Advanced Emergency Nursing Journal
Vol. 42, No. 4, pp. 284–292

PROCEDURAL
COLUMN

Column Editor: Jennifer Wilbeck, DNP, RN, FNP-BC, ACNP-BC, ENP-C, FAANP, FAAN

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Rapid Ultrasound for Shock and Hypotension

A Clinical Update for the Advanced Practice Provider: Part 2

Juan M. Gonzalez, DNP, APRN, AGACNP-BC, ENP-C, FNP-BC, CEN
Johis Ortega, PhD, APRN, ACNP-BC, FNP-BC, ENP-BC, FAAN, FAANP
Nichole Crenshaw, DNP, APRN, ACNP-BC, ANP-BC, FAANP
Lila de Tantillo, PhD, MS, APRN, FNP-BC

ABSTRACT
The Rapid Ultrasound for Shock and Hypotension (RUSH) examination is used for patients with hypotension without clear cause or undifferentiated hypotension. In the emergency department setting, clinicians may perform the RUSH examination to supplement the physical assessment and differentiate the diagnosis of hypovolemic, obstructive, cardiogenic, and distributive forms of shock. The key elements of the RUSH examination are the pump, tank, and pipes, meaning potentially causes of the hypotension are examined within the heart, vascular volume and integrity, and the vessels themselves. Clinicians follow a systemic protocol to seeking evidence of specific conditions including heart failure exacerbation, cardiac tamponade, pleural effusion, pneumothorax, abdominal aortic aneurysm, and deep vein thrombosis. Because ultrasonography is a user-dependent skill, the advanced practice nurse in the emergency department should be educated regarding the RUSH protocol and prepared to implement the examination. **Key words:** emergency department, hypotension, shock, ultrasonography, ultrasound

THE RAPID ULTRASOUND FOR SHOCK AND HYPOTENSION (RUSH) examination is a protocol used for evaluation of patients with unexplained hypotension. In Part I of this article series, a general overview of the RUSH examination was provided as well as how to evaluate the *pump*. The next step in the RUSH examination is the assessment of intravascular volume, which is referred to as the *tank*.

Author Affiliations: *University of Miami School of Nursing and Health Studies, Coral Gables, Florida (Drs Gonzalez, Ortega, and Crenshaw)Keigwin School of Nursing, Jacksonville University, Jacksonville, FL (Dr de Tantillo).*

Disclosure: *The authors report no conflicts of interest.*

Corresponding Author: *Juan M. Gonzalez, DNP, APRN, AGACNP-BC, ENP-C, FNP-BC, CEN, University of Miami School of Nursing and Health Studies, Coral Gables, FL 33146 (j.gonzalez48@miami.edu).*

DOI: 10.1097/TME.0000000000000322

THE VOLUME IN THE RESERVOIR AND INTEGRITY (TANK)

See Figure 1.

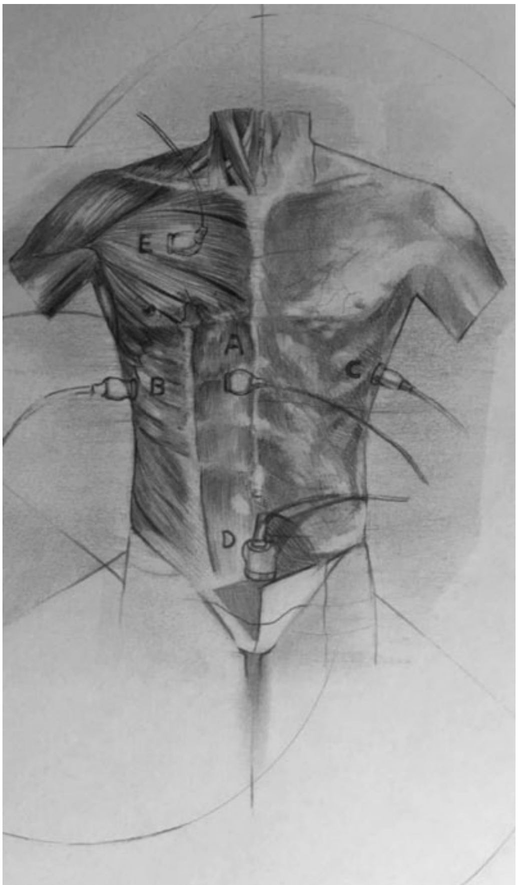

Figure 1. Volume and tank integrity assessment location: (A) IVC long axis, (B) eFAST RUQ with pleural view, (C) eFAST LUQ with pleural view, (D) eFAST pelvic view, and (E) lung pleural for pneumothorax and edema. eFAST = extended focused assessment with sonography for patient with trauma; IVC = inferior vena cava; LUQ = left upper quadrant; RUQ = right upper quadrant. Illustration courtesy of Yusmel Jimenez. Reprinted with permission.

