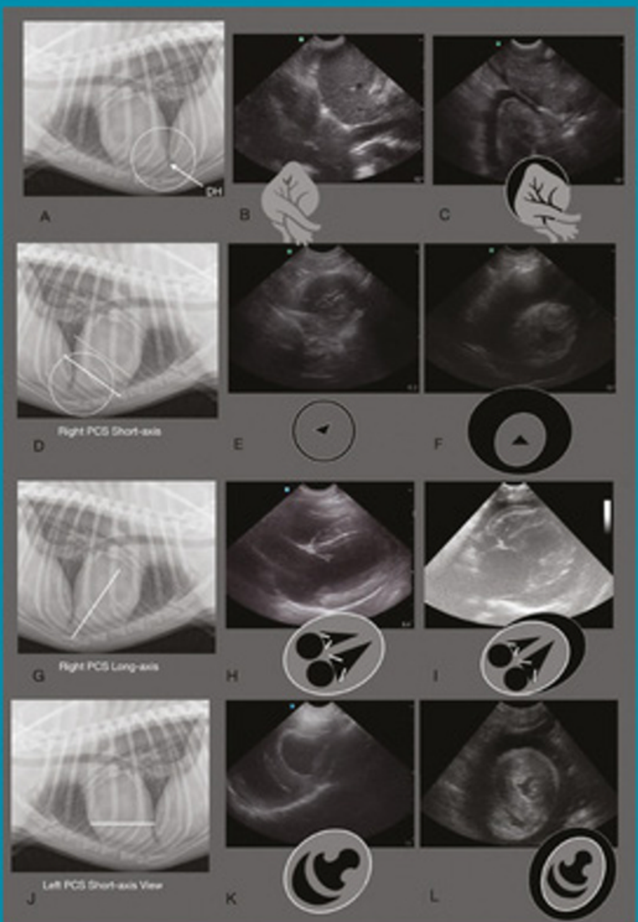
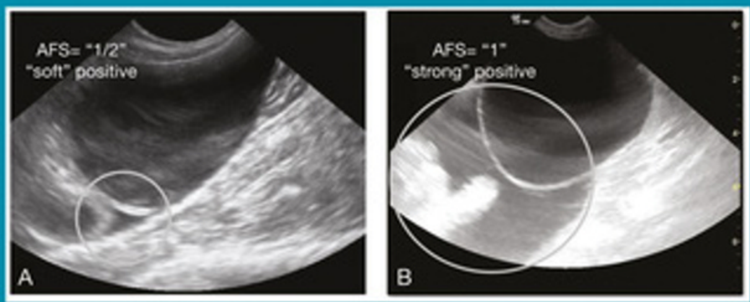
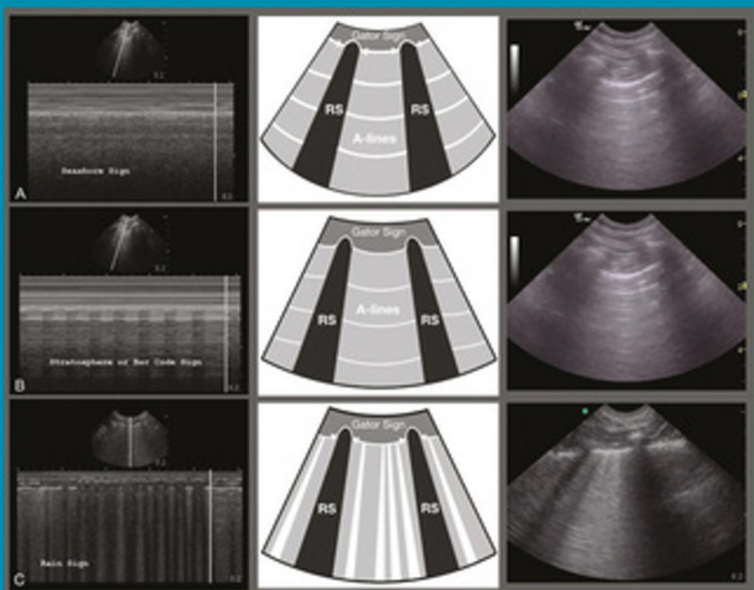
Point-of-Care Ultrasound Techniques for the Small Animal Practitioner

