Second Edition

Ultrasound-Guided Regional Anesthesia and Pain Medicine

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Preface to the First Edition

I began this atlas in Pittsburgh in 1988 with cadaver dissections, which I preserved in formalin tanks. In 1992, I began some simple ultrasound studies of the brachial plexus. By 1997, I was plastinating additional cadaver dissections at the University of Rochester and making simple line drawings of my dissections. Jooyeon Ha, Sara Bednarz, and Chris Bickel joined me from the departments of animation and medical illustration at Rochester Institute of Technology. Together, we created professional illustrations, animations, and three-dimensional virtual reality reconstructions. In 2002, I began ultrasound-guided nerve blocks. In 2006, I returned to Pittsburgh and was joined by Nizar Moayeri, who, along with Gerbrand Groen (University of Utrecht), had created a large archive of microanatomical dissections of the brachial, thoracic, and lumbar plexuses. In Pittsburgh, Jaques Chelly assigned some outstanding fellows (Alon Ben Ari, Melina Moreno, and David Burns) to work with me on new techniques in ultrasound-guided blocks. At the same time, Dr. Chelly introduced me to the editors at LWW and the formal foundation for this atlas was begun. C. C. Li, James Chien, Steven Damelin, and Jungha An contributed new ideas in image processing. Phil Cory and Stuart Grant added new ideas in radiofrequency imaging and ultrasound. Assad Oberei, Robert Borcala, and Yun Jing added new insights into needle design. Steve Orebaugh wrote many of the chapters. Other collaborators from around the world graciously joined us. Steven Breneman and Meg Stanbury edited many of the chapters and images. All together, my colleagues and I have spent more than 8,000 hours working on these dissections, drawings, animations, and researches. The Fulbright Foundation, the National Institute of Health, the National Science Foundation, Sleeping Gorilla, the University of Pittsburgh, SonoSite, B Braun, Life Tech, and the Manipulative Therapy Foundation of Holland contributed more than 1 million dollars in support. I hope you enjoy the atlas.

Paul E. Bigeleisen
Summer 2009, Rochester, NY and Pittsburgh, PA

Preface to the Second Edition

The first edition of *Ultrasound-Guided Regional Anesthesia and Pain Medicine* was a success when it was released in 2010. In general, the graphics and ultrasound images were better than in similar atlases produced at that time. Nonetheless, our Atlas was out of date within 2 years of its publication because of the rapid expansion of ultrasound into the diagnosis and performance of procedures for chronic pain conditions. In addition, the diagnosis and treatment of many other medical conditions with ultrasound guidance has found its way into the practice of anesthesiologists. For these reasons, I asked Michael Gofeld to join me as an editor on this edition for his expertise in the practice of ultrasound-guided musculoskeletal blocks. I also asked Sam Galvagno to write an introduction to other uses of ultrasound in the treatment of shock and trauma.

I would also like to thank the many new authors who have contributed 40 new chapters to this edition. I would especially like to thank:

Annelot Krediet, who was finally able to illustrate and elucidate the anatomy of the paravertebral space.

Michelle Odonkor and Bassem Asaad, who contributed many editorial suggestions.

Karen Boretsky, who really made the chapter on pediatric epidural and paravertebral blocks come to life.

Jooyoen Ha, who continued to provide extraordinary graphic support.

Steph Sadler and Susie Hancock, who created and edited many images.

Finally, both of my parents have passed away since the publication of the first edition. I am dedicating this edition to Grace and Jacob Bigeleisen, both of whom provided me with my spark of curiosity and wonder in life.

Contents

Ultrasound in Trauma and Critical Care

SAMUEL M. GALVAGNO JR AND JOSHUA SAPPENFIELD

Introduction and Indications: Ultrasound has become an indispensable tool for trauma and critical care practitioners. Ultrasound imaging provides an additional clinical tool that can be used to answer specific clinical questions and guide appropriate care. Due to advances in ultrasound technology, including improved visualization and portability, this technology has led to rapidly expanding applications. In this chapter, the focused cardiac ultrasound study (FOCUS) and the focused assessment with sonography (FAST) are introduced. In both of these exams, simple binary questions are posed. For the FOCUS exam, the operator systematically assesses left and right ventricular size and function, the pericardial space for fluid and tamponade, and a color Doppler assessment of valves to assess gross pathology. The inferior vena cava may also be imaged to assess dynamic fluid responsiveness parameters. In the FAST exam, four quadrants of the abdomen are imaged to determine the presence or absence of free fluid.