Inferior Vena Cava for Central Venous Pressure

The following step in the RUSH protocol is to assess the effective intravascular volume and areas where the integrity of the body may be affected, or in another words, the *tank* (Perera, Mailhot, Riley, & Mandavia, 2010). The evaluation of the inferior vena cava (IVC) correlates indirectly with the pressures found in the right atrium of the heart (Hasper, Schefold, & Kruse, 2015; Perera et al., 2010). During inspiration, intrathoracic pressure decreases, which leads to a decreased right atrial and, subsequently, IVC pressure. During the same phase of the respiratory cycle, intra-abdominal pressure increases, which, paired with lower atrial and IVC pressures, causes blood from the IVC to be suctioned into the thoracic cavity and a collapsing of the vessel occurs (Bodson & Vieillard-Baron, 2012). The clinician performing the RUSH protocol uses the motion (B) mode of the ultrasound to assess changes in the caliber of the vessel during the respirophasic cycle (Hasper et al., 2015; Perera et al., 2010). In patients with a dilated or noncollapsing IVC, less than 40%–50%, this finding in the examination is congruent with types of shock that do not respond to fluid resuscitation well, that is, cardiogenic shock. If during the evaluation of the IVC, respirophasic changes cause a collapse of greater than 40%–50%, this finding favors conditions that are associated with hypovolemia and are more fluid responsive (Hasper et al., 2015; Perera et al., 2010; Stone & Huang, 2013). It is important to stress that although IVC respirophasic evaluation is an indirect measure of circulating volume, it is not a true representation of volume. A collapsing IVC does not rule out a condition that may lead to hypovolemia in a patient in hypotension and shock; instead, it is a better predictor of fluid responsiveness (Muller et al., 2012).

To conduct this portion of the examination, the clinician uses a low-frequency transducer in the sagittal plane, with the indicator pointing cephalad. While in the subxiphoid area, the IVC is identified to the anatomical right of the patient. Most current studies measure the IVC diameter and respirophasic variation 2–4 cm near the junction of the IVC and right atrium of the heart caudal to the middle hepatic vein (Stone & Huang, 2013; see Figure 2).

If the patient has an IVC diameter of less than 2 cm and a variability in diameter of greater than 40%–50% during inspiration, the estimated central venous pressure (CVP) is

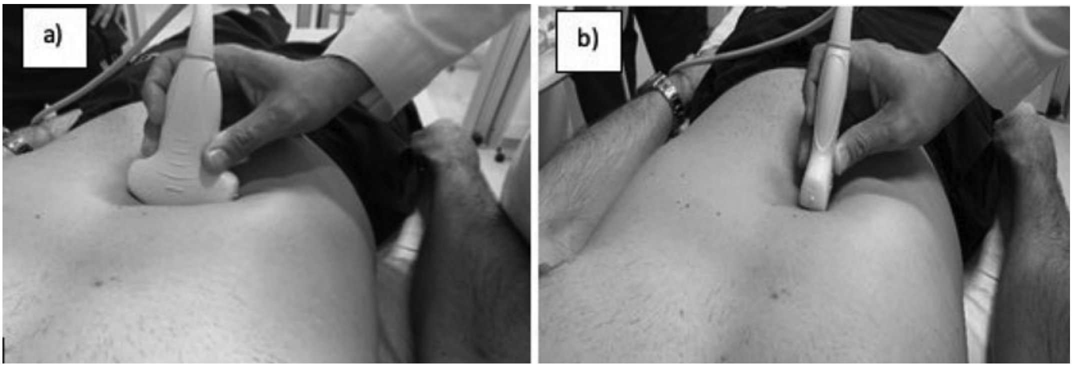

Figure 2. (a) Transverse view of IVC. (b) Longitudinal view of IVC. Once in position, the first step is to measure the diameter of the IVC during normal exhalation. The clinician documents whether the diameter is greater or lesser than 2 cm. When measuring the IVC diameter, the advanced practice provider looks 2 cm distally or caudally (away from the head) from where the hepatic vein enters the inferior vena cava (see Figure 3). The next step of the protocol is to assess the variability of diameter during inspiration, also known as respirophasic variation. The clinician is evaluating whether the patient has greater or lesser than 40%–50% variability (Perera et al., 2010; Stone & Huang, 2013). IVC = inferior vena cava. Photograph courtesy of Juan M. Gonzalez.

