

Effects of a standardized emergency department protocol on after-hours use of venous duplex ultrasound



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ABSTRACT

Objective: Vascular laboratory (VL) venous duplex ultrasound is the “gold standard” for diagnosis of lower extremity deep venous thrombosis (DVT), which is linked to many morbid conditions. Decreasing night and weekend use of VL services in the emergency department (ED) represents a potentially viable means of reducing costs as skilled personnel must remain on call and receive a wage premium when activated. We investigated the effects of workflow changes that required ED providers to use a computerized decision-making tool, integrated into the electronic medical record, to calculate a Wells score for each patient considered for an after-hours venous duplex ultrasound study for suspected DVT.

Methods: The rate of VL use and study positivity before and after implementation of the decision-making tool were examined in addition to measures of ED throughput, rate of concomitant pulmonary embolism, disposition of examined patients from the ED, observed thrombus distribution in duplex ultrasound studies positive for DVT, and calculated personnel costs of after-hours VL use.

Results: A total of 391 after-hours, ED-initiated venous duplex ultrasound studies were obtained during the 4-year study period ($n = 213$ before intervention, $n = 178$ after intervention; $P = .12$). Whereas the period immediately after the start of the intervention saw a decrease in VL use, this was not sustained. Studies performed after the intervention were not more likely to be positive for acute DVT (12.2% vs 18%; $P = .1179$). The average Wells score was 2.8 (range, 0-6). VL personnel were called in 347 times during the 4-year period, with a total cost of \$14,643.40. Nurse-ordered studies were significantly more likely to be positive, with 22% revealing acute DVT compared with 12% for physician-ordered studies ($P = .042$). The intervention resulted in significant improvements in ED throughput, with time between triage and study request falling from 226 minutes to 165 minutes ($P < .001$). Observed thrombus distribution revealed involvement of the most proximal external iliac system in a minority of cases (11%), whereas most thrombi (89%) were limited to the femoropopliteal, calf, and superficial venous systems.

Conclusions: A requirement for ED providers to document a Wells score before obtaining an after-hours venous duplex ultrasound study resulted in only a transient decrease in VL use but improved ED throughput. Studies ordered by nurses were significantly more likely to be positive, possibly as a result of consistent protocol adherence compared with the physicians. Future studies may warrant investigation into this provider variance. (*J Vasc Surg: Venous and Lym Dis* 2019;7:501-6.)

Keywords: Vascular laboratory; Deep venous thrombosis; Venous duplex ultrasound

Venous duplex ultrasound is the cornerstone examination for the diagnosis of acute and chronic deep venous thrombosis (DVT). Limb swelling and pain are symptoms frequently encountered in the emergency department (ED) and are often investigated using venous duplex ultrasound to evaluate DVT as a potential cause. Although most hospitals are well equipped to provide vascular laboratory (VL) services during business hours, after-hours (night and weekend) availability of venous duplex ultrasound is variable. Maintaining a staff of “on-call” skilled VL personnel after hours is costly and

exposes technologists to fatigue and burnout. Ideally, requests for VL services during off hours would be limited to cases in which a high pretest probability for DVT exists, thereby limiting VL use and the costs associated with after-hours use of VL services. Several scoring systems have been reported to aid in identifying patients most likely to be suffering from DVT on the basis of a combination of history and physical examination findings. One well-validated system, the Wells score, was originally described by Wells et al¹ in 1997 and later modified by Riddle and Wells² in 2004. Unfortunately, similar decision-making tools designed specifically for use in ED patients are currently lacking.

We hypothesized that adding a universal Wells score decision-making aid to the electronic physician order entry system in the ED will result in decreased after-hours VL use for venous duplex ultrasound.

METHODS

All aspects of the study took place at a single institution, the Raymond G. Murphy Veterans Affairs (VA) Medical Center in Albuquerque, New Mexico. All patients cared for in the ED from federal fiscal year 2011 to fiscal year

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2014 for whom an after-hours lower extremity venous duplex ultrasound examination was requested were included. After-hours was defined as after 5:00 PM and before 7:00 AM (night) and during the entire 48-hour period comprising Saturday and Sunday (weekend).

