting to the Emergency Department with suspected deep vein thrombosis (DVT). USS: ultrasound scan

the calf veins may be omitted when thrombosis had already been detected in the proximal veins, or in cases of time constraints, poor ultrasonographic windows (e.g. severe contractures, overlying wounds, plaster cast *in situ*) as well as issues with patient cooperation and operator experience. In patients who underwent imaging of both lower limbs, a positive finding of DVT in either limb was accepted.

Details of patients who presented with suspected DVT and who underwent USS were collected by the ED. These included age, gender, race, breakdown of the Wells scores, D-dimer results and any other relevant medical history. Patients were categorised as either positive or negative for DVT. Those from the latter group could have been discharged from ED with a provisional working diagnosis or admitted to the ward under a different diagnosis. We recorded these diagnoses as well. Electronic medical records, electronic inpatient medical records and USS (if any) in the Centricity Picture Archival and Communication Systems of these patients were then traced at one year after termination of the study to identify if any patient had represented to our institution or required treatment for DVT. This was undertaken to determine if DVT might have been missed in any patient on the initial USS.

Receiver operating characteristic curves were used to analyse the optimal cut-offs for D-dimer as well as the total Wells score in terms of classifying DVT-positive and -negative cases. The area under the curve was used to quantify the discriminatory ability of the model. The sensitivity, specificity as well as positive and negative likelihood ratios were also calculated. In addition, we used the independent Student's *t*-test to compare the mean age between the DVT-positive and -negative cases. Fisher's exact test was used to compare categorical variables such as race, gender, etc. Data was analysed using Stata Software version 10.2 (Stata Corp, College Station, TX, USA), and a p-value $< 0.05$ was considered to be statistically significant.

**Table I. Screening chart based on the modified Wells criteria.**

| Criteria | Points |
|---|---|
| Active cancer (treatment within last 6 months or palliative) | 1 |
| Paralysis, paresis or recent cast immobilisation of lower extremities | 1 |
| Major surgery requiring regional or general anaesthetic in the past 12 weeks or recently bedridden for > 3 days (including recent long-distance travel) | 1 |
| Localised pain along distribution of deep venous system | 1 |
| Swelling of entire leg and/or calf swelling > 3 cm compared to the other calf (measured 10 cm below tibial tuberosity) | 1 |
| Pitting oedema (confined to the symptomatic leg) | 1 |
| Collateral superficial veins (non-varicose) | 1 |
| Previously documented DVT and/or PE | 1 |
| Alternative diagnosis as likely or more likely than DVT | −2 |

DVT: deep vein thrombosis; PE: pulmonary embolism

## RESULTS

A total of 75 (39 male and 36 female) patients presented to the ED for suspected DVT and underwent USS. Their mean age was 56.0 (range 15–95; 95% confidence interval [CI] 51.7, 60.3) years. Those who were positive for DVT had a mean age of 54.4 years (95% CI 43.8, 64.9), while those negative for DVT had a mean age of 56.4 years (95% CI 51.6, 61.2). The ratio of Chinese, Malays, Indians and other races was 47:10:10:8. 37 patients had Wells scores < 2. Three (8.1%) of them had DVT. 38 patients had scores ≥ 2 (range 2–4), and 11 (28.9%) of them turned out to be positive for DVT. The probability of DVT was 16% for a score of 2, 40% for a score of 3, and 100% for a score of 4.

D-dimer testing was performed on 27 of the 75 patients. The mean D-dimer value was 0.71 µg/ml (range 0.1–3.11 µg/ml). The mean D-dimer values were 1.305 µg/ml and 0.595 µg/ml for those who were positive and negative for DVT, respectively. Of the 21 patients with elevated D-dimer values, three (14.3%) had DVT, with D-dimer values ≥ 0.99 µg/ml (mean 1.78 µg/ml). The majority (38.9%) of the remaining patients with elevated D-dimer values but no DVT had a diagnosis of cellulitis. Their mean D-dimer value was 0.904 µg/ml. Of the six patients with normal D-dimer values, only one had DVT (D-dimer 0.24 µg/ml). D-dimer testing was not performed for 48 patients, although 15 of them should have undergone this blood test, since they had a Wells score < 2. Of these 15 patients, only one (6.7%) had DVT. Of the remaining 33 patients who were rightfully excluded from D-dimer testing owing to a Wells score ≥ 2, nine (27.3%) were positive and 24 (72.7%) were negative for DVT (Table II).