less than 10 cmH_2O (Perera et al., 2010; Stone & Huang, 2013). If the IVC diameter is greater than 2 cm and the variability during inspiration is less than 40%–50%, then the estimated CVP is greater than 10 cmH_2O (Perera et al., 2010; Stone & Huang, 2013). A CVP below 10 cmH_2O is usually seen in patients with hypovolemia, whereas a CVP greater than 10 cmH_2O is expected in patients with euvolemia or hypervolemia (Stone & Huang, 2013; see Figure 3, normal CVP diameter and change during inspiration and Figure 4, collapsing of IVP during inspiration).

QUADRANT EVALUATION OF THE TANK

During evaluation of intravascular volume in the reservoir, the advanced practice clinician should look for potential defects or problems, or "holes" in the *tank*, that could lead to fluid moving from the intravascular compartment to the transcellular space such as the peritoneum (Perera et al., 2010). Free fluid in these areas would be demonstrated by an anechoic collection. The areas to assess for compromise of the tank are the right upper quadrant (RUQ) or Morison's pouch, left upper quadrant (LUQ) or splenorenal space, and pelvic area. Importantly, these components of the RUSH examination are also part of extended focused assessment with sonography for patient with trauma (eFAST) examination (González, Ortega, Crenshaw, & de Tantillo, 2019; Montoya et al., 2016). In addition, while evaluating RUQ and LUQ of the

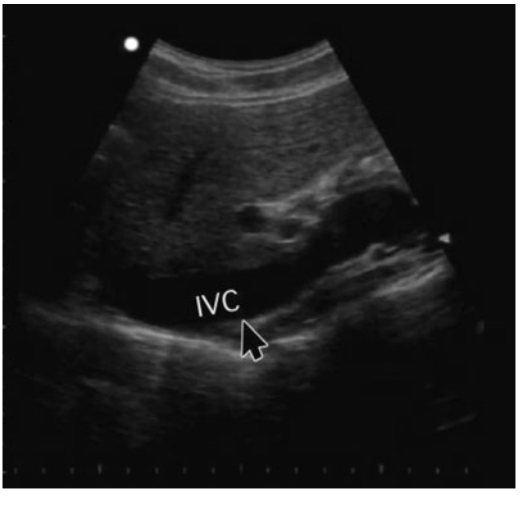

Figure 3. Arrow indicating location to measure inferior vena cava. IVC = inferior vena cava. Photograph reproduced with permission from SonoSim, Inc.

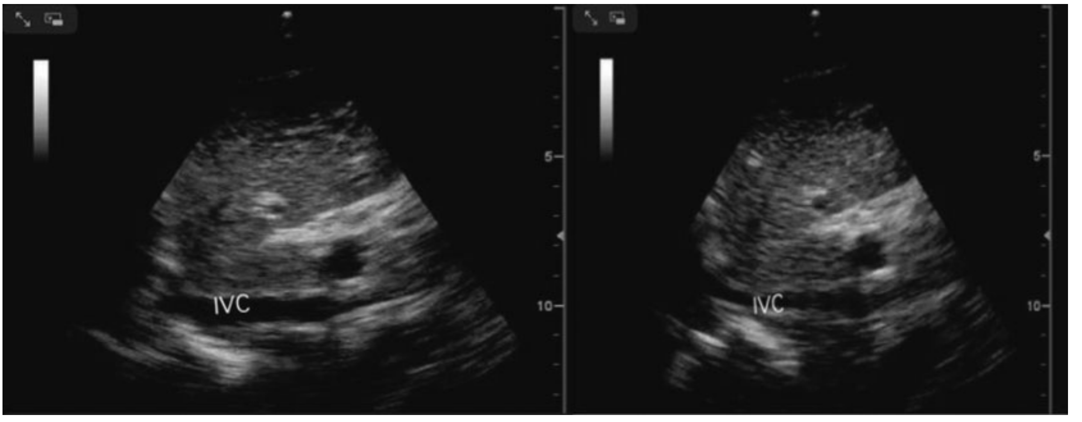

Figure 4. Respirophasic collapsing inferior vena cava. Photograph reproduced with permission from SonoSim, Inc.