Computerized decision-making tool and workflow intervention. A real-time computerized tool was designed on the basis of the Wells score criteria as modified by Riddle and Wells in 2004.² The scoring scheme was identical to that published in the literature and was completed by either the ordering physician or triage nurse at the time of placement of the electronic request for the venous duplex ultrasound study. The decision aid was a mandatory field, and a score of at least 1 was required to be documented to successfully request a VL examination. The Wells score was chosen on the basis of simplicity and the rapidity with which it can be calculated.

At the time of implementation of the computerized tool, the workflow surrounding requests for venous duplex ultrasound in the ED was changed. In the new workflow, ED triage nurses were empowered to request venous duplex ultrasound studies for patients considered to be at high risk for DVT based on the decision-making tool independent of the need for a physician's order. The aim of this intervention was to reduce the time between ED presentation and study request in an effort to streamline ED throughput for care related to this diagnosis.

Venous duplex ultrasound. All duplex ultrasound examinations were completed by the Intersocietal Accreditation Commission-accredited VL at the VA Medical Center by experienced vascular sonographers. Interpretation of images was performed by Registered Physician in Vascular Interpretation-certified attending vascular surgeons per usual clinical practice.

Data collection. A prospective administrative database was used to track all patients undergoing lower extremity venous duplex ultrasound examination during the study period and was used to produce the data set for the study. The Raymond G. Murphy VA Medical Center Institutional Review Board approved all study activities, and the need for individual patient informed consent was waived. Patients identified for inclusion in the study from the administrative database underwent retrospective chart review to abstract variables of interest, including details of the ED visit, ordering information and results of the duplex ultrasound examination, and demographic parameters. Data were available for a full 2 years after the clinical introduction of the computerized decision-making tool (postintervention group) and were compared with data from the 2 years before introduction of the tool (preintervention group).

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective cohort study
- **Key Findings:** Introduction of a clinical decision-making tool using the Wells score incorporated into the electronic medical record did not decrease after-hours use of 178 venous duplex ultrasound studies to evaluate for deep venous thrombosis and did not significantly increase study positivity compared with 213 historic controls (12.8% vs 18%; $P = .118$), although studies ordered by nurses were more likely to be positive than those ordered by physicians (22% vs 12%; $P = .042$).
- **Take Home Message:** The data suggest that overall, an electronic medical record Wells criteria-based decision-making tool does not reduce after-hours use of venous duplex ultrasound studies for evaluation of acute deep venous thrombosis. However, further investigation is needed to determine why the rate of positivity is higher with nurse-ordered vs physician-ordered studies.

Statistical analysis. Data were analyzed using GraphPad Prism software (version 7.0; GraphPad Software Inc, La Jolla, Calif). Student *t*-test was used for comparisons of continuous data; Fisher exact test was used to determine significance of differences in categorical data. Categorical data describing study results were organized into five discrete categories including positive for acute DVT, chronic DVT, superficial venous thrombosis, negative study, and study positive for other causes of symptoms (eg, incidentally discovered hematoma, Baker cyst).

RESULTS

A total of 391 after-hours venous duplex ultrasound examinations were requested by ED providers during the study period. During the preintervention period, 213 examinations were performed by on-call VL personnel, resulting in 12.2% ($n = 26$) and 7.5% ($n = 16$) of examinations positive for acute DVT and chronic DVT, respectively. Superficial venous thrombosis and alternative causes of lower extremity symptoms were diagnosed in 5.6% ($n = 12$) and 9.9% ($n = 21$), respectively. In the preintervention period, 64% ($n = 138$) of venous duplex ultrasound studies were negative.