Of the 75 patients, 14 were positive for DVT, all of which involved at least the proximal veins. 61 patients were negative for DVT. They had the following diagnoses: cellulitis (n = 18); musculoskeletal trauma (n = 15, of which five were haematomas); Baker's cyst (n = 7, with six of these showing definite rupture); varicose veins (n = 4); osteoarthritis (n = 3); reactive arthritis (n = 1); post-surgery (n = 1); claudication (n = 1); and pain of uncertain cause (n = 1). Another ten had oedema (three of

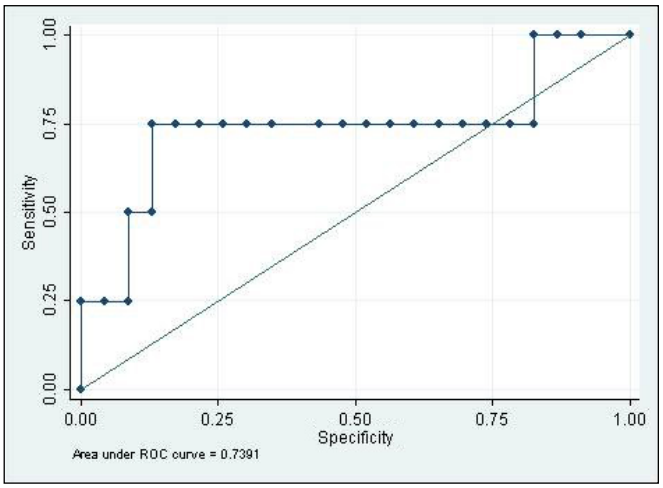


**Fig. 2** Graph shows ROC plot for D-dimer. The area under the curve is 0.7391. An optimal cut-point for D-dimer value is 0.99, with a sensitivity and specificity of 75% and 86.96%, respectively.

| Cutpoint | Sensitivity | Specificity | Correctly Classified | LR+ | LR- |
|---|---|---|---|---|---|
| ( ≥ .1 ) | 100.00% | 0.00% | 14.81% | 1.0000 | |
| ( ≥ .15 ) | 100.00% | 8.70% | 22.22% | 1.0952 | 0.0000 |
| ( ≥ .22 ) | 100.00% | 13.04% | 25.93% | 1.1500 | 0.0000 |
| ( ≥ .24 ) | 100.00% | 17.39% | 29.63% | 1.2105 | 0.0000 |
| ( ≥ .27 ) | 75.00% | 17.39% | 25.93% | 0.9079 | 1.4375 |
| ( ≥ .35 ) | 75.00% | 21.74% | 29.63% | 0.9583 | 1.1500 |
| ( ≥ .42 ) | 75.00% | 26.09% | 33.33% | 1.0147 | 0.9583 |
| ( ≥ .46 ) | 75.00% | 30.43% | 37.04% | 1.0781 | 0.8214 |
| ( ≥ .48 ) | 75.00% | 34.78% | 40.74% | 1.1500 | 0.7188 |
| ( ≥ .53 ) | 75.00% | 39.13% | 44.44% | 1.2321 | 0.6389 |
| ( ≥ .54 ) | 75.00% | 43.48% | 48.15% | 1.3269 | 0.5750 |
| ( ≥ .55 ) | 75.00% | 47.83% | 51.85% | 1.4375 | 0.5227 |
| ( ≥ .61 ) | 75.00% | 52.17% | 55.56% | 1.5682 | 0.4792 |
| ( ≥ .62 ) | 75.00% | 56.52% | 59.26% | 1.7250 | 0.4423 |
| ( ≥ .71 ) | 75.00% | 65.22% | 66.67% | 2.1562 | 0.3833 |
| ( ≥ .76 ) | 75.00% | 69.57% | 70.37% | 2.4643 | 0.3594 |
| ( ≥ .82 ) | 75.00% | 73.91% | 74.07% | 2.8750 | 0.3382 |
| ( ≥ .83 ) | 75.00% | 78.26% | 77.78% | 3.4500 | 0.3194 |
| ( ≥ .85 ) | 75.00% | 82.61% | 81.48% | 4.3125 | 0.3026 |
| ( ≥ .99 ) | 75.00% | 86.96% | 85.19% | 5.7500 | 0.2875 |
| ( ≥ 1.05 ) | 50.00% | 86.96% | 81.48% | 3.8333 | 0.5750 |
| ( ≥ 1.24 ) | 50.00% | 91.30% | 85.19% | 5.7500 | 0.5476 |
| ( ≥ 1.33 ) | 25.00% | 91.30% | 81.48% | 2.8750 | 0.8214 |
| ( ≥ 1.48 ) | 25.00% | 95.65% | 85.19% | 5.7500 | 0.7841 |
| ( ≥ 3.11 ) | 25.00% | 100.00% | 88.89% | | 0.7500 |
| ( > 3.11 ) | 0.00% | 100.00% | 85.19% | | 1.0000 |