abdomen, the clinician evaluates for mirror images of the liver or spleen above the diaphragm and the absence of what is known as "spine sign" (González et al., 2019). A pleural effusion or hemothorax is suspected if there is a lack of mirror image of the spleen or liver, anechoic collection above the diaphragm, and a positive spine sign (see Figure 5). When evaluating the integrity of the tank, it is important to assess for pleural sliding, comet tail artifacts in B mode, and the seashore sign in the M mode. The absence of pleural sliding and a lack of "seashore sign," also known as a "stratosphere sign," are findings that would support the diagnosis of a pneumothorax (Perera et al., 2010).

THE VESSELS (PIPES)

See Figure 6.

a. Ruptures (AAA, aortic dissections)
b. Clogging (DVT)

The last portion of the RUSH examination is to evaluate the vessels, or the *pipes*. In this portion of the examination, the advanced practice clinician attempts to determine whether the patient has an abdominal aortic

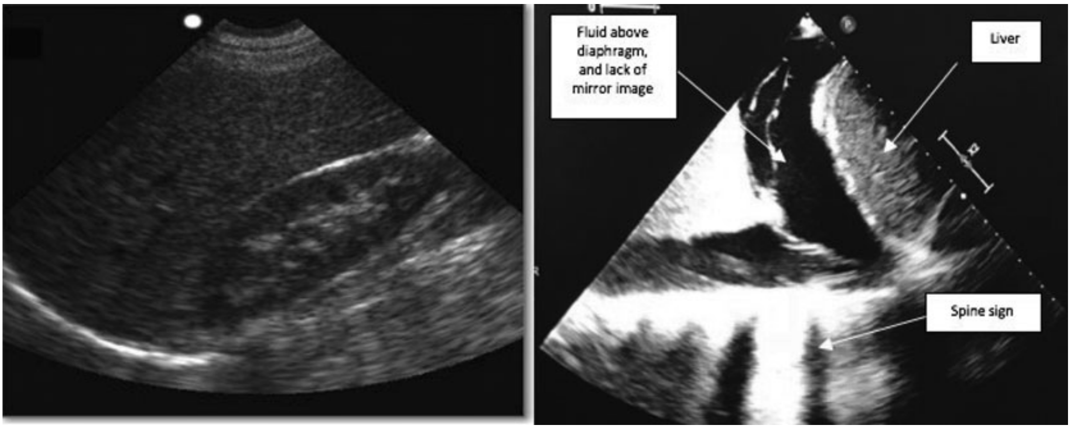

Figure 5. (A) Normal RUQ view of the liver and mirror image. (B) Abnormal RUQ view with lack of mirror image, positive anechoic collection, and positive spine sign. RUQ = right upper quadrant. Photograph courtesy of Juan M. Gonzalez. Photograph reproduced with permission from SonoSim, Inc.

Figure 6. Locations to evaluate the vessels: (A) suprasternal aorta, (B) parasternal aorta, (C) epigastric aorta, (D) supraumbilical aorta, (E) femoral vein, and (F) popliteal vein. Illustration courtesy of Yusmel Jimenez. Reprinted with permission.

aneurysm (AAA) or a deep vein thrombosis (DVT). An AAA can lead to hypotension as a result of hypovolemia. A large DVT can also lead to hypotension and would be important for the emergency department (ED) clinician to rule out this condition (Jameson et al., 2020; Perera et al., 2010).

To detect the aorta sonographically, the clinician should use a convex low-frequency probe (Rubens & Grant, 2011). The descending portion of the thoracic aorta can be seen via sonography from the cardiac apical window (Rubens & Grant, 2011). The clinician applies the transducer at the epigastric area in a cross-sectional or transverse plane, pressing down to move gas away from the image. The clinician can see the aorta anteriorly and to the anatomical left to the spine shadow (Perera et al., 2010). From this position, the advanced practice provider can use the spine shadow as the main landmark to find the aorta. The IVC will be seen to the anatomical right of the spine shadow. The aorta will be found below the superior mesenteric artery. Horizontally, the splenic vein returning to the portal circulation will be observed, just beneath the pancreas and the liver (see Figure 7A).