Anatomy: For the FOCUS exam, four main views are obtained. The first view, the parasternal long-axis view, involves a long-axis plane line through the left ventricular apex, capturing the left atrium, mitral valve, part of the left ventricle, and the left ventricular outflow tract. The right ventricle is poorly visualized with this view. The descending thoracic aorta is also visualized. The second view, the parasternal short-axis view, is perpendicular to the long-axis view and is obtained by rotating the ultrasound probe 90 degrees clockwise. The parasternal short-axis view provides visualization of the aortic valve, the mitral valve, papillary muscles, and the apex. The apical four-chamber view is perpendicular to both the long-axis and short-axis parasternal views. The ultrasound plane bisects the left ventricular apex and intersects both atria and both ventricles. The subcostal view also provides a four chamber view of both atria and the ventricles.

In the basic FAST exam, four ultrasound views are obtained. In the first view, the right upper quadrant is imaged to evaluate the presence of free fluid in the hepatorenal fossa (Morrison's pouch). In the second view, the probe is placed under the xiphoid process (subxiphoid view) to detect pericardial fluid. If this view is difficult to obtain (e.g., due to obesity, upper abdominal trauma), additional views from the FOCUS exam can be used to evaluate the pericardium. The left upper quadrant is imaged in the third view to detect perisplenic fluid. The final view involves placement of the ultrasound probe in the suprapubic area to evaluate the presence of free fluid in the rectouterine pouch (pouch of Douglas) and rectovesical pouch (**Fig. I.1**).

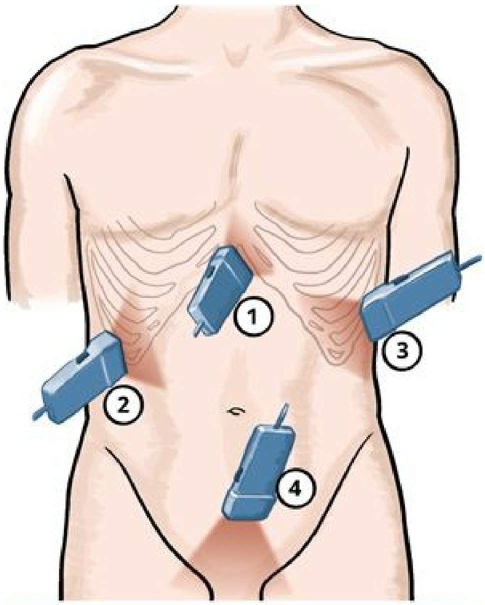

Figure I.1. Ultrasound probe positions for the basic FAST exam.

Patient position: For the FOCUS exam, the patient is positioned supine. The left lateral decubitus position may be used when possible to help the heart fall laterally to the left, beyond the sternum. Additionally, the left upper extremity may be abducted to open the intercostal spaces. In critically ill patients who cannot tolerate position changes, the only obtainable view may be the subcostal view. For the FAST exam, the patient is positioned supine.

Transducer: 1 to 5 MHz phased array probe

Approach and Technique: (**Fig. I.2**)

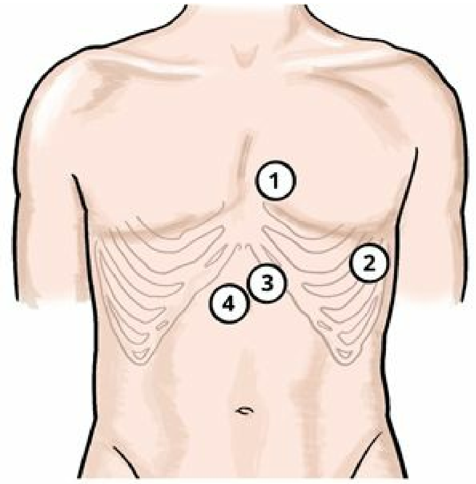

Figure I.2. General locations for ultrasound probe placement for the FOCUS exam. *1*, Parasternal long- and short-axis views. *2*, Apical four-chamber view. *3*, Subcostal view. *4*, View of the inferior vena cava.

