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Efficacy and safety of sonographer discretion to terminate a venous duplex ultrasound for diagnosis of deep venous thrombosis in COVID-19 patients

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Efficacy and safety of sonographer discretion to terminate a venous duplex ultrasound for diagnosis of deep venous thrombosis in COVID-19 patients

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Jessie W Ho, MD, Calvin L Chao, MD, Irene B Helenowski, PhD, Ann Dwyer, RVT, Ashley K Vavra, MD, Mark K Eskandari, MD, Katherine E Hekman, MD, PhD, Tadaki M Tomita, MD

*Co-senior authors

1Division of Vascular Surgery, Department of Surgery, Feinberg School of Medicine, Northwestern University

2Division of Vascular Surgery and Endovascular Therapy, Department of Surgery, Emory University School of Medicine

**Corresponding Author:** Jessie Ho, 475 N Fairbanks Ct, Tarry 2-725, Chicago, IL 60611

(jessie.ho@nm.org)

Post-publication **Corresponding Author:** Tadaki Tomita, 675 N St Clair St, Ste 1900, Chicago, IL 60611 (tadaki.tomita@nm.org)

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Keywords: DVT, Duplex ultrasound, COVID-19, Technologist exposure

ARTICLE HIGHLIGHTS

Type of Research: Single-center retrospective study

Key Findings: A modified COVID-19 duplex ultrasound protocol allowing sonographers to terminate the study early upon findings of an acute DVT allowed for significantly abbreviated ultrasounds in both upper (p<0.0001) and lower extremities (p<0.0001) without clinically significant compromise.

Take home Message: A modified COVID-19 duplex ultrasound protocol can significantly decrease ultrasound sonographer exposure to COVID-19, with minimal impact to clinical management.

Table of Contents Summary

Implementation of a modified COVID-19 venous duplex ultrasound protocol decreases ultrasound scan time in COVID-19 patients. Termination of a venous duplex ultrasound to reduce sonographer exposure time is justified without adverse clinical consequences.
Abstract

Objectives
Sonographers performing venous duplex ultrasounds (VDUS) in COVID-19 patients are placed at an increased risk for exposure due to close contact with these patients for an extended period. The objective of this study was to evaluate the efficacy of a modified COVID-19 VDUS protocol in reducing sonographer exposure to COVID-19 patients.

Methods
This was a single center retrospective review. Subjects who underwent a VDUS under the modified COVID-19 protocol between March 1, 2020, and June 30, 2020, with a confirmed or presumed COVID-19 diagnosis at the time of VDUS were included. The modified COVID-19 protocol was defined as the ability of the sonographer to terminate the examination upon detection of an acute deep venous thrombosis (DVT). The primary outcome measures were the number of anatomic deep venous segments recorded by the sonographer, used as a surrogate measure for sonographer exposure time, and the number of acute DVTs on follow-up examinations in segments not visualized on index VDUS.

Results
One hundred sixty lower extremity venous duplex ultrasounds (LEVDUS) and 72 upper extremity venous duplex ultrasounds (UEVDUS) were performed using the COVID-19 protocol. On index VDUS, 27.5% (44/160) of subjects who underwent LEVDUS and 36.6% (26/72) of subjects who underwent UEVDUS had an acute DVT. On follow-up imaging 17.9% (7/38) of LEVDUS and 10% (1/10) of UEVDUS demonstrated a new acute DVT. Malignancy and surgery 30 days prior to imaging were significantly associated with acute lower extremity DVTs, while mechanical ventilation and extracorporeal membrane oxygenation (ECMO) were associated with
acute upper extremity DVTs. On index DUS, there were averages of 10.6 of 14 total visualized segments on LEVDUS and 6.4 of 10 total segments on UEVDUS. In total index VDUS, 35.6% of LEVDUS and 78.6% of UEVDUS were abbreviated. Index VDUS that were positive for acute DVT had significantly fewer visualized segments for both lower (8.4 vs 11.5, p<0.0001) and upper extremities (4.2 vs 7.6, p<0.0001). On follow up examination, only 1 out of 8 new acute DVTs occurred in a subject whose index VDUS was abbreviated, and the corresponding segment not assessed. This finding did not impact the subject’s clinical course.

Conclusion

The modified COVID-19 VDUS protocol reduced sonographers’ potential exposure time to COVID-19. Additionally, the clinical efficacy was maintained, with no missed DVTs despite the abbreviation of VDUS examinations.
Introduction

Coronavirus disease 2019 (COVID-19) has been linked to a high rate of coagulation abnormalities driven by an underlying hypercoagulable state.\textsuperscript{1} COVID-19 infection is thought to directly impact the entirety of Virchow’s triad, including endothelial injury via direct invasion of endothelium, stasis from hospitalization, critical illness, change in activity level, and the aforementioned hypercoagulable state.\textsuperscript{2, 3} Deep venous thrombosis (DVT) remains a common finding in acutely ill COVID-19 patients, with both intensive care unit (ICU) and non-ICU populations demonstrating increased rates of DVT despite thromboprophylaxis.\textsuperscript{4, 5}