2
Second Edition

Edited by **Gregory R. Lisciandro**







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SECOND EDITION

Edited by

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This edition first published 2021

Edition History
John Wiley & Sons (1e, 2014)

Registered Office
John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

Editorial Office
111 River Street, Hoboken, NJ 07030, USA

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Library of Congress Cataloging-in-Publication Data

Names: Lisciandro, Gregory R., editor.
Title: Point-of-care ultrasound techniques for the small animal practitioner / edited by Gregory R. Lisciandro.
Other titles: Focused ultrasound techniques for the small animal practitioner.
Description: Second edition. | Hoboken, NJ : Wiley-Blackwell, [2020] | Preceded by Focused ultrasound techniques for the small animal practitioner / edited by Gregory R. Lisciandro. 2014. | Includes bibliographical references and index.
Identifiers: LCCN 2020000659 (print) | LCCN 2020000660 (ebook) | ISBN 9781119460985 (hardback) | ISBN 9781119460992 (adobe pdf) | ISBN 9781119461029 (epub)
Subjects: MESH: Ultrasonography–veterinary | Animal Diseases–diagnostic imaging | Point-of-Care Systems | Pets
Classification: LCC SF772.58 (print) | LCC SF772.58 (ebook) | NLM SF 772.58 | DDC 636.089/607543–dc23
LC record available at https://lccn.loc.gov/2020000659
LC ebook record available at https://lccn.loc.gov/2020000660

Cover Design: Wiley
Cover Image: © Courtesy of Gregory R. Lisciandro

Set in 10/12pt Palatino by SPi Global, Pondicherry, India

10 9 8 7 6 5 4 3 2 1

Dedication

To my late grandparents, Sam and Bernice Long, John and Mary Lisciandro, my parents Richard and Judy, and my lovely wife Stephanie, and our four beautiful children Noah, Hannah, Sarah, and Joshua for their patience and inspiration, to all those who have believed in Global FAST, and to the good Lord for making the textbook and all its many variables fall in place to its completion.

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Foreword

Over the past three decades, the technological miniaturization of ultrasound machines has made compact, portable ultrasound devices, ranging from pocket-sized devices to laptop-style machines, available to healthcare providers at the bedside. Healthcare providers are using ultrasound to look inside the body during their bedside evaluation of patients, which has given rise to a new field of clinical medicine called *point-of-care ultrasound*. Point-of-care ultrasound is defined as a goal-directed, bedside ultrasound examination performed by a healthcare provider to answer a specific diagnostic question or guide performance of an invasive procedure at the bedside. Providers from nearly all healthcare professions have begun to learn how to use point-of-care ultrasound, and veterinary medicine is ideally suited for integration of point-of-care ultrasound given the diverse complaints and wide range of animals that are cared for by veterinarians on a daily basis.

The first edition of this book, called *Focused Ultrasound Techniques for the Small Animal Practitioner*, was published in 2014 and described the most common focused ultrasound examinations in veterinary medicine. The first edition established a standardized approach to perform a multisystem veterinary ultrasound examination, particularly of the heart, lungs, and abdomen, and has served as a guide for veterinarians to incorporate ultrasound into their clinical practices around the world. The book has been translated into Spanish, Chinese, Greek, Japanese, and Polish, and over 2000 copies have been sold worldwide.

In this second edition, the reader experience has been enhanced in several ways. The core chapters describing the fundamental veterinary ultrasound examinations have been expanded to discuss a broader range of species, including exotic species, and a more in-depth discussion of feline species. Several new chapters have been added, including chapters on the use of ultrasound to evaluate marine mammals and zoo animals. Chapters on the nervous system describe evaluation of the brain and peripheral nerves, as well as performance of ultrasound-guided nerve blocks. The online video library has been expanded to include over 100 videos of normal and abnormal findings to supplement the book chapters.

For veterinary clinicians seeking to improve their knowledge and skills in point-of-care ultrasound, this book has evolved to become a standard reference for its high-yield chapters, online video content, and practical teaching points written by experts in the field.

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Preface

POCUS is point-of-care ultrasound. Veterinary POCUS (V-POCUS), which includes FAST ultrasound examinations, is defined as a goal-directed ultrasound examination(s) performed by a veterinary healthcare provider at the point of care (cageside) to answer a specific diagnostic question(s) or guide performance of an invasive procedure(s).