FOCUS exam:

1. **Parasternal long-axis view**
   The transducer is positioned in the 2nd to 4th intercostal space, parasternal. The index marker is angled toward the patient's right shoulder. Gentle movements, including tilting, angulation, and rotation, are employed to obtain optimal visualization of structures. Depth is typically 14 to 16 cm. The heart should be visualized in the most horizontal orientation possible. Mechanically ventilated patients may have a more vertical heart. This view does not provide an adequate view of the right ventricle; only the right ventricular outflow tract is usually visualized (**Fig. I.3**).

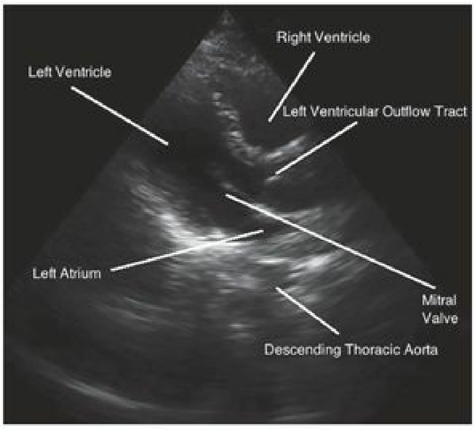

Figure I.3. Parasternal long-axis view.

2. **Parasternal short-axis view**
   The transducer is maintained at the same position as the parasternal long-axis view but rotated 90 degrees with the index marker pointing toward the patient's left shoulder. Gradual adjustments are made to visualize the left ventricle. Depth is typically the same as for the parasternal long-axis view (14 to 16 cm). Tilting the transducer cephalad helps obtain views of the aortic valve and pulmonary arteries. Tilting the transducer caudad brings the mitral valve and papillary muscles into view. This view is the ideal view for assessing left ventricular function (**Figs. I.4** and **I.5**).

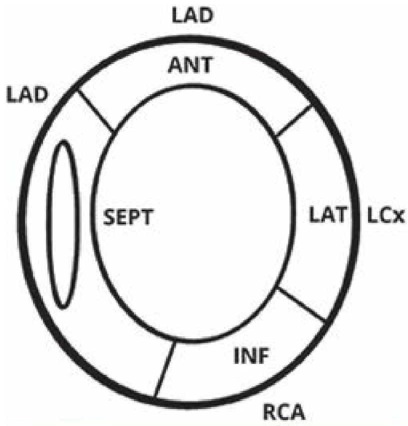

Figure I.4. The wall segments, and blood supply to the left ventricle, in the parasternal short-axis view. *ANT*, anterior ventricular wall; *INF*, inferior ventricular wall; *LAD*, left anterior descending artery; *LAT*, lateral ventricular wall; *LCx*, left circumflex artery; *RCA*, right coronary artery; *SEPT*, ventricular septum.

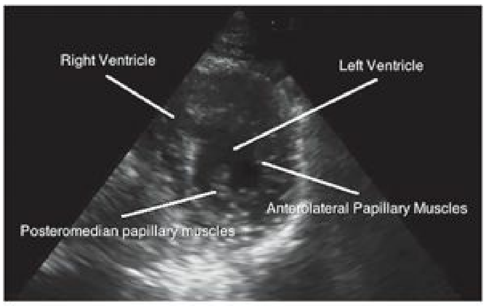

Figure I.5. Parasternal short-axis view.

3. **Apical four-chamber view**
   The transducer is placed laterally at medium depth (14 to 20 cm). The index marker on the transducer should be oriented in the 2 o'clock or 3 o'clock position, facing the patient's left shoulder. In spontaneously breathing patients, the transducer may be placed more medially to acquire the best view. Lateral decubitus positioning may help improve the view. Color Doppler can be applied to assess gross valvular function (i.e., severe regurgitation) (**Fig. I.6**).