For the 2 years after the decision-making tool was instituted, 178 total after-hours duplex ultrasound examinations were performed; 18% ($n = 32$) were positive for acute DVT, whereas 7.9% ($n = 14$) demonstrated chronic DVT. Superficial venous thrombosis and alternative causes of lower extremity symptoms were diagnosed in 6.2% ($n = 11$) and 7.9% ($n = 14$), respectively. In the postintervention period, 60% ($n = 107$) of venous duplex ultrasound studies were negative. The rate of study positivity for acute DVT did not differ between the preintervention

and postintervention periods ($P = .1179$). The quarterly utilization rate (examinations performed per quarter) for after-hours venous duplex ultrasound studies before and after the decision-making tool was introduced did not differ. For the preintervention period, the mean quarterly utilization rate was 27 studies per quarter compared with 22 studies per quarter after the intervention ($P = .24$). Figs 1 and 2 summarize the duplex ultrasound examination results for the two study periods.

Wells score was moderately well correlated with duplex ultrasound examination positivity for acute DVT, with a mean positivity rate of 7% and 17% when the calculated Wells scores were 0 to 1 and 4, respectively. A Wells score of 6 was found to be associated with a 50% study positivity rate; intermediate Wells scores had variable rates of study positivity ranging from approximately 7% to 30%. Fig 3 depicts the rate of duplex ultrasound examination positivity by Wells score.

After institution of the decision-making tool, the mean time between ED presentation and request for a venous duplex ultrasound study significantly decreased from 226 to 165 minutes ($P < .001$). Studies requested by triage nurses were significantly more likely to be positive for acute DVT (22% mean study positivity) compared with those ordered by ED physicians (12% mean study positivity; $P = .042$).

The extent of thrombus involvement, as a percentage of total, is depicted in Fig 4. A significant proportion of patients (21%) were found to have involvement of the superficial venous system, defined as thrombus present in the great saphenous and small saphenous veins. A similar portion of patients (22%) demonstrated thrombus present in the distal calf veins, including the posterior tibial veins, peroneal veins, gastrocnemius veins,

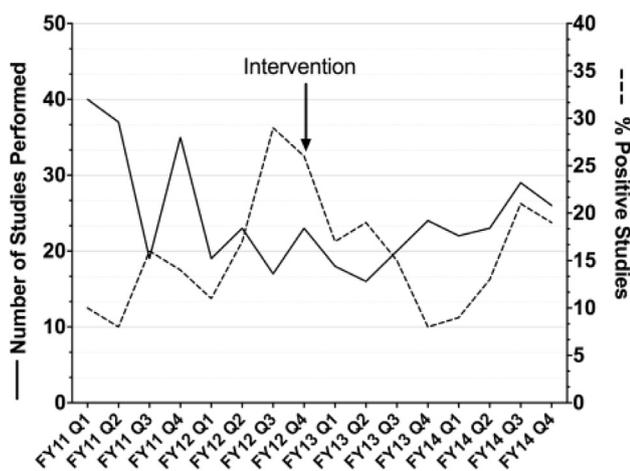
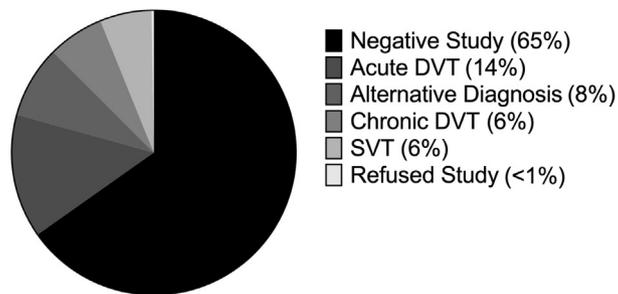


Fig 1. The gross number (plotted on left y-axis) of lower extremity venous duplex ultrasound studies performed during the 4-year study period and the percentage of studies positive for acute deep venous thrombosis (DVT; plotted on right y-axis). Intervention demarcates the clinical introduction of the Wells score decision-making tool. FY, Fiscal year.