The translational study from the human to the veterinary patient regarding the focused assessment with sonography for trauma (FAST) exam by Dr Søren Boysen and colleagues in 2004 was a landmark study opening the eyes of the veterinary world to the nonradiologist, noncardiologist use of ultrasound, and that the principle of FAST ultrasound, that the nonradiologist sonographer is able to recognize anechoic triangulations representing free cavitary fluid, was not only achievable but also had the potential to improve patient care and save lives.

The following year, 14 years after graduating from veterinary school, I began my residency training in emergency and critical care in San Antonio, Texas, a city supportive of military training with several bases, and thus a mecca for FAST ultrasound. At the time, my program mentor encouraged me to take on FAST ultrasound as my clinical research requirement. I balked at the idea, having failed a complete abdominal ultrasound course in 1999, six years earlier, and thus concluding that ultrasound was a skill I would never master. However, I finally agreed to read the Boysen et al. study, after which I thought: "This (FAST ultrasound) **will** improve patient care. And I only have to be able to recognize black (anechoic) triangles. I like anatomy and surgery. I **can** memorize four views. It's only four views."

Thus, I decided that I would give ultrasound one more try. The FAST study intrigued me in the numbers of dogs with occult injury missed with traditional screening tests of physical exam, baseline blood and urine testing and radiography, but captured using FAST ultrasound. The study raised many fascinating questions, including looking past the diaphragm, adding a fluid scoring system to better categorize a positive FAST examination, and exploring the thorax with its own FAST format. Thus, my unimaginable journey began with developing AFAST, its target organ approach and its fluid scoring system; developing TFAST for pneumothorax, pleural and pericardial effusion, and its echo views for cardiac abnormalities; and most recently Vet BLUE (Veterinary Brief Lung Ultrasound Exam). Initially (2005), we combined AFAST and TFAST and referred to the study as "Combo (Combination) FAST" because we quickly realized how important it was to screen both cavities. Combining these three formats circa 2010, the study is now referred to as Global FAST and serves as an extension of the physical exam.

Now, 15 years later, the ultrasound probe is not only used by emergency veterinarians but also other nonradiologist, noncardiologist specialists as well as general practitioners. The use of ultrasound as a first-line, daily imaging modality has become commonplace globally throughout veterinary medicine, improving patient care and saving lives often by capturing disease otherwise missed with traditional work-ups without ultrasound and detecting complications earlier in their course. Although there may not be the published evidence, I know how much I missed on a daily basis having practiced the first 13 years of my 28-year career as a general practitioner and then followed by the first three years in emergency and critical care *without* ultrasound. Many cases from the pre-FAST era still haunt me and how I failed my patient and their families by missing conditions easily recognized with the Global FAST approach.

The objectives for POCUS and FAST examinations are to rapidly answer important clinical questions to help *rule in* and *rule out* conditions, to see your "problem" list for a more streamlined diagnostic plan; to better decide on medical versus surgical and other interventional cases; and to keep the patient alive for gold standard testing and treatment, with a better chance of survival. "Seeing" your problem list as part of your physical exam provides more evidence-based information over traditional work-up paradigm(s). Every clinical specialist, including the internist, oncologist, cardiologist, criticalist, neurologist, surgeon, anesthesiologist, ophthalmologist, dentist, and dermatologist, and the ER veterinarian and general practitioner should make learning the basics of POCUS and FAST ultrasound a core skill and first-line evaluation (extension of the physical exam) for most if not every patient. The new mantra should be "Physical examination and Global FAST!" as the starting point for every patient, providing an unbiased set of data imaging points in both cavities, the abdomen and thorax, for every veterinarian seeing clinical cases.

In my internship year at the Animal Medical Center in New York City in 1991–1992, our Intern Director, the late Dr Michael Garvey, always emphasized that we should "never send a patient out the door with something you could have easily detected by performing a good physical exam and your quick assessment tests." The day has come when the Global FAST approach should be part of your quick assessment tests. In other words, Global FAST is "an extension of your physical exam," a term coined by Rozycki and colleagues over 20 years ago. Importantly, POCUS then follows the Global FAST approach for more targeted evaluations as subsequently explained.

