Introduction

- Accurate clinical diagnosis of deep venous thrombosis (DVT) is notoriously difficult
- The same is true of pulmonary embolism (PE)
- PE and DVT are part of the same process of venous thromboembolism
- Most DVT is believed to begin in the calves and about 90% of PE are believed to originate from the deep veins of legs/pelvis – usually begins around leaflets of venous valves, especially in calves, & can propagate superiorly

Ultrasound

- Introduced in the late 1980s
- Now the initial imaging test of choice for patients with signs/symptoms suggesting lower or upper extremity DVT
- Advantages:
  - Very high accuracy for thigh and arm evaluation for acute DVT
  - Relatively low cost
  - Portable
  - No ionizing radiation
  - Readily repeatable

- Current techniques still rely primarily on compression sonography
- If pressure from the transducer completely collapses the vein, DVT is absent; DVT is present if the vein does not completely collapse
- Obtain transverse images of common femoral vein (CFV), superficial femoral vein (SFV), & popliteal vein (PV) along their courses with a 5 or 7.5 MHz linear transducer

- Supplement with sagittal color & spectral Doppler images (although these are usually routine performed anyway)
- Color/spectral Doppler is helpful in obese patients/when imaging deep areas, especially the superficial femoral vein in the adductor canal (Lewis BD et al. Radiology 1994)
- Also helpful for indirect evidence of pelvic venous occlusion – a monophasic waveform in the common femoral vein is a reliable indicator of proximal venous obstruction (Lin EP et al. J Ultrasound Med 2007)

- Augmentation did not yield any additional diagnoses of DVT in a series of almost 2000 US examinations (Lockhart ME et al. AJR 2005)
- Acute DVT – venous distension can be present but ecogenic/visibility of clot is variable
- Alternative diagnoses may be identified with US – e.g. hematomas, ruptured popliteal fossa cyst (Gutierrez ME et al. J Emerg Med)
Ultrasound – Accuracy & Pitfalls
- Some authors advocate a limited examination with imaging at the groin and behind the knee only (Pezzuto JA et al. Radiology 1996).
- Clot isolated within the thigh to the SFV has an incidence approaching 20% (Maki DD et al. AJR 2000; Katz JS et al. Radiographics 2002; Ford MN et al. J Clin Ultrasound 2001) – so the literature does not support this practice.
- Duplication of the SFV is very common – up to 50% if not present in only one of two limbs, US may be falsely-negative if only the patient limb is seen (Sloenat NJ et al. Radiology 1998; Quinlan DJ et al. Radiology 2003).
- Most centers routinely scan both limbs unless there is a good reason not to.
- Ultrasound may be falsely-negative if only one clot is present, the latter series.

Ultrasound – Role in Patients without DVT Symptoms
- If US is done first in patients with r/o PE, if negative than PE is not excluded, while if positive the presence of PE is assumed and if actually present the extent of PE is not known.
- Much poorer results on US in asymptomatic patients when compared with conventional venography (e.g. patients after joint replacements) – the dots are usually smaller and non-occlusive, and the incidence of calf DVT is much higher (Wells PS et al. Radiology 1998) – so US may be falsely-negative.
- No proven role for US in such patients, especially if they are on DVT prophylaxes.

Ultrasound - Calves
- US of the calves (and pelvis) is not routinely performed at most centers because of low accuracy and the high incidence of non-diagnostic studies (Gottlieb RH et al. J Clin Ultrasound 1999).
- If a patient specifically reports focal pain in the calf – then do attempt to image the area of pain.
- The incidence & significance of therapy for isolated calf DVT remains controversial.
- Correctly recognizing chronic DVT (and acute on top of chronic DVT) is problematic on all non-invasive imaging modalities.

Ultrasound – Accuracy & Pitfalls
- However, these findings may not be present, the echogenicity of chronic DVT is variable, and chronic DVT may not be distinguishable from acute DVT (Murphy TP et al. Radiology 1996).
- Differentiating post-phlebitic syndrome from chronic DVT is important in symptomatic patients.
- Repeat US is very useful.
- Obtain repeat US in patients with DVT who become symptomatic after initial therapy, for a new future baseline, and to determine whether therapy should be continued or not (Murphy TP et al. Radiology 1996; Siragusa S et al. Blood 2006).

Ultrasound - Calves
- The incidence of upper extremity DVT (UEDVT) is increasing due to the widespread use of central venous catheters, pacemakers, AICDs, & other devices.
- UEDVT also may be related to hypercoagulability, malignancy, low-flow states, and ‘effort’ thrombosis in athletic young people (especially men with thoracic outlet syndrome) (Volturo CA et al. Emerg Med Clin North Am 1994).
- However, there is still some controversy whether to routinely image both limbs unless there is a good reason not to.