This portion of the RUSH protocol begins in the epigastric area and then moves down toward the iliac bifurcation of the aorta (see Figure 7B). In most patients, the bifurcation occurs at the level of umbilicus. The measurement of the aorta is performed by calculating anterior-to-posterior distance (Polak, 2012). Therefore, if an aneurysm is present, the advanced practice nurse would measure it anterior to posterior and document the widest distance from outer diameter to outer diameter (Polak, 2012; see Figure 8).

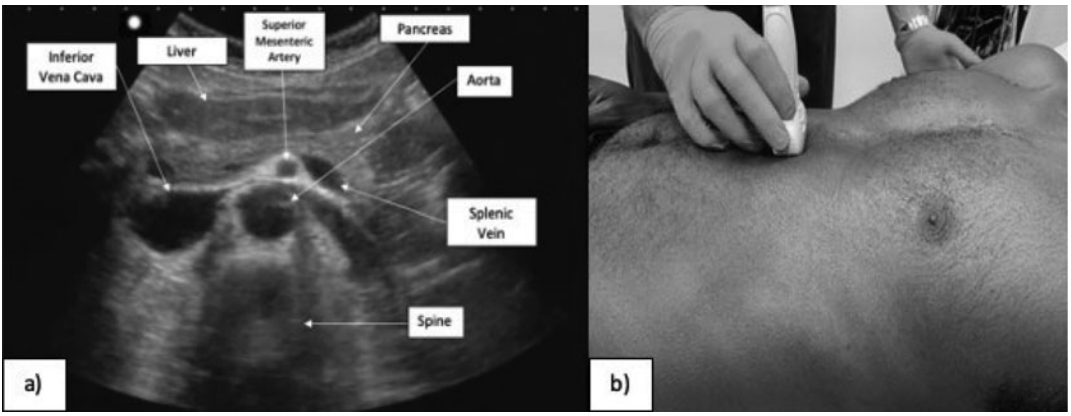

Figure 7. (A) Abdominal aorta and surrounding anatomy. (B) Probe location for evaluation of the aorta. Photograph courtesy of Juan M. Gonzalez. Photograph reproduced with permission from SonoSim, Inc.

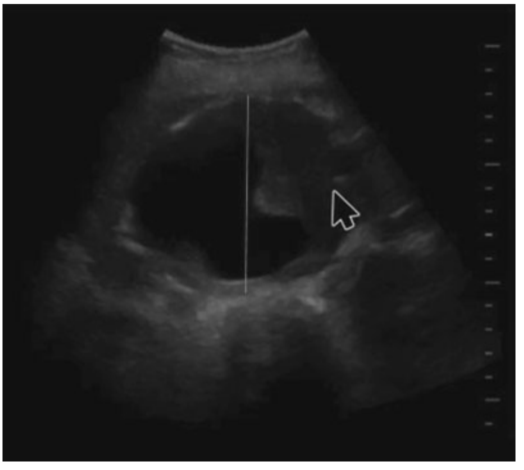

Figure 8. Abdominal aorta aneurysm with thrombus. Photograph reproduced with permission from SonoSim, Inc.

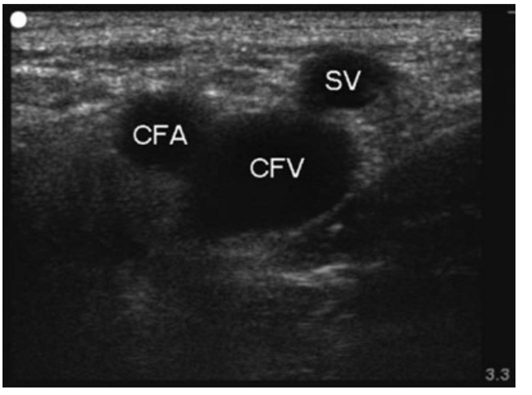

Figure 9. Right common femoral vein and surrounding vessels. CFA = common femoral artery; CFV = common femoral vein; SV = saphenous vein. Photograph reproduced with permission from SonoSim, Inc.