As the primary diagnostic modality of DVT remains venous duplex ultrasound (VDUS), vascular laboratories were required to adapt to the demand for screening and diagnostic uses on patients with active COVID-19 infection\textsuperscript{6-8}. These evaluations, typically performed by a vascular sonographer at bedside, require close patient contact in enclosed quarters for approximately 30 minutes, and represent a potential source of exposure to COVID-19. Critically ill patients, often with numerous support devices and catheters, may frequently undergo evaluation of both lower and upper extremities, further prolonging such encounters. Despite mitigation strategies and screening protocols, risk reduction of transmission to health care workers remains paramount. Vascular sonographers also represent a potential source of asymptomatic carriers as they routinely perform studies on both COVID-19 and non-COVID-19 patients.\textsuperscript{9} Efforts to decrease risk include algorithms to reduce the number of ordered VDUS or modified protocols to reduce sonographer exposure time.\textsuperscript{8, 10} However, while the Society for Vascular Ultrasound (SVU) permits limited examinations for patients with COVID-19, the implications of this have not been formally evaluated.\textsuperscript{11}
Any such protocol should ameliorate risk without compromising patient care in the form of missed venous thromboembolic (VTE) events. The objective of this study is to evaluate the safety and efficacy of a modified COVID-19 VDUS protocol to reduce sonographer exposure to COVID-19 patients. Our hypothesis was that a modified COVID-19 VDUS protocol could decrease sonographer exposure time to COVID-19 while maintaining the clinical efficacy of the examination.

Methods

Study Design

This was a single center retrospective review of subjects with COVID-19 who underwent a VDUS under the modified COVID-19 protocol, as described below, from March 1, 2020, to June 30, 2020. This study was approved by the Institutional Review Board of Northwestern University. Informed consent was waived. Subjects were included if they had tested positive or were presumed positive for COVID-19 at the time of VDUS order. The VDUS orders were reviewed by the vascular laboratory and subjects who met the criteria were placed on the modified COVID-19 protocol. Data was extracted from the medical record by three-independent data extractors (JWH, KEH, CLC). Data collection was completed January 2021.

Venous Duplex Ultrasound Scanning and Interpretation

All VDUS were performed by the institution’s vascular laboratory, which is accredited by the Intersocietal Accreditation Commission (IAC). The institution has a well-established and periodically audited protocol for upper and lower extremity VDUS. The institution’s standard lower extremity venous duplex ultrasound (LEVDUS) protocol was to image from proximal (common femoral vein [CFV]) to distal (peroneal) including muscular calf veins, with inclusion of the distal external iliac vein if a DVT was seen at the ipsilateral CFV. The standard upper
extremity venous duplex ultrasound (UEVDUS) protocol was to scan from proximal
(innominate) to distal (forearm). The greater saphenous, small saphenous, basilic, and cephalic
were the included. The upper and lower extremity veins visualized were divided into segments
based on the IAC reporting standards\textsuperscript{12} for peripheral venous testing and the institutional
vascular laboratory protocol. Compressions were performed every 2-3 cm in B mode, with
images acquired in each segment in grayscale and color Doppler. The total images saved were
also recorded. All vascular sonographers held a registered vascular technologist (RVT)
credential. Criteria distinguishing acute DVTs are as previously described\textsuperscript{13}.

\textit{Modified COVID-19 Protocol}

The modified COVID-19 protocol was defined by the ability for sonographers to
terminate the VDUS early if an acute DVT was detected. If no acute DVT was detected, then a
complete VDUS was performed.

Both upper and lower extremity VDUS were eligible for the modified COVID-19
protocol. Orders for the VDUS were placed at the discretion of the ordering provider, who
included intensivists, inpatient and outpatient internists, and emergency medicine providers. We
did not routinely screen patients for DVTs. All VDUS were ordered for symptoms or clinical
status changes. Ultrasound orders were received directly by the vascular laboratory and
reviewed. The vascular surgery team was consulted for clinical review of indications at the
discretion of the vascular laboratory. Vascular surgery review was typically requested for
indications that were atypical or non-specific for DVT such as tachycardia. Emergent indications
including phlegmasia cerulea dolens or compartment syndrome were also referred to the vascular
surgery service for consultation. However, if the indication for the study was typical for DVT
(ex. lower extremity edema or pain), then the study was completed as ordered. Follow-up studies
were conducted as clinically indicated per ordering provider. There were no requirements for follow-up VDUS given the goal of decreasing sonographer exposure.

Supplemental Table 1 displays the deep veins consisting of a complete examination for the purposes of this study. A bilateral LEVDUS and UEVDUS was considered complete if 12 and 10 segments were visualized respectively. All saved images including duplicates of the same segments were counted toward the number of images acquired. All DVTs were treated at the discretion of the ordering provider including infra-popliteal DVTs. Superficial veins (cephalic, basilic, saphenous) were not included in the number of segments for this study. Proximal lower extremity DVTs were defined as proximal to and including the popliteal vein. Proximal upper extremity DVTs were defined as proximal to and including the axillary vein.

