Objective. Swelling of an extremity may be a sign of peripheral deep venous thrombosis but may occasionally be due to more proximal or central venous obstruction. Venous Doppler sonography of the extremities is a commonly performed procedure to evaluate for the presence of deep venous thrombosis. Pulsed-wave Doppler sonography is performed as part of this procedure to evaluate for the presence of cardiac pulsatility or respiratory phasicity. The importance of information provided by the pulsed-wave Doppler waveform must not be undervalued. Thus, the purpose of this article is to discuss the pathology of the thorax, abdomen, and pelvis that can be discovered by identifying abnormal waveforms in the veins of the extremities.

Conclusion. Abnormal waveforms provide information for compression or obstruction of the proximal venous system in the thorax, abdomen, and pelvis. When these waveforms are abnormal, previous imaging should be reviewed or additional imaging performed to discover the cause.

It is estimated that more than 500,000 duplex venous sonography examinations are performed in the United States to evaluate for deep venous thrombosis of the lower extremities [1]. Often, the examination is obtained to evaluate the cause of swelling of an extremity. In addition to deep venous thrombosis, there are other causes for swelling. As part of the examination, pulsed-wave Doppler sonography of the veins should be performed. This can be done with augmentation, in which the extremity is squeezed distally and the vein is insonated proximally using pulsed-wave Doppler sonography. A rapid change in the venous waveform provides indirect evidence of patency of the vein between those two points.

Pulsed-wave Doppler sonography in a proximal vein in the extremity is also performed to evaluate the waveform for the presence of respiratory phasicity or cardiac pulsatility [2, 3]. A normal waveform provides indirect evidence for patency of the proximal venous system between the point of insonation and the diaphragm and heart. If a normal waveform is obtained in the subclavian or jugular veins, the proximal brachiocephalic vein and superior vena cava are patent. If a normal waveform is obtained in the common femoral vein, the proximal iliac veins and inferior vena cava are patent. If a normal waveform is obtained from these veins but a nonphasic or nonpulsatile (flat) waveform is obtained more distally, a venous occlusion between the points of insonation should be investigated.

There is tremendous variability in the appearance of normal venous waveforms between individuals because of differences in depth and rate of respiration, right heart function, tricuspid regurgitation, intravascular volume [4], body habitus, and other physiologic differences. In addition, for a given individual, the amplitude of the waveform decreases as the distance from the heart increases. To obtain an internal standard, the contralateral extremity can often be used. An abnormal waveform in one upper extremity or jugular vein should prompt pulsed-wave Doppler sonography of the veins of the contralateral upper extremity for comparison. If it is determined that the waveforms lack phasicity or pulsatility in one extremity, the ipsilateral brachiocephalic vein should be further evaluated by additional imaging for compression or obstruction. An abnormal waveform of both upper extremities or both jugular veins should prompt evaluation of both brachiocephalic veins and the superior
vena cava by additional imaging. There have been numerous published reports of proximal venous obstructions in the thorax that were discovered by the absence of pulsatility or phasicity [5–9].

An abnormal waveform present in one of the lower extremities should prompt pulsed-wave Doppler sonography of the veins of the contralateral lower extremity for comparison. If it is determined that the waveforms lack phasicity or pulsatility in one extremity, the ipsilateral iliac vein should be further evaluated by additional imaging for compression or obstruction. An abnormal waveform present in both lower extremities should prompt evaluation of both iliac veins and the inferior vena cava. There has been a report of venous occlusion of an iliac vein because of lymphadenopathy that was discovered due to lack of a normal waveform [10]. However, abnormalities of the abdomen and pelvis have not been as well recognized as abnormalities of the thorax. There is much pathology in the thorax, abdomen, and pelvis that can be discovered from identifying abnormal waveforms in the veins of the extremities.