Total=391

Fig 2. Overall outcome of all lower extremity venous duplex ultrasound examinations performed throughout the study period. DVT, Deep venous thrombosis; SVT, superficial venous thrombosis.

and soleus veins. More proximal extent of thrombus burden, with involvement of the femoropopliteal deep venous system, was demonstrated in up to 46% of patients and was distributed evenly along the length of the common femoral, superficial femoral, and popliteal venous segments. Propagation of thrombus cephalad to the iliac segment was a comparatively rare occurrence, with only 11% of patients having demonstrable external iliac vein clot on duplex ultrasound examination. All patients with external iliac thrombosis were found to have thrombus present in the femoropopliteal segment, and 70% demonstrated thrombosis of one or more tibial veins as well.

During the 4-year study period, 75 patients were found to have either acute DVT ($n = 45$ [60%]) or chronic (post-thrombotic; $n = 30$ [40%]) thrombus within the deep venous system. Of those with acute DVT, 76% ($n = 34$) were free from clinical pulmonary embolism (PE) on evaluation. Eleven patients with acute DVT (24%) were demonstrated to have concurrent PE on chest imaging; however, only five patients (11%) were clinically symptomatic with vital sign abnormalities such as tachycardia or

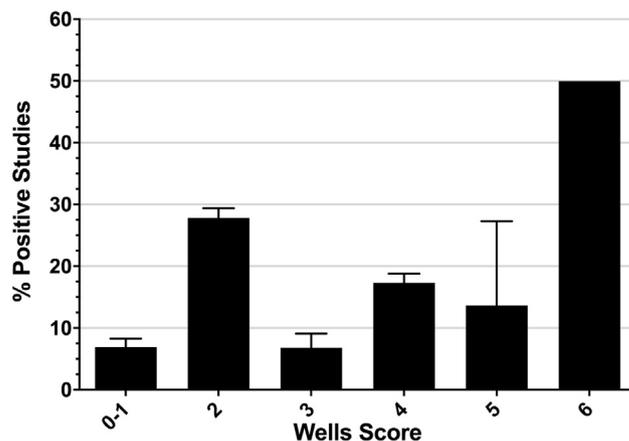


Fig 3. Percentage of duplex ultrasound examinations positive for acute deep venous thrombosis (DVT) by calculated Wells score.

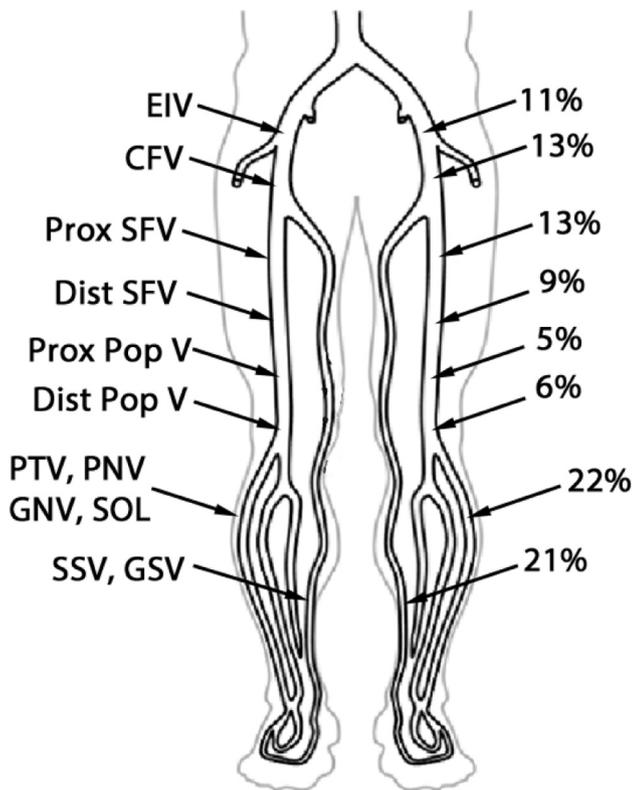


Fig 4. Distribution of observed deep vein thrombosis (DVT) by imaged anatomic venous segment (percentage of total). *CFV*, Common femoral vein; *Dist*, distal; *EIV*, external iliac vein; *GNV*, gastrocnemius vein; *GSV*, great saphenous vein; *PNV*, peroneal vein; *Pop V*, popliteal vein; *Prox*, proximal; *PTV*, posterior tibial vein; *SFV*, superficial femoral vein; *SOL*, soleus vein; *SSV*, short saphenous vein.