When evaluating the vessels, the last component for the clinician to assess is whether the patient has a DVT. The advanced practice provider starts proximally by placing the probe inferior to the inguinal ligament to assess for DVTs in the lower extremities. The clinician uses a linear high-frequency 5- to 10-MHz probe in a transverse plane. From this perspective, the superficial femoral artery is seen superiorly, the deep femoral artery (DFA) is seen inferiorly, and the common femoral vein (CFV) is seen medially (see Figure 9). The clinician should compress sequentially down the CFV through the bifurcation of the femoral vein and DFV. A lack of ability to compress or collapse the vein fully is considered indicative of a clot ((Adhikari, Zeger, Thom, & Fields, 2014; Hertzberg & Middleton, 2016; Perera et al., 2010; see Figure 10).

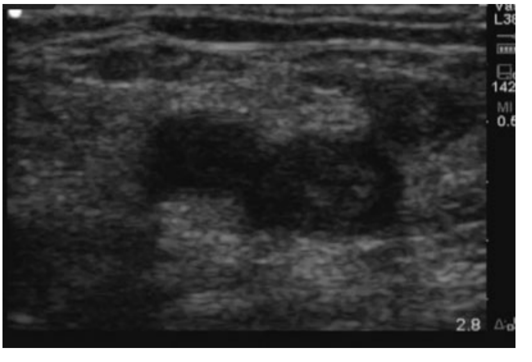

Figure 10. Right femoral vein with thrombus. Photograph reproduced with permission from SonoSim, Inc.

The final area for the clinician to evaluate is the popliteal vein. The advanced practitioner places the linear 5- to 10-MHz probe in the transverse position (see Figure 11). The popliteal vein is seen on the ultrasound scan above or superficial to the popliteal artery. The clinician should compress sequentially from the top of the popliteal fossa all the way down to the top of the calf. In normal vasculature, the clinician is able to compress

Figure 11. Probe location for evaluation of the popliteal vein. Photograph courtesy of Juan M. Gonzalez.

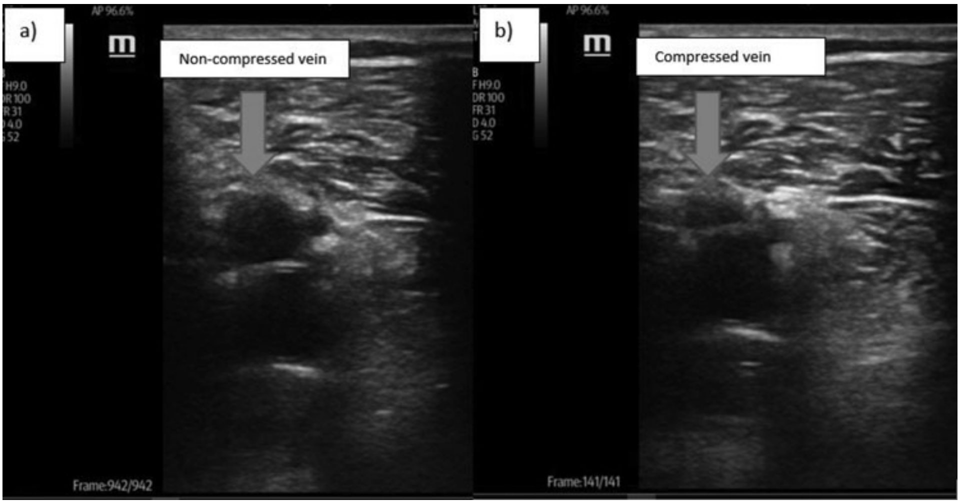

Figure 12. (A) Noncompressed popliteal vein. (B) After pressure with the transducer, compressed popliteal vein. Photograph courtesy of Juan M. Gonzalez.

the vein with pressure (see Figure 12). To assist with this portion of the examination, the clinician applies counterpressure to the knee area. To make a diagnosis of DVT, the clinician is looking for lack of ability to fully compress or collapse the vein. If present, a blood clot inside the vein prevents the vasculature from collapsing and rapidly expanding (Hertzberg & Middleton, 2016; Perera et al., 2010; see Figure 13, positive for clot popliteal). This phenomenon is frequently referred as lack of "wink" back, a normal finding of compression and expansion when pressure is being applied. As the advanced practice provider presses on the vein, it is possible the artery may collapse but not the vein, for example, in the case of an intraluminal clot. During this portion of the examination, it is imperative for the clinician to be very careful and not overly or unnecessarily compress a known or suspected clot. An iatrogenically dislodged clot could lead to a pulmonary embolism or even stroke in a patient with an atrial or ventricular septal defect