**Outcomes and Analysis**

Primary outcomes of interest included DVT rates, number of venous segments visualized, and number of “missed” DVTs. Segments visualized was used as a surrogate for ultrasound scan time. “Missed” DVTs were defined as an acute DVT that was identified on follow-up VDUS in a segment not previously visualized on the index VDUS. Demographic information (age, sex, race, ethnicity), co-morbidities (malignancy, prior DVT, prior pulmonary embolus (PE), stroke), PE rates, and mortality rates were collected. Additional subject characteristics collected were body mass index (BMI), use of extracorporeal membrane oxygenation (ECMO), presence and location (femoral, internal jugular, subclavian, peripheral) of central venous catheters (CVC) (triple lumen catheters, dialysis catheters, introducer sheaths, and peripherally inserted central catheters), need for mechanical ventilation, surgery up to 30 days prior to VDUS, and anticoagulation. Anticoagulation was defined as therapeutic anticoagulation. Prophylactic doses of anticoagulation were not captured in this dataset. ECMO cannulation strategies were variable.
Protek Duo (Cardiac Assist, Pittsburgh, PA) cannulas were placed in the internal jugular. For a bi-caval strategy, the second cannula was placed in a femoral vein, as all ECMO subjects in this cohort underwent veno-venous ECMO.

Subjects who underwent upper and lower extremity VDUS examinations were combined for the purposes of evaluating demographic information and cohort characteristics. For all additional analyses, we examined the LEVDUS and UEVDUS cohorts separately. Descriptive statistics were included for continuous outcomes. Dichotomous outcomes were recorded using counts and percentages. DVTs were classified as acute, chronic, age indeterminant, resolved, or unchanged. Univariate odds ratios and Fisher’s exact test were used for analysis. The segments visualized and images acquired in each DVT group were compared using Wilcoxon rank-sum test. An alpha-level of 0.05 was used to determine significance. Statistical analysis was performed using SAS version 9.4 (SAS Institute, Cary, NC, USA), R 4.0.3, and Microsoft Excel 2010.

Results

Cohort characteristics

From March 2020 to June 2020, 168 unique subjects with COVID-19 underwent VDUS, with a total of 160 LEVDUS studies and 72 UEVDUS studies. Overall, the population was predominantly men (58.3%) with a mean age of 56 years. The mean BMI was 32.63 (Table 1). Most subjects were critically ill in the ICU (70.6% of LEVDUS, and 90.1% of UEVDUS) including 14% on ECMO at the time of VDUS.

DVT types and distribution

Of the LEVDUS cohort, 27.5% (n=44) demonstrated an acute lower extremity DVT on index VDUS. Thirty-eight subjects underwent a follow-up LEVDUS, with 18.4% (n=7) of those
showing a new acute DVT. Among the UEVDUS cohort, 36.6% (n=26) showed an acute DVT on index VDUS (Table 2). Ten subjects underwent a follow-up UEVDUS with 10% (n=1) showing a new acute DVT. The average time between the index and follow-up VDUS was 14 days for both upper and lower extremity VDUS.

Table 3 shows the distribution of acute DVTs in index VDUS. One third of all acute DVTs involved proximal segments (n=20), and two-thirds involved distal segments (n=40). Multiple DVTs (two or more segments) were found in 40.9% with an acute DVT in the lower extremity and 15.4% with an acute DVT in the upper extremity. No patients in this cohort underwent thrombolysis for acute DVTs found on either index or follow-up VDUS.

Risk factors for DVT

Baseline demographics such as gender, race, ethnicity, and age were not significantly associated with acute DVT on index VDUS in either imaging cohort (Table 4). Significant risk factors for acute lower extremity DVT included malignancy (OR 3.51, 95% CI [1.0-12.8], p=0.048) and surgery within 30 days (OR 4.98, 95% CI [1.56-17.4], p<0.05). For the UEVDUS cohort, mechanical ventilation (OR 6.00, 95% CI [1.5-40.5], p =0.025) and ECMO (OR 4.06, 95% CI [1.29-13.8], p=0.02) were associated with increased risk for acute DVT. There was no correlation between location of CVC placement and acute DVT.

Sonographer exposure time

The number of segments visualized and images acquired were utilized as a surrogate for sonographer exposure time and are displayed in Figure 1. A total of 35.7% (n=57) of index LEVDUS and 78.6% (n=55) of index UEVDUS were abbreviated. Subjects who had an acute DVT had significantly fewer average images acquired and segments visualized in both LEVDUS
(images: 18.7 vs 21.9, p<0.003; segments: 8.4 vs 11.5, p<0.0001) and UEVDUS (images: 9.8 vs 17.0, p<0.0001, segments: 4.2 vs 7.6, p<0.0001).

For subjects with an abbreviated LEVDUS, 7.0% had an acute PE diagnosed following VDUS versus 9.7% of subjects with a complete LEVDUS, which was not significant (p=0.77).

There was no significant difference in mortality between abbreviated vs complete groups (19.2% vs 15.0%, p=0.77). For the UEVDUS cohort, there was also no significant difference in PE (0% vs 3.6%) or mortality (27.3% vs 13.3%, p=0.32) between those who had an abbreviated vs complete VDUS.

Indications for follow-up VDUS were extremity pain, edema, and change in clinical status including hypoxia, fever, and increase in D-dimer. The purpose of a follow-up VDUS in those with an acute DVT on index duplex was to evaluate for thrombus extension. There was a total of 8 new acute DVTs on follow-up VDUS (7 lower extremity, 1 upper extremity). The cases are presented in Table 5. Two subjects with a new acute DVT on follow-up had an abbreviated index VDUS. In one case, the segments affected in the follow-up study (axillary, subclavian, brachial) were visualized without acute DVT in the index VDUS. Since the acute DVT occurred in a segment that was previously visualized on the index VDUS, we considered this a new DVT and not a “missed” DVT. In the second case, the acute DVT on follow-up study was found in a segment not previously visualized on the index VDUS. The DVT was in the gastrocnemius whereas, there was a proximal DVT in the CFV on the index VDUS leading to an abbreviated examination per protocol. Thus, there was one “missed” DVT in the combined cohorts. This subject was being treated with anticoagulation at the time of the follow-up VDUS, given the index VDUS findings of a proximal acute DVT.