With POCUS examinations now being used in human and veterinary medicine on a daily basis, standardization with clear objectives is imperative not only establishing for validity and a healthy respect among our colleagues but for perfecting your skills. Recording data on goal-directed templates that demonstrate an organized, well-defined imaging protocol for answering clinically relevant questions is also key for veterinary medicine as a whole to embrace this movement. These questions must be realistically achievable, often binary, for the nonradiologist, noncardiologist sonographer. In this second edition, we have tried to make POCUS and FAST ultrasound examinations as clear as possible.

However, even with this approach, we think that caution should be exercised in how *individual* POCUS examinations are applied to patients. For example, a POCUS gallbladder examination may prove unremarkable, but if the Global FAST approach is applied to every patient as part of the *initial* evaluation process, the pericardial effusion, poor systolic function (dilated cardiomyopathy), low-grade peritonitis or small-volume hemoabdomen would *not* have been missed or delayed in its detection. In other words, the Global FAST approach should be considered your baseline imaging test with POCUS examinations considered as adjuncts. This imaging strategy prevents "satisfaction of search error" to which POCUS examinations by themselves are prone. Global FAST prevents the picking and choosing of whichever POCUS examination helps fulfill your preconceived clinical bias by providing a mandated, standardized set of imaging data points of the abdomen and thorax.

In another example, the POCUS heart provides an overview for cardiac information but is *too* focused, missing lung abnormalities and comorbidities within the patient's abdominal cavity. Through a Global FAST approach plus the *add-on* of a POCUS heart, the enlarged caudal vena cava suggesting right-sided heart congestive failure is detected, or the splenic mass or small-volume ascites is not missed, that was not even considered by the clinician but found as an unexpected comorbidity. Lastly, an unremarkable POCUS heart exam on a coughing dog, without an integrated approach with Global FAST, misses the widespread small lung nodules or the aspiration pneumonia that are *inapparent* on thoracic radiography. The "POCUS only" analogy would be similar to a selective physical examination, in which *only* the abdomen is palpated in a vomiting cat, or *only* the heart and lung ausculted in a coughing dog, or *only* the limb evaluated in a limping older dog. Most of us are aware of missing major problems when doing incomplete physical exams.

You may have or soon will have the epiphany of how powerful a tool first-line ultrasound is. The same epiphany has occurred in human medicine with similar stories of how first-line medical personnel are capturing aortic dissections in patients who have recovered and compensated, ectopic pregnancies with internal intermittent bleeding, and pulmonary thromboembolism as life-saving examples that historically would have been delayed or completely missed (possibly resulting in death). Capturing these traditionally problematic life-threatening conditions is now possible on *initial* evaluation within minutes of presentation by "seeing" the problem.

In this second edition, we provide additional knowledge on what we have learned since the first edition, with more chapters and additional topics. These include additional chapters on eye and musculoskeletal exams as well as ultrasound-guided procedures, including the thoracic procedures and nerve blocks. Moreover, we devote an entire chapter to cats. We continue to push the envelope with the addition of more species including exotic companion mammals, marine mammals, birds, and reptiles. Personally, after performing thousands more exams, publishing numerous clinical studies, and through training over 1000 veterinarians in these techniques, we also share what we have learned using the Global FAST approach. We also welcome not only our previous chapter authors, who have also learned much since the first edition, but also a new set of thought-leading authors sharing their expertise in their respective chapters.

And, finally, as I prepared this second edition, reading through lists and lists of references, it became even more apparent that this paradigm change would not be possible without the many sonographers, veterinarians, residents, radiologists, and cardiologists who have painstakingly worked through untold hours of scientific research and clinical studies that have laid the foundation, for where veterinary diagnostic ultrasound is today. We extend a big thank you!

So let's get on with it. We welcome feedback by email at FASTSavesLives@gmail.com and via our Facebook page, www.facebook.com/FASTVet, or our website www.FASTVet.com. Your stories and experiences as general practitioners, emergency and critical care veterinarians, and clinical specialists are awaited. Your stories and experiences help keep the POCUS and FAST train moving forward, helping with advancements in training, perfecting imaging techniques, and their clinical applications.