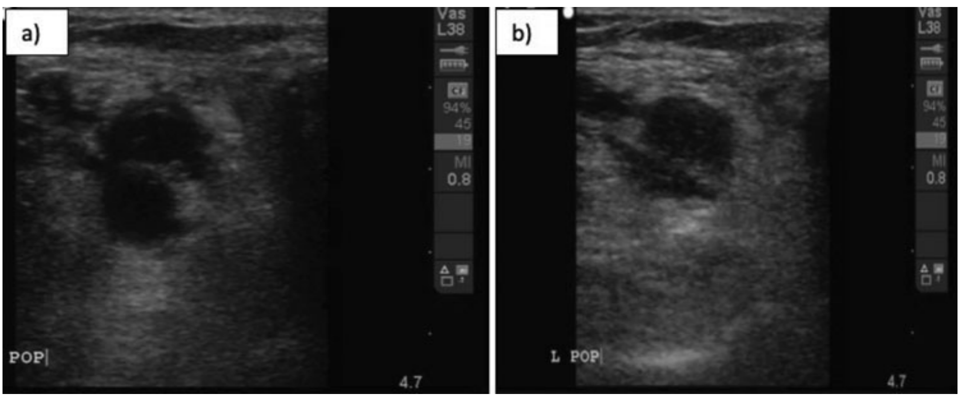

Figure 13. (A) Popliteal vein and artery of a patient with deep vein thrombosis. (B) Pressure applied and only the artery inferiorly is compressing, not the vein. Photograph reproduced with permission from SonoSim, Inc.

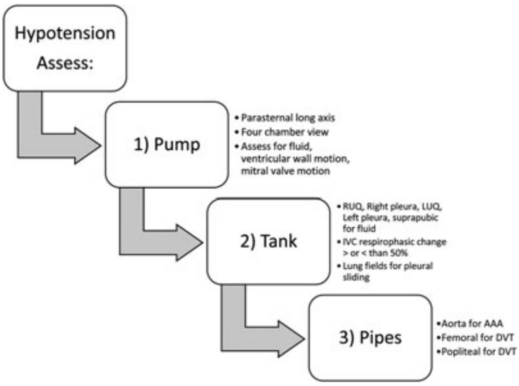

Figure 14. Steps for RUSH. AAA = abdominal aortic aneurysm; DVT = deep vein thrombosis; LUQ = left upper quadrant.

(Hertzberg & Middleton, 2016; Perera et al., 2010).

IMPLICATIONS FOR ADVANCED PRACTICE CLINICIANS

The availability of RUSH protocol has changed the way clinicians in the emergency setting manage patients presenting with hypotension. Clinicians must consider the many possible causes for hypotension, including hypovolemic, septic, obstructive, cardiogenic, and distributive. By utilizing RUSH examination in the ED, the advanced practitioner can assess whether the patient requires fluids or inotropic support. If RUSH examination findings indicate normal global left ventricular function (i.e., movement of the anterior mitral leaflet close or in contact to the left interventricular septum and tight opposition of the posterior wall of the left ventricle with the interventricular septum), the clinician understands that fluid resuscitation and/or vasopressors will be the corrective measure. Conversely, if the advanced practice nurse observes poor global left ventricular function, inotropic support would be the priority, with very careful fluid administration. Making this determination with physical examination alone would be exceptionally difficult. To remain at the forefront of patient care, advanced practice providers in the emergency setting must be equipped with the knowledge and expertise to operate ultrasound scan at the bedside and perform and interpret the RUSH protocol.

When evaluating a patient with hypotension in the ED, the advanced practice clinician needs to remember the three main areas of the RUSH examination to help differentiate and treat the different forms of shock: the pump, the tank, and the pipes (see Figure 14). The RUSH examination together with the physical examination, and ancillary diagnostic/laboratory testing, can help with early identification of various causes and treatment of patients with hypotension and shock.

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