Discussion
Venous duplex ultrasound, the test of choice for evaluating extremity DVTs, requires close patient contact to perform, which presents a potential occupational hazard for sonographers when scanning COVID-19 positive patients. This study finds that a modified COVID-19 VDUS protocol in which a VDUS can be terminated early following findings of an acute DVT can shorten sonographers’ exposure time without adverse clinical consequences. This study provides a practical protocol for reducing sonographer occupational hazard while maintaining the clinical integrity of VDUS examinations.

COVID-19 is associated with a hypercoagulable state with a multifactorial etiology related to endothelial injury leading to microvascular thrombi formation and fibrinolysis\textsuperscript{14}. High DVT rates in COVID-19 patients range from under 10\% to 35\%, with studies in critically ill patients citing up to 79\%\textsuperscript{4,15,16}. A systematic review reports a pooled VTE rate of 31.3\%, with a rate of 29.4\% in symptomatic patients and 37.1\% in screened patients\textsuperscript{15}. Our study found an overall acute DVT rate of 29.2\%, with a 27.5\% rate of acute lower extremity DVTs and a 36.6\% rate of upper extremity DVTs. Studies evaluating screening have demonstrated no significant benefit in asymptomatic patients with COVID-19, further supported by findings that 67.6\% of patients with a PE did not have a prior DVT\textsuperscript{17-19}. Current guidelines from the National Institute of Health (NIH) and American College of Chest Physicians (CHEST) do not recommend routine screening, however clinicians should have a low threshold to perform VDUS examinations in patients with a clinical suspicion for DVT\textsuperscript{20,21}.

Given the existing body of literature on high DVT rates in COVID-19, the goal of this study was to evaluate the impact of an abbreviated VDUS on clinical care and sonographer exposure. We recognize that there are significant ramifications of DVTs in COVID-19 patients, but we should also note the occupational hazards that may accompany the mode of diagnosis.
Previous studies have demonstrated workplace exposure to be a risk for COVID-19 transmission among healthcare workers and patients. While there are no specific prior articles evaluating the risks of COVID-19 exposure in sonographers, it has been demonstrated that there is an increased risk for transmission for nurses, staff working on COVID units, and those who have high-risk exposures.

Our standard institutional protocol assesses all vessels of interest at 2-3 cm intervals. This typically correlates with several images per segment and may require contact with patients for a variable amount of time. Typically, 45 minutes is allotted for a LEVDUS and 60 minutes is allotted for an UEVDUS including transit, scan, annotation, and uploading time. The scan and exposure time can vary considerably from 15-45 minutes depending on the patient height, indwelling catheters/cannulas, and model of ultrasound machine. Indwelling catheters and ECMO cannulas may also make VDUS more difficult requiring increased time and positioning while in close contact. This may also account for the abbreviated scans, particularly in the upper extremities, in which segments were unable to be scanned due to catheters/cannulas. While the SVU permits shortened exams to decrease exposure, there are no standard recommendations or protocols.

Dua et al established an institutional protocol with a goal to decrease the length of VDUS examinations and limit the number of VDUS examinations performed. Their protocol triaged orders by, suggesting initiation of anticoagulation for those with a high likelihood of VTE and attending physician discussion for those requesting a VDUS, resulting in cancellation of 72% of orders. Their study found that examinations performed under the COVID-19 protocol required 50% less time to complete than a conventional examination with a median examination time of 13 minutes vs 6 minutes, for a conventional vs modified COVID-19 protocol respectively.
decrease the scan time, the protocol did not image infra-popliteal veins and limited color/spectral Doppler imaging to proximal veins. Our protocol allowed for termination of the study if an acute DVT was detected by the sonographer. Using segments visualized as a surrogate for scan time, we found that implementation of the protocol decreased the segments visualized in both the upper (4.2 vs 7.6) and the lower extremity (8.4 vs 11.5) cohorts in subjects who had an acute DVT. This finding demonstrates that the protocol was effectively implemented and resulted in abbreviated examinations for those who had an acute DVT. While we do see a significantly decreased number of segments visualized in VDUS with an acute DVT, the study also demonstrates a 31.4% rate of multiple DVTs, implying that more VDUS had the potential to be abbreviated.

There were few proximal lower extremity DVTs detected in this study, with no subjects requiring thrombolysis following VDUS. Majority of DVTs in lower extremities were distal DVTs. While there are no definitive guidelines on management of infra-popliteal DVTs, a meta-analysis indicates that anticoagulation can decrease the recurrence of VTE and DVT with no increase in clinically relevant non-major bleeding events\textsuperscript{28, 29}. Thus, there may remain value for management in detecting distal lower extremity DVTs. While the decision for treatment of DVTs was made by the ordering clinicians, our practice pattern is to initiate anticoagulation for infra-popliteal DVTs.