Upper Extremity DVT Imaging
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Upper Extremity DVT Imaging

- The prevalence of UEDVT in oncology patients with central venous catheters is very variable; whether symptomatic or not (range 7 – 48%), but is higher than in non-oncology patients (Gariit E et al. J Ultrasound Med 2006)
- The initial test of choice is US, which is up to 95% accurate (Lewis BD 1998)
- The superior vena cava and central portions of brachiocephalic veins are not routinely seen
- The subclavian vein is not easily imaged

CTVPA: Technique & Findings

- 3 to 3.5 minutes from the start of IV contrast for CTPA – obtain consecutive 5 mm images in groups of four, with 2 to 3 cm gaps, from diaphragm to ankles
- Recommend contrast with at least 300 mg I/mL and use 120 – 150 mL
- Clot: filling defect within a deep vein; acute DVT often expands the vein, and has associated pheuvenous edema/enhancement of the venous wall (Loud PA et al. AJR 1999)
- Prefer the “survey” technique and not continuous images, to reduce overall radiation burden and number of images to review

Combined CT Venography and Pulmonary Angiography

- CT pulmonary angiography is the non-invasive test of choice for suspected PE
- Since PE and DVT are aspects of the same disease, if the deep veins are imaged with CT immediately after the lungs, the presence/absence of PE and the overall burden and distribution of clot can be demonstrated

CTVPA: Technique & Findings

- Various controversies regarding CTV – whether to do it, when, how, is it cost-effective; how much evidence is there to support its use (Dodd JD et al. Radiology 2007; Goodman LR et al. Radiology 2009)
- The more recent literature has been more mixed but is still somewhat positive towards the utility of CTV, which reflects the decreased yield of CTV (increased radiation exposure c/w CTPA alone)

CTVPA: Accuracy

- High accuracy has been reported for CT venography, for thigh DVT identification or exclusion (Loud PA et al. Radiology 2001; Ghaye B et al. Eur Radiol 2002; Cham MD et al. Radiology 2000 & Radiology 2005)
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- In 398 patients – 97% sensitivity & 100% specificity c/w US (Loud PA et al. Radiology 2001)
- Addition of CTV to CTPA has increased the overall diagnostic yield of venous thromboembolism by 20% – 27%+ in earlier series (Cham MD et al. Radiology 2005; Richman PB et al. J Thromb Haemost 2003; Ghaye B et al. Radiology 2006)
- CTV increased the sensitivity of CTPA alone from 83% to 90% in PIOPED II (Stein PD et al. NEJM 2006)
CTVPA: Calves and Complex Anatomy

- Recommend routine imaging of the calves on CT venography, although this is controversial.
- Although as noted the clinical importance of calf DVT remains controversial, although in contrast to ultrasound, DVT is usually readily and rapidly identified or excluded on CTV.
- CTV clearly reveals complex anatomy and pathology.
- e.g. superficial venous clot; clot in the profunda femoral vein in a substantial minority of patients with DVT (an area not usually imaged with US); and pelvic DVT, which may be difficult to image with US.

CTV Venography: Evaluation of Underlying Anatomic IVC/Iliac Vein Anomalies

- Contiguous multi-detector CT venography acquisition provides information on underlying anatomic abnormalities in iliofemoral DVT – perform in very selected circumstances for dedicated venous imaging.
- 45 of 56 patients with iliomesenteric DVT (44 left-sided) had anatomic abnormalities evident, especially compression of the left common iliac vein by the right common iliac artery (exaggerated by a bony spur in nine) (Chang JW et al. JVIR 2004).
- Also use a contiguous acquisition for occasional problem solving (e.g., a dedicated CT venogram of the pelvis and/or legs after non-diagnostic US – we have done this in a small number of patients in the past few years).

CTVPA: Pelvic & Chronic DVT

- Report of 1745 patients – DVT on 167 CTV exams (9.6%), and 23% of these had iliac vein and/or interior vena cava involvement (Cham MD et al. RSNA 2003; published in modified form, Radiology 2005).
- Accurate detection of chronic DVT is also problematic as on other cross-sectional imaging studies – and not well studied yet.
- Findings parallel those on US (small veins, partial filling defects, no perivenous edema or venous wall enhancement, and calcification).