Materials and Methods

To examine the upper extremity, real-time images (Logiq 9, GE Healthcare) of the axillary and brachial veins before and after compression were obtained. Color and pulsed-wave Doppler sonography of the internal jugular, subclavian, axillary, and brachial veins was also performed. If an abnormal pulsed-wave Doppler waveform was present, attempts were made to evaluate the brachiocephalic vein by real-time and color Doppler imaging. CT of the thorax to evaluate the brachiocephalic vein and superior vena cava was also performed.

For the lower extremity, real-time images of the common femoral, deep femoral, femoral, and popliteal veins were obtained before and after compression. Color and pulsed-wave Doppler sonography also was performed. If an abnormal pulsed-wave Doppler waveform was present, real-time images and Doppler sonograms of the iliac veins and inferior vena cava were obtained. If available, previous CT scans were reviewed. CT was also performed if needed.

A waveform obtained by pulsed-wave Doppler sonography was interpreted as normal if cardiac pulsatility (Fig. 1) or respiratory phasicity (Fig. 2) was shown. A waveform was interpreted as abnormal if there was a flat or nearly flat waveform. If there was any uncertainty about the appearance of the waveform, pulsed-wave Doppler sonography was repeated.

Fig. 1—Normal venous waveforms obtained from healthy volunteers. R = right, V = vein, CFV = common femoral vein. A and B, Normal venous waveforms in 27-year-old woman show cardiac pulsatility in subclavian vein (A) and CFV (B). C, Normal venous waveform from CFV in 25-year-old woman shows pulsatility with much lower amplitude. There is significant variability in amplitude between individuals.

Fig. 2—Normal venous waveform in 40-year-old woman healthy volunteer shows respiratory phasicity. CFV = common femoral vein.

Fig. 3—51-year-old woman with non-Hodgkin’s lymphoma. A and B, Pulsed-wave Doppler sonograms of right internal jugular vein (IJV) (A) and right subclavian vein (SUBCL V) show low-amplitude pulsatile waveforms. C, CT scan of thorax shows severe compression of superior vena cava due to lymphadenopathy.
of the contralateral extremity was performed to provide comparison with a normal waveform. All waveforms were interpreted with the patient breathing normally. Respiratory maneuvers, such as panting or Valsalva maneuver, were not used.

In all cases, the interpreter of the duplex venous examination was unaware of the results of any previous imaging examinations at the time of the interpretation. The cause of the thoracic, abdominal, or pelvic pathology was discovered on respective review of previous CT scans or after performing additional imaging using ultrasound or CT.

Results

Patient 1 was a 51-year-old woman who presented with swelling of the head and upper extremities. Pulsed-wave Doppler sonography revealed low-amplitude pulsatile wave forms in the right internal jugular (Fig. 3A) and subclavian (Fig. 3B) veins. Review of a recent CT scan (Fig. 3C) showed severe compression of the superior vena cava from lymphadenopathy due to non-Hodgkin’s lymphoma.

Patient 2 was a 65-year-old woman who was found to have liver metastases on initial CT of the abdomen. Subsequently, she was referred for imaging because of bilateral lower extremity swelling. On pulsed-wave Doppler sonography, she had low-amplitude respiratory waveforms in the common femoral veins bilaterally (Fig. 4A). Review of the previous CT scan (Fig. 4B) showed that the metastases compressed the intrahepatic inferior vena cava, which had not been previously recognized.

Patient 3 was a 22-year-old woman who was referred for left lower extremity swelling. Pulsed-wave Doppler sonography revealed a normal or low-amplitude phasic waveform in the common femoral vein (Fig. 5A) and a flat waveform in the femoral vein (Fig. 5B). There was no thrombus or venous occlusion between the two points of insonation. Therefore, a proximal venous abnormality was suspected. The right common femoral vein also was examined, which showed a low-amplitude phasic waveform. A CT scan (Fig. 5C) was then obtained that revealed absence of the right kidney and inferior vena cava, with numerous collateral veins in the subcutaneous fat. The patient then provided additional history of having had a right nephrectomy with ligation of the inferior vena cava shortly after birth for treatment of a malignant tumor of the kidney.