There were few DVTs found on follow-up that were not present in the index VDUS. There was only one DVT in a follow-up VDUS in a segment that was not previously imaged. If detected on the index VDUS, the finding ultimately would not have changed management given that the patient had an acute DVT in a more proximal segment and was anticoagulated as a result. The second DVT following an abbreviated index VDUS was in a segment previously
imaged and can be interpreted as a new DVT. Thus, additional follow-up VDUS were unlikely to be necessary due to “missed” DVTs from an abbreviated examination. Furthermore, there were no significant differences in PE and mortality rates between those with an abbreviated VDUS and those with a complete VDUS. As the clinical value to performing a VDUS is the prevention of life-threatening PEs, it is critically important that implementation of a new VDUS protocol does not increase PE rates. These findings demonstrate that the modified COVID-19 VDUS protocol maintains the clinical integrity of the examination while allowing for shorter VDUS examination times.

Limitations

This study is inherently limited by its retrospective nature, small number of subjects, and single-institution design. There are also limitations to data obtained via chart review. We also may not have fully captured those who had COVID-19 and underwent a VDUS. Additionally, we were unable to collect data on outcomes of those who did not undergo an ultrasound due to the triage system. Therefore, we were unable to distinguish whether patients had a deferred VDUS for emergent versus insufficient clinical indications. While there are now other articles describing institutional triage systems, this data was unavailable at the time of protocol initiation given the early implementation during the pandemic. Thus, the triage system was not validated prior to implementation.

We also used segments visualized and images acquired as surrogates for time spent exposed to the subject. While fewer segments visualized or images acquired strongly suggests that there was less contact, we did not record the scan or in-room time. Thus, the scan time was unable to be compared between individual sonographers or trended throughout the protocol period. Given that the decision to terminate the scan was made by the sonographer, some
sonographers may have variable levels of scanning experience and may consistently have chosen to complete the scan despite findings of an acute DVT evidenced by scans with findings of multiple DVTs. While the reason for completing scans is unclear, sonographers may benefit from education or encouragement that a complete scan may not alter management. While we did not consider this a protocol violation requiring remediation, the deviation requires evaluation for the underlying rationale and will be a target for future improvement.

Lastly, if on follow-up VDUS, there is proximal extension of the thrombus, this would be detected, as the images are collected from proximal to distal. This allows for detection of treatment failure due to proximal extension. However, in an abbreviated VDUS the distal extent of the thrombus is unknown so distal extension of thrombus due to increased distal thrombus burden is unable to be evaluated in this protocol. If the distal extent of the thrombus presents value in a possible need for thrombolysis, it is likely that further imaging would be completed prior to or at the time of thrombolysis.

Future work should evaluate the risk reduction in sonographers associated with abbreviated exams. This would require a larger cohort of sonographers to collect data on the incidence of COVID-19 infections while maintaining anonymity. Currently, the protocol has become optional due to decreasing rates of COVID-19 infection. We continue to advocate for minimizing COVID-19 exposure for sonographers and will reinstate promotion and education for sonographers on the protocol if there is a resurgence of COVID-19 rates. The protocol may also be utilized if a future pandemic or contact transmissible disease affects our population in large numbers. A specific population prevalence of COVID-19 has not yet been set as a trigger for re-instituting the protocol, but this may be considered in the future.

**Conclusion**
This study contributes to the paucity of literature addressing sonographer occupational hazards during the COVID-19 pandemic. Our study discusses the successful implementation of a modified COVID-19 VDUS protocol, which may allow for decreased workplace exposure to COVID-19 for sonographers. Furthermore, these findings demonstrate that the efficacy of the examination can be maintained without changes to clinical management despite abbreviation.

**Author Contributions**

Concept and Design: JWH, KEH, CLC, AKV, MKE, TTM

Analysis and Interpretation: JWH, KEH, IBH

Statistical Analysis: IBH

Data Collection: JWH, KEH, CLC

Writing the manuscript: JWH, CLC, KEH

Critical revision of the article: JWH, KEH, CLC, MKE, AKV, TTM, IBH
References

1. Connors JM, Levy JH. Thromboinflammation and the hypercoagulability of COVID-19. J Thromb Haemost. 2020;18:1559-61.

2. Perico L, Benigni A, Casiraghi F, Ng LFP, Renia L, Remuzzi G. Immunity, endothelial injury and complement-induced coagulopathy in COVID-19. Nat Rev Nephrol. 2021;17:46-64.

3. Ahmed S, Zimba O, Gasparyan AY. Thrombosis in Coronavirus disease 2019 (COVID-19) through the prism of Virchow's triad. Clin Rheumatol. 2020;39:2529-43.

4. Voicu S, Bonnin P, Stépanian A, Chousterman BG, Le Gall A, Malissin I, et al. High Prevalence of Deep Vein Thrombosis in Mechanically Ventilated COVID-19 Patients. J Am Coll Cardiol. 2020;76:480-2.

5. Santoliquido A, Porfidia A, Nesce A, De Matteis G, Marrone G, Porceddu E, et al. Incidence of deep vein thrombosis among non-ICU patients hospitalized for COVID-19 despite pharmacological thromboprophylaxis. J Thromb Haemost. 2020;18:2358-63.

6. Llitjos JF, Leclerc M, Chochois C, Monsallier JM, Ramakers M, Auvray M, et al. High incidence of venous thromboembolic events in anticoagulated severe COVID-19 patients. J Thromb Haemost. 2020;18:1743-6.