CTVPA: Accuracy and Pitfalls

- A relatively small percentage of CTV studies are non-diagnostic – especially in patients with poor cardiac function and/or substantial lower extremity atherosclerosis (Kota DS et al. Radiographics 2002; Ghaye B et al. Eur Radiol 2002; Arakawa H et al. AJR 2007).
- If CTPA is negative in such patients or additional information is needed regarding the lower extremities, then US should be performed.
- US and CTV are complementary in a subset of patients.

MR Imaging for DVT

- MR for DVT imaging was first introduced in the early 1990s.
- High accuracy of MR (i.e., MR venography, or MRV) compared with conventional venography for the pelvis and the thighs, but MR is less accurate for the calves (Cantwell CP et al. JVIR 2006).
- MR is also advantageous for imaging suspected central thoracic venous clot – readily see veins compared with US, and the causes of clot, e.g. a central mass.
- Can also find central thoracic DVT/thrombosis on CTPA.

MR Imaging for DVT

- DVT findings on MR: absent venous flow, filling defects, and (in a minority of patients) perivenous inflammation – analogous to the findings on CTV.
- MR may be superior to US and CTV for the determination of chronicity of DVT – although this has not been well studied (Spritzer CE et al. Radiology 1998).
- MR is used as a problem-solving tool in most practices, especially for pelvic venous imaging.
- The true frequency of pelvic DVT is underestimated with US – and in pregnant patients, recent pelvic surgery, or pelvic malignancy, DVT may start in the pelvis and propagate inferiorly into the thighs (Spritzer CE et al. Radiology 2001).
MR Imaging for DVT

- Study of 212 patients with DVT extending proximal to the inguinal ligament on US; the patients then underwent MR (Borst-Krafek B et al. J Vasc Surg 2003)
  - Extension to iliac veins/IVC: 89%
  - Iliac veins were involved in 142 patients and the IVC in 46 patients
  - Iliac DVT was 2X more frequent on the left compared with the right
  - Extent of DVT had no correlation with the frequency of symptomatic PE

In patients with a contraindication to iodinated contrast who can receive gadolinium – can do MR pulmonary angiography and venography:
  - Obtain axial GRE images after MR pulmonary angiogram
  - Gadolinium augments MR signal in patent veins

Combined MR pulmonary angiography & venography protocol – increased yield by 16% over MRA alone in one study (Kluge A et al. AJR 2006)

Current Role of Contrast Venography

- Diagnostic venography is now limited to specific scenarios:
  - Prior to placement of IVC filters
  - Evaluation of central DVT in the proximal arms/chest
  - As a prelude for intervention: thrombolysis, thrombectomy, and stent placement
  - With indeterminate US in obese patients or a markedly swollen leg, and when other modalities do not or cannot solve the problem
  - In suspected calf DVT in patients with negative or indeterminate US, where the findings would change management (although the latter two scenarios may be evaluated with CTV or MRV)

- Non-visualization of portions of the subclavian and innominate veins and of the superior vena cava – as noted is a common situation with US
- Can easily evaluate these veins with a contrast injection into the antecubital vein or via basilic/brachial vein access with catheterization of the subclavian vein, under fluoroscopic control
- Diagnostic venography is performed routinely immediately prior to IVC filter placement: to evaluate for clot and venous anomalies, and also to measure the IVC to determine the type of filter to place

- At our institution, we routinely hand inject into the ipsilateral iliac vein when planning to place an IVC filter via the femoral approach, to evaluate for iliac DVT
- We then perform an “IVC gram” via a left iliac venous injection, to look for congenital anomalies
- We then perform a selective left renal venogram to check for a circumaortic renal vein, which can serve as a collateral pathway for emboli around the IVC (Beckman CF et al. AJR 1979; Phillips E 1969)

Summary

- Ultrasound is the imaging test of choice for suspected lower or upper extremity DVT
- US has high accuracy in asymptomatic patients for the deep thigh veins and in the arms
- US is less accurate for the calves and the pelvis, and in asymptomatic patients
- Combined CT pulmonary angiography and CT venography permits comprehensive assessment for PE and DVT, & serves as a roadmap for therapy, although the yield of CTV has decreased substantially in recent years as PTA has been increasing used/over-utilized, and CTV is not routinely performed at many institutions/practices, although there is still evidence to support its use, especially in high risk patients
- MR is a helpful problem-solving test, & can also be combined with MR pulmonary angiography
- Conventional venography is mostly of historical interest when used solely as a diagnostic study for the lower extremities
- Venography via an inguinal approach is still performed at some centers, including ours, as a road mapping technique immediately prior to IVC filter placement
- Venography of the lower and upper extremities is routinely performed as part of a variety of therapeutic procedures for DVT – including thrombolysis, percutaneous thrombectomy, angioplasty, and stent placement

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