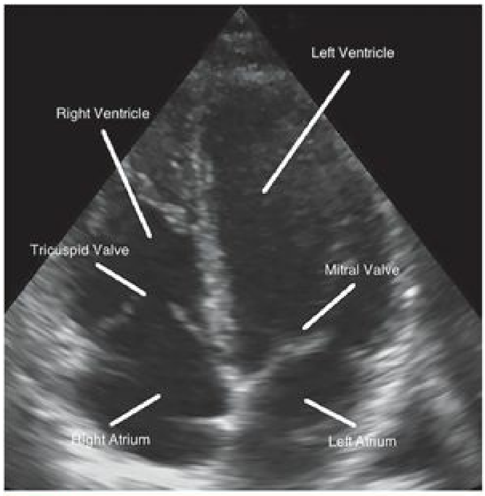

Figure I.6. Apical four-chamber view.

4. **Subcostal four-chamber view**
   The patient should be positioned supine. The transducer is introduced under the xiphoid process, with the index marker oriented to the patient's left side. Because this is another four-chamber view, this view is useful for assessing pericardial fluid and right ventricular size and function; however, off-axis views can lead to under- or overestimation (**Fig. I.7**).

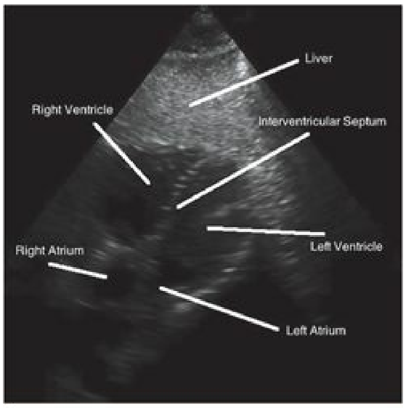

Figure I.7. Subcostal four-chamber view.

5. **Inferior vena cava**

   Estimation of the size and collapsibility of the inferior vena cava (IVC) may be useful in the evaluation of cardiac preload and circulating fluid status. The use of ultrasound-guided IVC measurements has been validated primarily in spontaneously breathing patients. In mechanically ventilated patients, IVC measurements are less reliable due to a high prevalence of IVC dilation. The IVC diameter should normally be greater than 1 cm (10 mm) but less than 3 cm (30 mm). In conscious patients, the patient is asked to take a brief inspiration or "sniff." A normal response to the sniff test is an inspiratory decrease in the diameter (>50%) of the IVC. An abnormal response to the sniff is a dilated IVC (>20 mm) without an inspiratory decrease in IVC diameter (<50%). An abnormal sniff test may indicate elevated right atrial pressure and fluid overload. Alternatively, an IVC less than 1 cm (10 mm) may indicate hypovolemia (**Fig. I.8**).

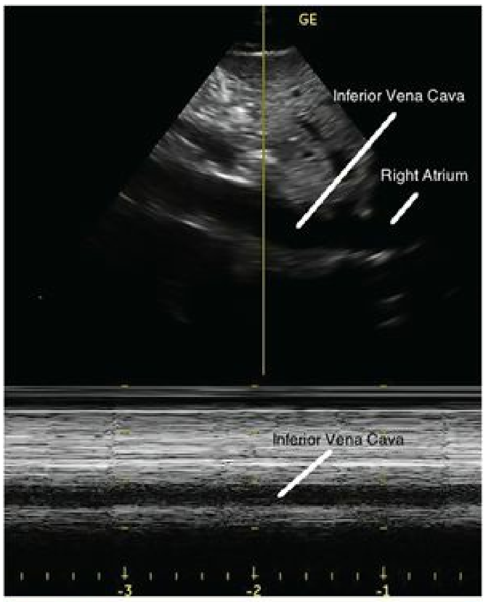

Figure I.8. Ultrasound view of the inferior vena cava (IVC). The IVC can be assessed by either two-dimensional echo *(top)* or M-mode *(bottom)*.