hypoxia. The observed incidence of PE in those with chronic DVT was 0%. Of those presenting with acute DVT, 58% ($n = 26$) were admitted to the hospital, whereas only 13% ($n = 4$) of those with chronic thrombus required admission. Admission for care specifically related to the newly diagnosed acute DVT was observed in 65% of patients ($n = 17$) compared with 35% admitted for care primarily for another medical diagnosis ($n = 9$). No patient with chronic DVT was admitted for care related solely to that diagnosis, and all were admitted for other medical reasons.

VL personnel were called in 347 times during the 4-year study period to perform after-hours venous duplex ultrasound examinations, with a total direct cost of \$14,643.40 in on-call pay.

DISCUSSION

The development of DVT and subsequent PE represents a source of potentially significant morbidity and mortality. The "gold standard" method of diagnosing acute DVT is lower extremity duplex ultrasound provided by a qualified VL. After-hours evaluation for possible DVT, particularly in the ED, is complicated by the need for

skilled VL personnel to be available on call, leading to increased administrative and nontangible costs as finite staff resources struggle to meet the demand. These pressures may contribute to staff burnout and abnormally high VL staff turnover. As such, understanding the natural history of after-hours evaluations for DVT, including the distribution and acuity of thrombus burden and frequency of concomitant PE, may aid VL administrators in determining optimal night and weekend staffing. Furthermore, maximizing the pretest probability of duplex ultrasound examination before incurring the administrative cost associated with activating on-call VL personnel should reduce costs and improve efficiency.

The widespread adoption of the electronic medical record (EMR) has paved the way for inclusion of a variety of clinical decision-making tools into staff and physician workflow. In this study, we included a well-validated outpatient scoring system, the Wells score, in the EMR in an effort to maximize the pretest probability that a true DVT exists with the intention of decreasing after-hours VL examination requests and maximizing efficiency of after-hours testing. The intervention resulted in neither decreased VL use nor increased likelihood of positive findings on examination for acute DVT. Many factors may account for this finding, including questions as to the utility of the Wells score in an ED population, which may better approximate an inpatient cohort as opposed to an outpatient population, in which the score was originally described and validated. The observation that triage nurse-driven procurement of duplex ultrasound examinations (after using the Wells score decision-making tool) was statistically more likely to produce an examination positive for DVT (compared with physician-ordered tests) may represent better adherence to the recommendations of the tool on the part of nursing staff. Although artificial score inflation on the part of ordering physicians was suspected on the basis of this pattern, this could not be proven because of deficiencies in provider documentation, limiting our ability to calculate the Wells score independently. Despite the underwhelming effects on physician behavior, the intervention was successful in having an impact on the timeliness of venous duplex ultrasound study requests by decreasing the time from triage to study order by an average of 61 minutes. Although not explicitly reported in our data, the implication would be improvement in ED throughput for those patients presenting with clinically suspected DVT.

The Wells score is composed of three objective parameters and six subjective parameters. As such, inter-rater reliability can be challenging, and these factors may be heightened in a high-acuity environment such as the ED. The clinical utility of the Wells score for exclusion of DVT has been examined by Geersing et al³ using a large patient-level data set derived from the raw data gathered during 13 previous studies. The authors concluded that a

Wells score <1 combined with a negative D-dimer test result was associated with a $<2\%$ probability of acute DVT being present on duplex ultrasound imaging. Similarly, Rahiminejad et al⁴ reported a 0% rate of positive findings on duplex ultrasound examination in those outpatients demonstrating a negative D-dimer test result, low (<1) Wells score, and no clinical risk factors for DVT. Conversely, evidence supporting the use of Wells criteria in hospitalized patients has been underwhelming. Silveira et al⁵ conducted a prospective study examining 1135 inpatients thought to have acute DVT. A 5.9% rate of acute proximal DVT was observed even in the low-risk Wells score (<1) group, with the area under the receiver operating characteristics curve reported as 0.60. The authors suggested that Wells criteria are prone to an unacceptably high failure rate in the inpatient setting, possibly because of the inherently different prevalence of DVT risk factors, such as immobilization and cancer in the hospitalized population. This finding is in keeping with our data reflecting a 7% risk of acute DVT with a Wells score of 0 to 1 in the examined ED population.