7. Hamadé A, Jambert L, Tousch J, Talbot M, Dervieux B, El Nazer T, et al. Systematic duplex ultrasound screening in conventional units for COVID-19 patients with follow-up of 5 days. J Vasc Surg Venous Lymphat Disord. 2021;9:853-8.

8. Dua A, Thondapu V, Rosovsky R, Hunt D, Latz C, Waller HD, et al. Deep vein thrombosis protocol optimization to minimize healthcare worker exposure in coronavirus disease-2019. J Vasc Surg Venous Lymphat Disord. 2021;9:299-306.
9. Black JRM, Bailey C, Przewrocka J, Dijkstra KK, Swanton C. COVID-19: the case for health-care worker screening to prevent hospital transmission. Lancet. 2020;395:1418-20.

10. Gawande RS, Vadvala HV, Shan A, Sheth S. Ultrasound Studies of COVID-19-Positive Patients and Patient Under Investigation: Pandemic Experience of Body Imaging Division at a Tertiary Medical Center. Ultrasound Q. 2021;37:254-60.

11. Ultrasound SfV. Vascular Laboratory Responses During the COVID-19 Pandemic. 2020 [cited 2021 November 10]; Available from: https://www.svu.org/svu-news/4183/.

12. The IAC Standards and Guidelines for Vascular Testing Accreditation. Intersocietal Accreditation Commission 2018 [cited 2022 January 25]; Available from: https://www.intersocietal.org/vascular/standards/html/2018/b_4.html.

13. Hekman KE, Chao CL, Morgan CE, Helenowski IB, Eskandari MK. Direct oral anticoagulants decrease treatment failure for acute lower extremity deep venous thrombosis. Vascular. 2021:17085381211042231.

14. Kichloo A, Dettloff K, Aljadah M, Albosta M, Jamal S, Singh J, et al. COVID-19 and Hypercoagulability: A Review. Clin Appl Thromb Hemost. 2020;26:1076029620962853.

15. Di Minno A, Ambrosino P, Calcaterra I, Di Minno MND. COVID-19 and Venous Thromboembolism: A Meta-analysis of Literature Studies. Semin Thromb Hemost. 2020;46:763-71.

16. Yu Y, Tu J, Lei B, Shu H, Zou X, Li R, et al. Incidence and Risk Factors of Deep Vein Thrombosis in Hospitalized COVID-19 Patients. Clin Appl Thromb Hemost. 2020;26:1076029620953217.
17. Tung-Chen Y, Calderón R, Marcelo C, Deodati F, Mateos M, Castellano A, et al. Duplex Ultrasound Screening for Deep and Superficial Vein Thrombosis in COVID-19 Patients. J Ultrasound Med. 2021.

18. Sebuhyan M, Mirailles R, Crichi B, Frere C, Bonnin P, Bergeron-Lafaurie A, et al. How to screen and diagnose deep venous thrombosis (DVT) in patients hospitalized for or suspected of COVID-19 infection, outside the intensive care units. J Med Vasc. 2020;45:334-43.

19. Suh YJ, Hong H, Ohana M, Bompard F, Revel MP, Valle C, et al. Pulmonary Embolism and Deep Vein Thrombosis in COVID-19: A Systematic Review and Meta-Analysis. Radiology. 2021;298:E70-e80.

20. Moores LK, Tritschler T, Brosnahan S, Carrier M, Collen JF, Doerschug K, et al. Prevention, Diagnosis, and Treatment of VTE in Patients With Coronavirus Disease 2019: CHEST Guideline and Expert Panel Report. Chest. 2020;158:1143-63.

21. Antithrombotic Therapy in Patients With COVID-19. National Institute of Health; 2021 [updated February 11, 2021; cited 2021 December 13].

22. Stüven P, Mühlenbruch G, Evenschor-Ascheid A, Conzen E, Peters C, Schablon A, et al. COVID-19 infections in staff of an emergency care hospital after the first wave of the pandemic in Germany. GMS Hyg Infect Control. 2022;17:Doc04.

23. Wilson S, Mouet A, Jeanne-Leroyer C, Borgey F, Odinet-Raulin E, Humbert X, et al. Professional practice for COVID-19 risk reduction among health care workers: A cross-sectional study with matched case-control comparison. PLoS One. 2022;17:e0264232.

24. Correa-Martínez CL, Schwierzeck V, Mellmann A, Hennies M, Kampmeier S. Healthcare-Associated SARS-CoV-2 Transmission-Experiences from a German University Hospital. Microorganisms. 2020;8.
25. Biernat MM, Zięczuk A, Biernat P, Bogucka-Fedorczuk A, Kwiatkowski J, Kalicińska E, et al. Nosocomial outbreak of SARS-CoV-2 infection in a haematological unit - High mortality rate in infected patients with haematologic malignancies. J Clin Virol. 2020;130:104574.

26. Wang X, Zhou Q, He Y, Liu L, Ma X, Wei X, et al. Nosocomial outbreak of COVID-19 pneumonia in Wuhan, China. Eur Respir J. 2020;55.

27. Wratil PR, Schmacke NA, Osterman A, Weinberger T, Rech J, Karakoc B, et al. In-depth profiling of COVID-19 risk factors and preventive measures in healthcare workers. Infection. 2022;50:381-94.