Patient 4 was a 79-year-old woman who had swelling of both lower extremities. Pulsed-wave Doppler sonography of the left (Fig. 6A) and right (Fig. 6B) common femoral veins revealed flat or low-amplitude waveforms. CT of the abdomen (Fig. 6C) revealed a small or absent inferior vena cava of unknown cause, with a collateral dilated left ovarian vein.

Patient 5 was a 21-year-old man with end-stage renal disease. Pulsed-wave Doppler sonography of the left common femoral vein revealed a flat waveform (Fig. 7A). CT of the abdomen and pelvis (Fig. 7B) revealed a large, loculated fluid collection that...
Doppler Sonography of the Extremities

Compressed the left common iliac vein as it coursed between the right common iliac artery and the lumbar spine. The left iliac vein was dilated below this level.

Patient 6 was an 85-year-old woman who underwent radical hysterectomy for endometrial carcinoma 7 months previously. A flat venous waveform from the right common femoral vein was obtained. Sonography of the pelvis revealed a mass. CT (Fig. 8) revealed that the right common iliac vein was compressed by a lymphocele. The lymphocele was drained, and swelling in the right lower extremity resolved.

Patient 7 was an 80-year-old man with prostate cancer. Pulsed-wave Doppler sonography of the left common femoral vein (Fig. 9A) revealed a flat waveform. Subsequent CT of the pelvis (Fig. 9B) revealed a lack of visualization of the left external iliac vein, most likely from previous thrombosis.

Patient 8 was an 83-year-old woman with peritoneal metastases. Abnormal waveforms in the right and left common femoral veins were obtained. Color Doppler sonography of the right iliac vein revealed absence of flow (Fig. 10), consistent with thrombosis. The inferior vena cava was shown to be occluded on CT.

Patient 9 was a 29-year-old pregnant woman. She had swelling of the right lower extremity. She was found to have a flat venous waveform in the right common femoral vein (Fig. 11) because of compression of the iliac vein by the enlarged gravid uterus.

Patient 10 was a 49-year-old man who suffered rupture of an aneurysm of the anterior cerebral artery. Several days later, he developed swelling of both lower extremities. Pulsed-wave Doppler sonography of the right and left common femoral veins (Fig. 12A) revealed low-amplitude waveforms. Sonography of the pelvis (Fig. 12B) then revealed an overstretched bladder that compressed the external iliac veins bilaterally. The patient was immediately catheterized and 1,500 mL of urine was recovered. After catheterization, repeat pulsed-wave Doppler sonography of the common femoral veins (Fig. 12B) revealed normalized waveforms because of lack of compression of the external iliac veins by the bladder.

Table 1 provides more details on study participants and results.

Discussion

Swelling of an extremity may be a sign of peripheral deep venous thrombosis but may

Fig. 6—79-year-old woman with small or absent inferior vena cava. A and B, Pulsed-wave Doppler sonograms of left (A) and right (B) common femoral veins (CFV) show flat or low-amplitude waveforms. C, CT scan of abdomen shows small or absent inferior vena cava (arrow) with collateral dilated left ovarian vein (arrowhead).

Fig. 7—21-year-old man with end-stage renal disease. A, Pulsed-wave Doppler sonogram of left common femoral vein (CFV) shows flat waveform. Note that velocity range is set very low, which spuriously creates appearance of pulsatility. B, CT scan of pelvis shows large, loculated fluid collection that compresses right and left common iliac arteries and left common iliac vein as it courses between right common iliac artery and lumbar spine. Iliac vein was dilated below this level (not shown).