FAST exam:

The basic FAST exam is a four-view abbreviated ultrasound technique directed at identifying the presence of free intraperitoneal or pericardial fluid, usually due to hemorrhage. Results are interpreted as positive, negative, or indeterminate. Sensitivity varies between 42% and 96%, although specificity is often higher. The FAST may reduce the need for diagnostic peritoneal lavage (DPL), may reduce the requirement to obtain a computed tomography (CT) scan, and may reduce the time from initial diagnosis and time in the emergency department to the operating room (**Figs. I.9** to **I.11**).

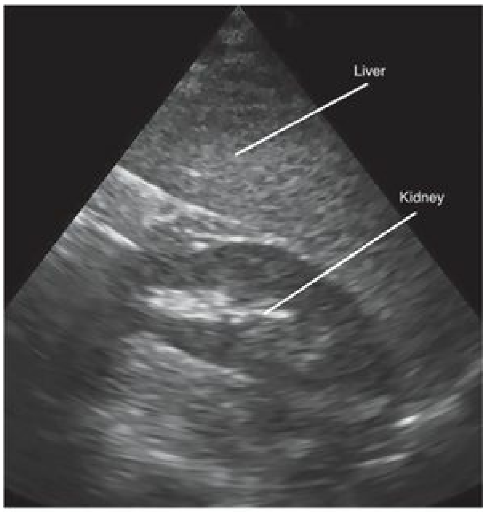

Figure I.9. Right upper quadrant (hepatorenal fossa).

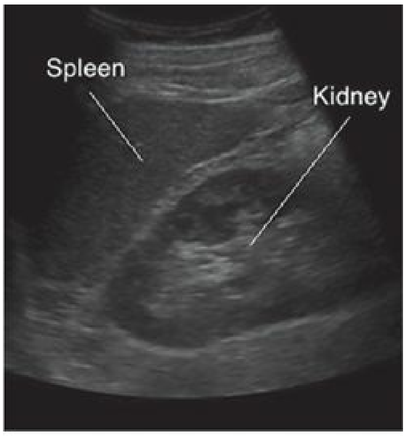

Figure I.10. Left upper quadrant.

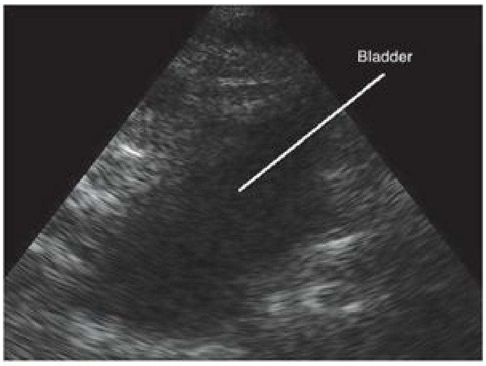

Figure I.11. Suprapubic/pelvic view.

Tips:

1. The three principles of the FOCUS exam are patient positioning, image acquisition, and image interpretation.
2. Basic echocardiography is best learned with a "hands-on" approach. Excellent introductory courses are available from the Society of Critical Care Medicine (www.sccm.org) and the American College of Chest Physicians (www.accp.org).
3. The FOCUS exam is designed to answer binary questions. For example, the assessment includes left and right ventricular size and function (normal versus abnormal), pericardial space (presence or absence of fluid or tamponade), and color Doppler to assess the aortic, mitral, and tricuspid valves for gross abnormalities (i.e., severe regurgitation, stenosis).
4. The FAST exam is a "rule-in" triage tool for patients with blunt abdominal trauma; CT remains the gold standard for detecting injuries in patients with blunt trauma.
5. Free fluid in the pelvis can be missed when the bladder is empty. Hence, whenever possible, the bladder should be scanned before a urinary catheter is placed.
6. Retroperitoneal hemorrhage is missed with the FAST, although some newer protocols are designed to improve detection.
7. Both FOCUS and FAST exams may be limited in morbidly obese patients or in patients with subcutaneous emphysema.