**Fig. 3** List of sensitivities and specificities for each cut-off score of ROC analysis. LR+ and LR– denote positive and negative likelihood ratios, respectively.

which could be attributed to congestive cardiac failure, myocardial infarction and dependency). The follow-up records of patients who were negative on USS revealed four patients who re-presented 4–15 months after their initial episode. None of the presentations were for DVT or PE.

## DISCUSSION

VTE includes DVT and PE, the latter being fatal.[1-3] Diagnosing DVT in the ED can be difficult given the time constraints, limited availability of diagnostic tools as well as the myriad differential diagnoses that mimic this condition.[4] Between November 2007 and July 2008, the nine months preceding this study, ED records revealed 231 persons with possible DVT, but they did not have USS done in the ED. Instead, they were admitted to the ward for management of concomitant problems and had their USS done within the next 48 hours. This increased the hospital bed occupancy as well as workload at all levels. Of these 231 patients, 40 (17.3%) had DVT whereas 191 (82.7%) did not. Slightly more than half (56.3%) were deemed to have a higher suspicion of DVT given their provisional working diagnoses of DVT, previous VTE and lower limb swelling. Cellulitis was a common differential diagnosis in 27.7% of patients and appeared as a confounder. The remaining patients had USS done for other broad categories that included heart, renal or hepatic failure, stroke, cancer and musculoskeletal conditions. The period between August 2007 and April 2008 was also considered since these nine months were of a similar timeframe, albeit in the preceding year. This was to account for public holidays and local festivals, which may skew the statistics; however, the figures were not too dissimilar. ED records showed that 225 patients were admitted, with 29 (12.9%) who turned out to be positive for DVT and 196 (87.1%) negative.

Radiologic testing for all patients suspected to have DVT is not cost-effective.[10] Up to 90% of patients with suspected DVT would eventually turn out to be negative.[2,7] Hence, the development of a clinical prediction rule is thought to be helpful.[5] The Wells prediction rule for DVT, published in 1995, is the most popular.[5-8] This has been further simplified by stratifying patients into either likely or unlikely risk groups, i.e. modified Wells score,[11] with ten components and a cut-off score for unlikely at ≤ 1.[1,4,9] With low pre-test scores, DVT can be safely excluded,[2] thus sparing patients from further testing with USS or anticoagulation therapy.[4,11]

Adding D-dimer testing to the Wells scoring algorithm has made the diagnosis of DVT convenient and cost-saving by foregoing unnecessary USS.[1] D-dimer is a sensitive test and has a high negative predictive value for DVT.[1] With high pre-test scores, performing a D-dimer test is unnecessary, as 24% patients may still have DVT, even with a normal reading.[2] Given that the D-dimer value should parallel the extent and burden of thromboembolic disease,[12] we obtained higher average D-dimer values for those who were positive for DVT compared to those without DVT, i.e. 1.305 µg/ml vs. 0.595 µg/ml. Among the patients with elevated D-dimer values, three had DVT, and their values were ≥ 0.99 µg/ml. As such, we recommend a higher index of suspicion of DVT in those with D-dimer values at or above this level (Figs. 2 & 3). Incidentally, this value is higher than the 0.5 µg/ml level recommended during screening for PE,[13] and it is understandable since the consequences of missing PE would be more fatal. Apart from VTE, D-dimer levels are also elevated post trauma or surgery, in infective or inflammatory conditions,

