Critically ill patients are at the highest risk for developing compression ultrasonography. The embolic risk of a LEDVT is related to its location within the venous system. Proximal LEDVT’s, those arising in the iliacs, femoral and popliteal veins have a 50% risk of PE [2]. Distal LEDVT’s, those arising in the calf veins, have a much lower risk of embolization and is related to the risk of extension into the proximal venous system. Distal LEDVT’s make up only 20% of all LEDVTs. When found they extend proximally with a wide variation ranging from 0 to 29% [12, 13].

Diagnosing distal LEDVT’s is more complex, time consuming and is not routinely done by our critical care physicians. If a negative CUS is performed and the risk remains high a repeat CUS is performed within one week. This should pick up any missed distal LEDVT that may have extended proximally. This strategy is supported in the literature. In a recent meta-analysis by Righini, six large prospective outcome studies, comprising 5876 patients, of serial proximal CUS were reviewed. In all of these studies CUS of the proximal veins were evaluated. If negative for LEDVT they were repeated one week later. The second CUS yielded a 1 to 5.7% new proximal LEDVT, which may be related to extension of a previously undiagnosed calf DVT. The pooled three month thromboembolic risk was 0.6% [12].
DIAGNOSIS OF LEDVT

The diagnosis of LEDVT can be made by both ultrasound and non-ultrasound modalities, all of which have different sensitivities and specificities, ease of performance, and risk to the patient. Understanding their limitations is essential for the proper selection of appropriate testing. Listed below are those modalities available to the clinician in pursuit of a diagnosis of LEDVT.

Contrast Venography: It is still considered the “Gold Standard” for diagnosing LEDVT, with a high sensitivity and specificity. This modality has little utility in the critically ill patient population due to invasiveness, transportation issues, contrast nephropathy, and dye allergies.

CT Venography: Shown to have similar sensitivity and specificity to Ultrasound. It adds to the sensitivity of CT angiograms in the diagnosis of PE [14]. It has similar disadvantages to contrast venography.

Impedance Plethysmography: This method evaluates changes in blood volume by electrical impedance variation of the lower limbs. It has been shown to have inferior accuracy to ultrasound [15]. Its major limitation is that it does not detect nonoclusive thrombus, which is easily seen by compression ultrasonography [16].

MR Venography: Alternative to CT venography in patients with contrast allergy. MR should not be used in critically ill patients due to transportation issues.

ULTRASOUND FOR THE DETECTION OF LEDVT

Compression Ultrasound: Using B-mode 2-D imaging and a high frequency linear transducer the examiner locates the vessel of interest and in transverse plane performs a compression maneuver. Using the adjacent artery as a reference point, full compression of the vein with minimal deformation of the artery indicates absence of thrombus. If a vein is compressible the walls of the vessel will join together under direct pressure from the transducer resulting in the disappearance of the vessel lumen. (Video 1 Normal Compression)

Duplex and Triplex Ultrasound: Combines compression ultrasound with pulse-wave Doppler (duplex) and both pulse-wave and color Doppler (triplex). According to the Intersocietal Commission for the Accreditation of Vascular Laboratories (ICAVL) duplex ultrasonography with color flow Doppler must be provided as Instrumentation in order for a vascular laboratory to obtain accreditation [17].

Ultrasound Strategies: Compression Ultrasound is a highly accurate and easy to use modality in the detection of LEDVT. Kearon et al. performed a large meta-analysis on the sensitivity and specificity of CUS, for the detection of LEDVT in symptomatic outpatients. There was an estimated overall sensitivity of 89%, specificity of 94%, and positive predictive value of 94% for the detection of both proximal and distal LEDVT. For just proximal LEDVT the sensitivity and specificity were both higher (97% and 98% respectively with a 97% PPV) [15].

What constitutes a “standard ultrasound examination” of the lower extremity venous system is still debatable. A standardized ultrasound examination performed by both vascular and radiology laboratories typically includes a combination of pulse wave and color flow analysis with CUS of the entire lower extremity venous system. There is still some controversy as to whether compression ultrasound alone is equivalent to both duplex and triplex scanning.

Birdwell et al. studied whether anticoagulation can be withheld on the basis of a negative compression ultrasonography exam on 405 symptomatic outpatients. The common femoral vein was imaged from the inguinal line to its bifurcation into the superficial femoral vein and profunda femoris. The popliteal vein was imaged from the proximal popliteal fossa to a point 10 cm distal from the mid-patella. If the compression was normal anticoagulation was withheld and a repeat exam was done in 5 to 7 days. Of the 405 patients 70 had a LEDVT diagnosed; of the remaining, only 2 patients had a LEDVT diagnosed at 3 month follow-up. Based on these results it is reasonable to withhold anticoagulation following a normal compression ultrasonography [18].