28. Kirkilesis G, Kakkos SK, Bicknell C, Salim S, Kakavia K. Treatment of distal deep vein thrombosis. Cochrane Database Syst Rev. 2020;4:Cd013422.

29. Fleck D, Albadawi H, Wallace A, Knuttinen G, Naidu S, Oklu R. Below-knee deep vein thrombosis (DVT): diagnostic and treatment patterns. Cardiovasc Diagn Ther. 2017;7:S134-s9.
|                      | Patients N=168 |
|----------------------|----------------|
| Gender               |                |
| Male                 | 98 (58.3%)     |
| Female               | 70 (41.7%)     |
| Race                 |                |
| Caucasian            | 50 (29.7%)     |
| Black                | 66 (39.2%)     |
| Asian                | 6 (3.6%)       |
| Other                | 42 (25%)       |
| Declined             | 4 (2.4%)       |
| Ethnicity            |                |
| Hispanic             | 61 (36.3%)     |
| Age                  |                |
| Mean                 | 56             |
| Median [min, max]    | 56 [17, 93]    |
| BMI                  |                |
| Mean                 | 32.63          |
| Median [min, max]    | 31.15 [17.72, 81.81] |

**Table 1.** Demographics for complete cohort
| Type of DVT          | Lower Extremity | Upper Extremity |
|---------------------|-----------------|-----------------|
|                     | Index Duplex    | Follow-up Duplex| Index Duplex | Follow-up Duplex |
|                     | (N=160)         | (N=38)          | (N=72)       | (N=10)           |
| No DVT              | 108 (67.5%)     | 22 (57.9%)      | 45 (62.5%)   | 6 (60%)          |
| Acute DVT           | 44 (27.5%)      | 7 (18.4%)       | 26 (36.6%)   | 1 (10%)          |
| Chronic DVT         | 8 (5.0%)        | 2 (5.3%)        | 0            | 0                |
| Age Indeterminant DVT | 0              | 0              | 1 (1.4%)     | 0                |
| Resolved DVT        |                 | 3 (7.9%)        |              | 1 (10%)          |
| Unchanged DVT       | 4 (10.5%)       | 2 (20%)         |              |                  |

*Table 2.* Deep venous thrombosis (DVT) type in lower extremity and upper extremity duplexes
| Segments (LE) | # of Acute DVTs | Segments (UE) | # of Acute DVTs |
|--------------|----------------|---------------|----------------|
| Iliac        | 0              | Innominate/Brachiocephalic | 2              |
| Common Femoral | 9              | Internal Jugular         | 13             |
| Femoral      | 5              | Subclavian            | 1              |
| Popliteal    | 6              | Axillary              | 9              |
| Posterior Tibial | 13            | Brachial              | 5              |
| Peroneal     | 10             | Forearm               | 0              |
| Gastrocnemius | 13             |                     |                |
| Soleus       | 24             |                     |                |