**Table II. Results with a Wells cut-off score of 2.**

| Patients presenting to the ED (n = 75) | | USS | |
|---|---|---|---|
| Wells score | D-dimer testing | Negative | Positive |
| < 2 (n = 37) | Normal (n = 5) | 4 | 1 |
| | Elevated (n = 17) | 16 | 1 |
| | Not done (n = 15) | 14 | 1 |
| ≥ 2 (n = 38) | Normal (n = 1) | 1 | 0 |
| | Elevated (n = 4) | 2 | 2 |
| | Not done (n = 33) | 24 | 9 |

ED: Emergency Department; USS: ultrasound scan

**Table III. Results with a Wells cut-off score of 3.**

| Patients presenting to the ED (n = 75) | | USS | |
|---|---|---|---|
| Wells score | D-dimer testing | Negative | Positive |
| < 3 (n = 62) | Normal (n = 6) | 5 | 1 |
| | Elevated (n = 19) | 17 | 2 |
| | Not done (n = 37) | 33 | 4 |
| ≥ 3 (n = 13) | Normal (n = 0) | 0 | 0 |
| | Elevated (n = 2) | 1 | 1 |
| | Not done (n = 11) | 5 | 6 |

ED: Emergency Department; USS: ultrasound scan

with cancer or pregnancy as well as in the elderly,[10,12] which would be more common in hospitalised patients.[12] In our study, the majority of patients with a falsely raised D-dimer were diagnosed with cellulitis.

We found a cut-off Wells score ≥ 2 to be optimal (sensitivity 78.57% and specificity 57.74%) for likely probability, approximating that of the modified Wells score (sensitivity 75% and specificity 55%).[9] Our attempt to tweak the Wells score by raising the cut-off value to ≥ 3, so as to reduce the number of USS, yielded the following results (sensitivity 50.00% and specificity 90.16%) (Table III). Thus, increasing the cut-off score by one point would result in us missing a large percentage of DVT cases.

There were some limitations to our study. Firstly, the study involved a small number of patients and was conducted over a short duration. A longer trial period adhering to our current protocol may yield more definitive results. In addition, 15 patients with Wells score < 2 should have had D-dimer testing, but they had been bypassed due to the ED physician's prerogative. Over-riding the protocol is acceptable, especially when a clinician's judgement conflicts with that of the Wells score, which is more to complement rather than displace the physician's empirical assessment.[7] In addition, there were also ED physicians who may have been rooted in their individual methods of investigating DVT and were reluctant to conform to this newly implemented protocol. However, in these 15 patients, only one (6.7%) turned out to be positive for DVT. Moreover, there were random occasions where USS was concluded after scanning the proximal veins. However, follow-up records of all patients who were negative for DVT on the initial USS, especially those in this group, did not reveal development of VTE, suggesting a degree of accuracy in our USS technique.

In conclusion, the implementation of an algorithm has managed to reduce the number of USS referred from the ED and wards from > 200 to < 100 patients. This ensured that USS, if done later in the admission, would be more targeted and not merely to allay initially raised fears of suspected DVT at the ED level. Furthermore, with a Wells score ≥ 2, the pick-up rate of USS at 28.9% fared better than the rates of 12.9% (August 2007 to April 2008) and 17.3% (November 2007 to July 2008). This algorithm is potentially time- and cost-saving to the institution. In addition, we opine that a cut-off score ≥ 2 used in our algorithm, incorporating the modified Wells criteria and D-dimer testing as a guide to determine the need to proceed with USS, is suitable for use in the local ED setting. An unexpected but welcome observation was that only patients with a raised D-dimer value of ≥ 0.99 µg/ml had DVT. Thus, we recommend further work-up for these individuals, which may include single or serial USS. However, further large-scale studies will better determine an optimal cut-off value of D-dimer to be used as a guide to proceed with USS. In the event of a negative USS, the most likely differential for a raised D-dimer is cellulitis, this being the case in almost two-fifths of our cohort.

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