Acknowledgments

The following are acknowledged for their illustrative contributions: Suji Park, Englewood Cliffs, New Jersey (www.sujisuji.com); Dr Judy Brown, DVM, Dipl. ACVECC, Toronto, Canada; Hannah M. Cole, Adkins, Texas; Nancy Place, MS, Association of Medical Illustrators, San Antonio, Texas; Alice MacGregor Harvey, Medical Illustrator, North Carolina State University; and Randi Taggart, Richmond, Virginia.

Dr Karin Vomend, MVZ, Cuernavaca, Mexico, for editorial help and Dr William A. Seleen Jr, Bemus Point, New York, who read the entire manuscript and provided editing and content suggestions that helped improve the manuscript.

The entire Wiley team, including Erica Judisch, Commissioning Editor, and Jayadivya Saiprasad, Project Editor, and her staff, Holly Regan-Jones, freelance editor, for their expertise, patience, and encouragement throughout the construction and editing of the second edition, which became far bigger than originally foreseen.

The chapter authors from the United States and internationally, who not only believe in the potential for point-of-care and FAST ultrasound to make a positive impact in veterinary medicine but also generously gave their time and expertise in making this second edition possible.

Lastly, Drs Kelly Mann, DVM, DACVR, and Geoff Fosgate, DVM, PhD, DACVPM, University of Pretoria, who have helped me generously since my residency training with publishing clinical research; Dr Søren Boysen for his help, support, and friendship throughout the years; and my wife, Dr Stephanie C. Lisciandro, DVM, Dipl. ACVIM, who with her support, sacrifice, and dedication over the past decade has made it possible for me to invest the tremendous amount of time and effort needed to accomplish this task. I am forever grateful.

About the Companion Website

Don't forget to visit the companion website for this book: www.wiley.com/go/lisciandro/ultrasound2

There you will find valuable material designed to enhance your learning, including:

- Video clips

Scan this QR code to visit the companion website.

SECTION I

Basics of Ultrasound and Imaging

CHAPTER ONE

POCUS: Introduction

Gregory R. Lisciandro

Veterinary POCUS (V-POCUS) Defined

- *POCUS is point-of-care ultrasound.*
- *FAST is focused assessment with sonography for trauma, triage, and tracking (Lisciandro 2011).*
- *Veterinary POCUS (V-POCUS), which includes FAST examinations, is defined as a goal-directed ultrasound examination(s) performed by a healthcare provider at point of care (cageside) to answer a specific diagnostic question(s) or guide performance of an invasive procedure(s).*

We will use the acronyms POCUS and FAST throughout the textbook. It is important to read the Preface *prior to* Chapter One.

Terminology Updates

Briefly, we will mention some of the more important changes and developments since our first edition. A more complete list of terminology and abbreviations is found in the Appendices. For a grasp of some of the basic concepts within this textbook, let's define a few things.

The "T³" of Trauma, Triage, and Tracking

We have mostly dropped the "T³" designation that previously emphasized the "3-T approach" of applying FAST for *T*rauma, *T*riage, and *T*racking (T³), primarily because since the first edition, the T³ approach has become routine throughout North America, South America, Europe, and the Middle East in the author's experience.

COAST³ is Out, POCUS is In

COAST³ or "cageside organ assessment with sonography for trauma (triage and tracking)" is out (similar to BOAST in human medicine) and POCUS is now the preferred mainstream term similar to what has occurred in human medicine (Rozycki et al. 2005; Lisciandro et al. 2014).

We have replaced COAST with POCUS in this second edition and advocate for POCUS (or Focused) X, or POCUS (Focused) Y, or POCUS (Focused) Z as giving better clarity to the examination and have proposed approaches to the various systems throughout this edition. The use of FoCUSED for "Focused Cardiac Ultrasound" and other confusing acronyms we hope to avoid in veterinary medicine. FoCUSED in human medicine would have been better named POCUS (or Focused Heart) Heart or POCUS (or Focused Echo) Echo. The term "Focused" as in our first edition similarly provides clarity to the examination and may be used interchangeably with specific POCUS examinations.