Should One Evaluate the Whole Lower Extremity Venous System or can we Image Selectively at Certain Key Points?

A recent study by Bernardi et al. evaluated the equivalence of so called “two-point” CUS to standard duplex lower extremity ultrasonography. Similar to Birdwell’s study, CUS was performed at the common femoral region and the popliteal fossa to the point of the calf veins. 2098 patients, who were suspected on clinical examination to have a LEDVT, were randomized to either two point compression or whole leg duplex ultrasonography. All patients randomized to the two-point strategy also received D-dimer testing. Patients with an elevated D-Dimer at baseline with a normal two-point compression study had their study repeated 5-7 days later. Anticoagulation was withheld on all negative ultrasound exams in both the two-point and whole leg ultrasonography groups. All patients then received a repeat lower extremity ultrasound exam at 3 months. The incidence of confirmed LEDVT during the follow-up at 3 months was similar with both strategies. LEDVT occurred in 0.9% of the two-point group and 1.2% of the whole leg group demonstrating that serial two point compression is equivalent to whole leg color Doppler ultrasonography [19].

How Difficult is CUS to Perform?

Two-Point ultrasonography is a rapid and efficient method to detect LEDVT. Emergency Medicine attending physicians were shown to be highly accurate and had a median scanning time of 3min and 21 seconds [20]. Emergency medicine residents were shown to be accurate in detecting LEDVT after training in a limited two site examination. They received a 90 minute training session consisting of both lecture and hands on training [21]. Compared to trained vascular technicians, these residents showed 89% sensitivity for the detection of LEDVT.

To date no studies assessing the accuracy of intensivists performing CUS for the detection of LEDVT compared to vascular or radiology technicians have been completed. Based on Emergency Medicine attending and resident data and the relatively steep learning curve in performing CUS there is no reason to believe that accuracy rates would be significantly lower compared to ultrasound technicians. Further, the bedside clinician performs the exam in real time,
anytime, and can perform an appropriate follow-up exam when necessary.

Which Compression Strategy to Employ?

Published studies suggest that compression ultrasound of the lower extremity with color and pulse wave Doppler does not increase the accuracy of the examination, over CUS alone [18, 19, 21, 22]. In our ICU we employ CUS without the use of Doppler interrogation of the venous system. In cases where the patient is edematous or obese and identification of a venous segment is in question, an augmentation maneuver may be performed. This maneuver is done by manually compressing the calf, with the vascular probe over the vessel of interest. With the color Doppler on, the venous segment should fill with color.

The main question is which CUS technique to employ; a complete or limited two-point compression exam. In a complete exam you compress at approximately 2cm segments over the entire proximal venous system to the trifurcation of the popliteal veins. In the two-point compression strategy the common femoral vein is compressed at the level where the great saphenous vein enters; then the popliteal vein is compressed (Fig. 1).

The rational for two point CUS is that very few thrombi are isolated to the segments not visible with this two point strategy. That is to say that the ultrasonographer will pick up very few additional LEDVT’s by scanning the entire venous system. In two different patient series the incidence of isolated superficial femoral vein clot was 1% [23, 24]. In contrast Maki et al. found the incidence of acute deep venous thrombosis isolated to the SFV to be 22.3% [25]. This study included both symptomatic and asymptomatic patients, while the other studies included only symptomatic patients. An incidence of 4.6% for isolated superficial femoral vein thrombus was observed by Fredrick et al. when they assessed whether the ultrasound examination can be abbreviated. The recommendation from the authors was that the exam should include scanning the entire length of the vessels [26].

Since a missed diagnosis of LEDVT in the critically ill may have devastating consequences and the data are conflicted with regards to the two point CUS strategy, we routinely scan the entire proximal venous system, from the CFV to the trifurcation of the popliteal vein.

Anatomy of the Lower Extremity Venous System

While a thorough understanding of the lower extremity venous anatomy is essential to the sonographer, this proves to be an easily and rapidly obtainable objective. Deep veins are usually paired with an artery. The common femoral artery lies laterally to the common femoral vein (CFV). The great saphenous vein (GSV) joins the common femoral vein in proximity to the inguinal ligament. This area is important sonographically because a thrombus identified at the junction between the GSV-CFV needs to be treated as a DVT. This is because of a high probability of extension into the CFV proper. Approximately 2 cm from the inguinal ligament the CFV splits into the profunda femoris vein and the superficial femoral vein (SFV). While its name, SFV, seems misleading, a thrombus identified anywhere along its length is considered a DVT and appropriate treatment should be initiated. The profunda femoris dives deep between the muscles and usually cannot be seen. The SFV continues downward to Hunter’s Canal (Adductor Canal) at which point it is now the popliteal vein. The popliteal vein continues caudad until its trifurcation into the calf veins.