A substantial proportion of patients demonstrated thrombus burden isolated to the deep veins at or below the knee or the superficial venous system only. A relative minority of patients with DVT presented with thrombus in the most proximal iliofemoral system. These findings imply that the majority of those evaluated in the ED with acute DVT have thrombus present in a distribution thought to be of low or nearly zero risk of pulmonary embolization. This observation suggests that definitive workup for the presence of DVT may be safely deferred until daylight hours without undue risk of PE conferred to the patient. Martin et al⁶ have proposed an after-hours protocol capitalizing on this observation that involves triage of ED patients into low- and high-risk categories based on Wells score paired with D-dimer testing and administration of a single dose of anticoagulant, such as low-molecular-weight heparin, to those with high probability for the presence of DVT. Patients are then referred for venous duplex ultrasound during daylight hours, when a final diagnosis will be rendered. The authors concluded that the use of on-call after-hours venous duplex ultrasound studies could be effectively and safely eliminated by using the protocol. The data presented herein also support this conclusion as we have shown that among those with clinically suspected DVT, a significant proportion (43%) will ultimately be shown to have thrombotic pathologic processes harboring minimal or no embolic risk, such as thrombus limited to the superficial venous system or isolated to the calf veins. Of those that remain, the majority are afflicted with femoropopliteal DVT, which is generally managed medically with anticoagulation alone. Only a small proportion of patients presenting to the ED harbor thrombus in the iliac segment (11% of total in our series) that may require consideration of surgical consultation

for catheter-directed therapies and is thought to represent the highest risk for embolization. These findings add to an increasing body of evidence suggesting that definitive diagnosis of after-hours DVT may be safely deferred to the following day without compromising optimal management.

Limitations. Whereas this study does add to the collective knowledge regarding the natural history of DVT in the ED population and informs our understanding of how medical providers interact with the EMR, it is not without notable limitations. First, the use of a Wells score of 1 as a threshold for obtaining duplex ultrasound studies would not be expected to have as dramatic an impact as a higher score cutoff or if the addition of ancillary testing, such as D-dimer testing, were implemented. To be successful, decision support tools like the one described herein must weigh efficacy with the realities of clinical practice, and a higher threshold or additional required testing was thought to be unacceptable from a medicolegal and ED throughput standpoint. In addition, as reviewed before, a threshold of 1 is in keeping with previous literature that has defined those with a Wells score of <1 as low risk.

As discussed before, limitations in provider documentation in the EMR rendered us unable to independently calculate the Wells score for each study patient. Therefore, the accuracy of the scores documented using the computerized tool could not be verified.

CONCLUSIONS

An electronic Wells score decision-making tool integrated into the clinical care environment failed to affect overall use of after-hours VL services but did significantly affect timeliness of venous duplex ultrasound study requests. ED nursing staff were significantly more successful in using the tool to increase the pretest probability of VL testing compared with ED physician staff. Given the observed natural history of DVT in the ED population, the utility of maintaining a staff of on-call after-hours VL personnel can be called into question.

AUTHOR CONTRIBUTIONS

Conception and design: RC, DW, JG, EK

Analysis and interpretation: RC, JG, EK

Data collection: RC, DW, EK

Writing the article: RC, EK

Critical revision of the article: RC, DW, JG, EK

Final approval of the article: RC, DW, JG, EK

Statistical analysis: RC

Obtained funding: Not applicable

Overall responsibility: RC

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