FAST Survives and Continues

FAST stands for Focused Assessment with Sonography for Trauma and has been applied to the abdomen (FAST) and extended thorax (EFAST) in people (Rozycki 1998; Rozycki et al. 2001; Kirkpatrick et al. 2004). Its applications have expanded to

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Companion website: www.wiley.com/go/lisciandro/ultrasound2

nontrauma and tracking (Lisciandro 2011, 2016; McMurray et al. 2016). Problems arise in the human literature with terminology and they are not always right. For example, what exactly is EFAST? Is it a FAST *and* the thorax or *only* the thorax? What if we just do the thorax, then what FAST do we call it? Abdominal FAST (AFAST) and thoracic FAST (TFAST) give exact clarity and have been standardized and validated in published studies (Lisciandro et al. 2008, 2009; Lisciandro 2016; McMurray et al. 2016). Their acoustic windows have *exact clarity*, as does the "FAST" lung examination called Vet BLUE (Lisciandro et al. 2014, 2017).

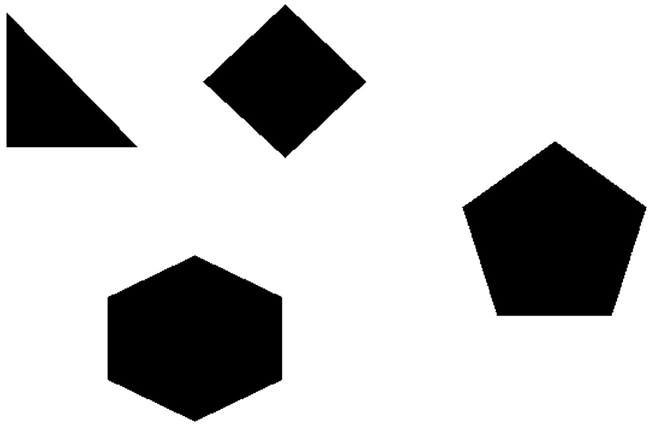

Figure 1.1. The premise of FAST ultrasound – anechoic triangulations are abnormal and represent free cavitary fluid. The nonradiologist can be readily trained to recognize anechoic (black) triangulations within cavities and spaces, which are abnormal in adult patients. The "Flash" exam answers a simple binary question of whether fluid is present or absent, whereas the AFAST provides more information through fluid scoring and its target organ approach, TFAST through echo views and volume status, and Vet BLUE through a regional, pattern-based approach. Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

The Flash Exam is Not a FAST Exam

The "Flash Exam" term is applied for a general whole-cavity acoustic window approach to rapidly answer a simple binary question: is free fluid present or not in the abdominal and thoracic cavity? And now, with lung ultrasound becoming accepted among colleagues, are B-lines present or not? There is so much more to gain by using standardized acoustic windows of AFAST and TFAST (and Vet BLUE) that take about the same amount of time as the "Flash" approach. The "Flash" usually is followed by "looking around," often leading to a "satisfaction of search error" approach. Again, in the *same* amount of time, you could have done AFAST, TFAST, and Vet BLUE (Global FAST) with *standardized* acoustic windows following a protocol and gained so much more unbiased baseline patient information, while avoiding "satisfaction of search error." AFAST, TFAST, and Vet BLUE are not "Flash" exams and the terms should not be used interchangeably. We should stop teaching the "Flash" approach, just as we would not teach limited physical examinations – such as only quickly palpating the abdomen of a vomiting cat to draw clinical conclusions without looking further (Figure 1.1).

Radiologist and Cardiologist Studies

We will refer to these studies as complete detailed abdominal ultrasound" and "complete detailed echocardiography." "Diagnostic" is a term that can be more universally applied as both a POCUS (or Focused) and FAST examination are potentially diagnostic, for example for ascites, pleural and pericardial effusion, calcaneus tendon rupture, skull fracture, a splenic mass, gallbladder mucocele, to name a few.

Other Terms

We have done our best to make this second edition uniform in terminology and up to date with the current consensus in both human and veterinary medicine. Some examples in which multiple terms relating to similar things are used are listed here.

The preferred term is listed first but each may be considered synonymously.

- POCUS exam and Focused exam
- sonographer and ultrasonographer
- ultrasonographically and sonographically
- color Doppler and color flow Doppler
- beam and scanning plane
- acoustic window and view
- fanning and tilting
- longitudinal and sagittal (and long axis)
- transverse (and short axis)
- orientation and plane
- probe and transducer
- curvilinear probe and microconvex probe
- B-lines and ultrasound lung rockets
- lung sliding and glide sign
- gallbladder halo sign, gallbladder halo effect, and gallbladder double rim effect

- FAST diaphragmatico-hepatic view and subxiphoid view
- acoustic coupling and probe–skin contact

We have provided a comprehensive list of abbreviations, terms, and definitions in the Appendices.