How to Perform the Exam?

The transducer of choice to perform the examination is a 5 to 10 MHz linear array probe. Lower frequencies give you deeper penetration while higher frequencies give you better spatial resolution. Most ultrasound machines in use in ICU’s today have color and pulse wave Doppler capabilities. As previously mentioned these can be used to identify vascular structures in the edematous/obese patients and to help differentiate an artery from a vein.

To maximize vessel image acquisition and compressibility the patient should be placed in the supine position, with the thigh externally rotated. To better expose the popliteal fossa the knee should be flexed at a 45 degree angle and externally rotated. Bandages and other barriers, including femoral vein catheters, make it difficult to ultrasound the lower extremity. All bandages in ultrasound field should be removed. If sterility is a concern a sterile ultrasound cover may be used.

The two sonographic findings that are diagnostic of a venous thrombosis are non-compressibility of the venous segment and/or echogenic intra-luminal material. Most acute thrombi are hypoechoic, and not well visualized. If a thrombus is identified within the vessel lumen, a compression maneuver is not essential. Excessive compression may dislodge a thrombus. If ambiguity still exists longitudinal scanning may help confirm the echogenic material as an intra-luminal thrombus (Video 2 thrombus longitudinal).

To begin the compression maneuver the probe is held by convention with marker to the patient’s right. The vein and
artery should be found in the transverse plane. With pressure, the anterior and posterior walls of the vessel should come together obliterating the vessel lumen (Fig. 2).

A positive exam, i.e. LEDVT, occurs when an appropriate level of pressure fails to bring apposition of the vessel walls (Fig. 3).

One potential pitfall in CUS is the amount of pressure exerted over the vessel. Too little and the vessel walls will not appose, misleading the sonographer into a false positive finding. The appropriate level of pressure is gauged by the deformation of the adjacent artery. If the vessel walls do not appose with enough pressure to deform the adjacent artery the vein must have a thrombus, whether visible or not. A second pitfall is the angle of the pressure exerted over the vessel walls. Pressure must be exerted perpendicular to the venous segment or even with appropriate pressure the venous segment may not collapse.

We begin our exam just above the GSV-CFV junction. At this level the examiner should locate the CFA-CFV in transverse plane. It is sometimes referred to as a “peanut sign” (Fig. 4).

The common femoral artery should lie laterally to the vein. A compression maneuver is done, as described. Then the CFV-GSV junction is identified and compressed. If negative we repeat compression maneuvers at 2cm increments until either the popliteal region is approached or we lose sight of the vessel. The CFV will split into the SFV and Profunda or deep femoral vein (Video 3 Splitting of CFV). The accompanying artery will also split into the superficial femoral artery (SFA) and profunda or deep artery. It is crucial to scan back and forth “through” the bifurcations to identify the artery from vein. The SFA usually lies anterior to the SFV. We follow the SFV down to the adductor canal. Another pitfall is that compression may become challenging as it nears the adductor canal. Counter-pressure with the opposite hand to the probe may overcome this problem. Visual loss of the SFV is not uncommon as it dives deeper into the thigh. Sometimes increasing or decreasing the depth can bring the vein back into focus.

We then move on to the popliteal vein. The patient’s leg should be positioned as stated above; flexed at a 45 degree angle at the knee. The transducer is placed in the popliteal fossa. The popliteal vein is easily compressed and even slight pressure may obscure it. The vein usually lies anterior to the artery. A compression maneuver is performed. We will scan this vessel with compression maneuvers until we reach the trifurcation into the calf veins. If negative, we move onto the opposite side completing the exam in the same manner.

CONCLUSION

LEDVT is a common and probably under-diagnosed condition in the critically ill. A rapid, repeatable, and easy to perform bedside modality is desirable. CUS, performed by the treating physician, in real time has obvious application. With a rapid, steep learning curve, CUS may become the
“gold standard” for the diagnosis of DVT in critically ill patients.

SUPPLEMENTARY MATERIAL

This article contain 5 video files and it can be viewed at www.bentham.org/open/toccmj

REFERENCES