Fig. 8—85-year-old woman who underwent radical hysterectomy for endometrial carcinoma 7 months previously. Flat venous waveform from right common femoral vein was obtained (not shown). CT scan shows right common iliac vein is compressed by lymphocele that was subsequently drained, after which, right lower extremity swelling resolved.
occasionally be caused by more proximal venous obstruction. Duplex venous sonography of the extremities is a commonly performed procedure to evaluate for this possibility. As a part of this examination, pulsed-wave Doppler sonography is used to evaluate for augmentation that provides evidence of venous patency between the levels that the extremity is squeezed and the point of insonation. Pulsed-wave Doppler sonography is also used in the most proximal vein of an extremity. A normal waveform with cardiac pulsatility or respiratory phasicity provides indirect evidence of venous patency between the levels of the heart or diaphragm and the point of insonation. The importance of this finding should not be underestimated because it creates a “window” through which the brachiocephalic veins and superior vena cava can be evaluated when examining the veins of the neck or upper extremities. When examining the lower extremities, it creates a window through which the iliac veins and inferior vena cava can be evaluated. Although deep venous thrombosis may cause extremity swelling, there are many other conditions that can occur proximal to the affected extremity that may cause the patient’s symptoms. Careful analysis of the waveform should be made to discover an intrathoracic, intrabdominal, or intrapelvic cause for the swollen extremity or extremities.

When interpreting the waveform, there are several important points to keep in mind. First, physiologic reasons cause considerable variability in the appearance of a normal venous waveform. The contralateral upper or lower extremity can often be used as an internal standard to determine what is normal for a given patient’s venous waveform. Second, if the velocity range for pulsed-wave Doppler sonography is set very low, the waveform may falsely appear to have normal pulsatility or phasicity (Fig. 7A). Third, if the velocity range for the pulsed-wave Doppler sonography is set very high then the waveform may falsely appear to be flat (nonphasic, nonpulsatile). Fourth, even if there is obstruction...
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TABLE I: Study Participants and Results

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Underlying Condition</th>
<th>Veins Examined</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>F</td>
<td>Non-Hodgkin’s lymphoma</td>
<td>Right internal jugular and subclavian veins</td>
<td>Superior vena syndrome</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>F</td>
<td>Liver metastases</td>
<td>Right and left common femoral veins</td>
<td>Compression of intrahepatic inferior vena cava</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>F</td>
<td>Remote treatment of renal cancer</td>
<td>Left and right common and left femoral veins</td>
<td>Ligation of inferior vena cava</td>
</tr>
<tr>
<td>4</td>
<td>79</td>
<td>F</td>
<td>Swelling of lower extremities</td>
<td>Right and left common femoral veins</td>
<td>Absent or small inferior vena cava</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>M</td>
<td>End-stage renal disease</td>
<td>Left common femoral vein</td>
<td>Fluid-filled pelvic mass</td>
</tr>
<tr>
<td>6</td>
<td>85</td>
<td>F</td>
<td>Metastatic endometrial cancer</td>
<td>Right common femoral vein</td>
<td>Right iliac lymphocele</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>M</td>
<td>Prostate cancer</td>
<td>Left common femoral vein</td>
<td>Occlusion of left iliac vein</td>
</tr>
<tr>
<td>8</td>
<td>83</td>
<td>F</td>
<td>Peritoneal metastases</td>
<td>Right and left common femoral veins</td>
<td>Thrombosis of inferior vena cava and right iliac vein</td>
</tr>
<tr>
<td>9</td>
<td>29</td>
<td>F</td>
<td>Pregnant</td>
<td>Right common femoral vein</td>
<td>Enlarged gravid uterus</td>
</tr>
<tr>
<td>10</td>
<td>49</td>
<td>M</td>
<td>Ruptured cerebral aneurysm</td>
<td>Right and left common femoral veins</td>
<td>Overdistended bladder</td>
</tr>
</tbody>
</table>

References

4. Shelley KH, Dickstein M, Shulman SM. The detection of peripheral venous pulsation using the pulse oximeter as a plethysmograph. J Clin Monit 1993; 9:283–287