**Table 3.** Number of acute deep venous thromboses (DVTs) by segment found on index duplex. (LE=lower extremity, UE=upper extremity)
| Risk Factors       | Lower Extremity | Upper Extremity | Odds Ratio (95% CI) | P value | Odds Ratio (95% CI) | P value |
|-------------------|----------------|----------------|---------------------|---------|---------------------|---------|
|                   | No DVT (N=108) | Acute DVT (N=44) |                   |         | No DVT (N=46)      |         |
| Male              | 58 (53.7%)     | 30 (68.2%)     | 1.87 (0.91, 3.97)  | 0.10    | 25 (54.3%)          | 2.17 (0.78, 6.50) | 0.15 |
| Non-White         | 80 (74.1%)     | 27 (61.4%)     | 0.67 (0.32, 1.45)  | 0.30    | 30 (65.2%)          | 1.0 (0.34, 3.10) | >0.99 |
| Hispanic          | 42 (28.9%)     | 16 (36.4%)     | 0.98 (0.47, 2.01)  | 0.95    | 20 (43.4%)          | 0.72 (0.26, 1.92) | 0.51 |
| Age >65           | 31 (28.7%)     | 13 (29.5%)     | 0.90 (0.41, 1.88)  | 0.77    | 10 (21.7%)          | 1.85 (0.63, 5.46) | 0.26 |
| Prior DVT         | 9 (8.3%)       | 5 (11.4%)      | 0.93 (0.29, 2.63)  | 0.90    | 3 (6.5%)            | 0.56 (0.03, 4.64) | 0.62 |
| Prior PE          | 8 (7.4%)       | 1 (2.3%)       | 0.25 (0.01, 1.35)  | 0.19    | 1 (2.2%)            | 0       |
| Stroke            | 4 (3.7%)       | 4 (9.1%)       | 2.22 (0.53, 8.79)  | 0.25    | 3 (6.5%)            | 0       |
| Malignancy        | 4 (3.7%)       | 6 (13.6%)      | 3.51 (1.0, 12.8)   | **0.05**| 3 (6.5%)            | 1.17 (0.15, 7.52) | 0.87 |
| ECMO              | 11 (10.2%)     | 3 (6.8%)       | 1.38 (0.49, 3.59)  | 0.52    | 6 (13.0%)           | 4.06 (1.29, 13.8) | **0.02** |
| UE CVC            |                | 26 (56.5%)     | 21 (80.8%)         | 2.55 (0.85, 8.76) | 0.11 |
| LE CVC            | 1 (0.9%)       | 3 (6.8%)       | 4.17 (0.67, 32.5)  | 0.12    | 3 (6.5%)            | 0.55 (0.03, 4.54) | 0.61 |
| Mechanical Ventilation | 61 (56.5%) | 28 (63.6%) | 1.35 (0.66, 2.80)  | 0.42    | 30 (65.2%)          | 6.00 (1.5, 40.5) | **0.03** |
| Surgery within 30 days | 5 (4.6%) | 8 (18.2%) | 4.98 (1.56, 17.4)  | **0.01**| 3 (6.5%)            | 0.55 (0.03, 4.54) | 0.61 |
| On AC             | 2              | 4              | 0.79 (0.21, 2.39)  | 0.70    | 8                  | 3.91 (0.71, 29.8) | 0.13 |
Table 4. Univariate analysis of risk factors for acute DVTs. DVT= deep venous thrombosis, PE=pulmonary embolism, ECMO=extracorporeal membrane oxygenation, UE CVC= upper extremity central venous catheter, LE CVC= lower extremity central venous catheter, AC= anticoagulation
| Case # | Segments with acute or chronic DVT, index study | Complete Index Study? | Segments with acute DVT, follow-up study |
|-------|-----------------------------------------------|-----------------------|----------------------------------------|
| 1     | None                                          | Yes                   | Left: Gastrocnemius                     |
| 2     | None                                          | Yes                   | Right: Popliteal, Left Common Femoral Vein |
| 3     | None                                          | Yes                   | Right: Posterior Tibial                 |
| 4     | Right: Common Femoral Vein                    | No                    | Right: Gastrocnemius*                   |
| 5     | Right: Gastrocnemius, Peroneal, Soleus Left: Posterior tibial | Yes                   | Right: Gastrocnemius, Peroneal, Soleus (unchanged) Left: Peroneal |
| 6     | Left: Peroneal (chronic)                      | Yes                   | Left: Gastrocnemius                     |
| 7     | Right: Popliteal, gastrocnemius, peroneal (chronic) Left: Gastrocnemius, peroneal, soleus (chronic) | Yes                   | Right: peroneal, popliteal, gastrocnemius (chronic) Left: peroneal, soleus (acute), gastrocnemius (chronic) |
| 8     | None                                          | No                    | Left: subclavian, axillary, brachial**  |

Table 5. Segments visualized in the index and follow up studies in patients with an acute deep venous thrombosis (DVT) on follow-up study

*New acute DVT not visualized on index study

**Segments with new acute DVT in segment previously visualized on index study
| Lower Extremity Venous Segments | Upper Extremity Venous Segments |
|--------------------------------|--------------------------------|
| Common Femoral                 | Internal Jugular               |
| Femoral                        | Innominate                    |
| Popliteal                      | Subclavian                    |
| Posterior Tibial               | Axillary                      |
| Peroneal                       | Brachial                      |
| Gastrocnemius                  |                                |

**Supplement Table 1.** Veins visualized in a complete lower extremity and upper extremity venous duplex
Figure 1. Segments visualized and images acquired in upper and lower extremity venous duplexes by deep venous thrombosis (DVT) type. Upper extremity venous duplex ultrasound=UEVDUS, lower extremity venous duplex ultrasound=LEVDUS. A. Images acquired on UEVDUS by DVT type (images: 9.8 vs 17.0, *p<0.0001) B. Segments visualized on UEVDUS by DVT type (segments: 4.2 vs 7.6, *p<0.0001) C. Images acquired on LEVDUS by DVT type (18.7 vs 21.9, +p<0.003) D. Segments visualized on LEVDUS by DVT type (segments: 8.4 vs 11.5, *p<0.0001)
Table 1. Demographics for complete cohort

Table 2. Deep venous thrombosis (DVT) type in lower extremity and upper extremity duplexes

Table 3. Number of acute deep venous thromboses (DVTs) by segment found on index duplex. (LE=lower extremity, UE=upper extremity)

Table 4. Univariate analysis of risk factors for acute DVTs. DVT= deep venous thrombosis, PE=pulmonary embolism, ECMO=extracorporeal membrane oxygenation, UE CVC= upper extremity central venous catheter, LE CVC= lower extremity central venous catheter, AC= anticoagulation

Table 5. Segments visualized in the index and follow up studies in patients with an acute deep venous thrombosis (DVT) on follow-up study
*New acute DVT not visualized on index study
**Segments with new acute DVT in segment previously visualized on index study

Supplement Table 1. Veins visualized in a complete lower extremity and upper extremity venous duplex

Figure 1. Segments visualized and images acquired in upper and lower extremity venous duplexes by deep venous thrombosis (DVT) type. Upper extremity venous duplex ultrasound= UEVDUS, lower extremity venous duplex ultrasound= LEVDUS. A. Images acquired on UEVDUS by DVT type (images: 9.8 vs 17.0, *p<0.0001) B. Segments visualized on UEVDUS by DVT type (segments: 4.2 vs 7.6, *p<0.0001) C. Images acquired on LEVDUS by DVT type (18.7 vs 21.9, +p<0.003) D. Segments visualized on LEVDUS by DVT type (segments: 8.4 vs 11.5, *p<0.0001)