Recording Your Findings on Goal-directed Templates

Recording data on goal-directed templates with clear objectives for answering defined clinical questions is imperative to gain the respect of our colleagues, to stay disciplined during the respective POCUS or FAST examination, to allow *post hoc* evaluation of studies, and to detect training strengths and deficiencies. Without recording your data, you cannot measure. If you cannot measure, you cannot critically study with the potential to improve. We have made great strides in Global FAST training by reevaluating our results recorded on goal-directed templates and saved video clips. A prime example is the establishment of clear tenets for the accurate TFAST diagnosis of pericardial effusion (Lisciandro 2016).

We have presented POCUS and FAST goal-directed templates and methods to efficiently save video clips for you to adapt and modify for your practice according to the types of cases you see, your practice type, and your skill level in the Appendices and Chapter 45.

Echogenicity – Whites, Grays, and Blacks

The jargon of ultrasound can be intimidating to the novice sonographer. Clarity may be accomplished through acknowledging that *ultrasound is generally the opposite of how free fluid, air, and soft tissue appear on radiographic studies* (our brain needs to reformat itself). For example and very simplistically, air is white on ultrasound and black on radiographs. Fluid is black on ultrasound and white on radiographs. However, bone is black (shadows) on ultrasound? And white on radiographs? Or white along its proximal surface with acoustic shadowing through the far field. Now if we are losing you, hang in there. The figures help (Figures 1.2, 1.3, 1.4, 1.5). *Study them now.*

The ultrasound terms describing whites, grays, and blacks are anechoic (black), degrees of echogenicity (hypoechoic, shades of gray), and hyperechoic (white).

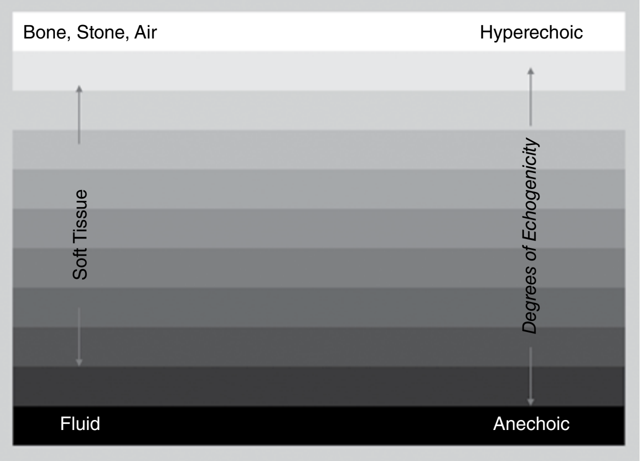

Figure 1.2. The figure shows the ultrasound differences in B-mode gray scale of various tissues, with bone, stone and air being most reflective of the ultrasound beam and thus portrayed as white along its surface, to soft tissues being shades of gray, to fluid which is black. Ultrasound terminology corresponds to these gray-scale colors as hyperechoic, degrees of echogenicity (hypoechoic), and anechoic. Study this chart to get the visual of what these gray-scale terms mean. Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

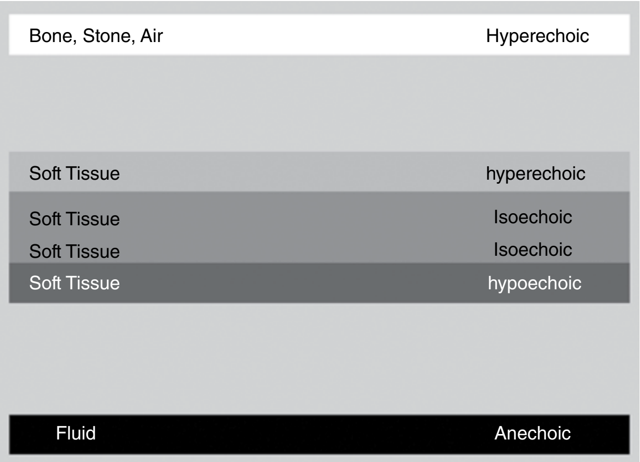

Figure 1.3. This figure is similar to Figure 1.2 but with some of the gray scale removed to illustrate how descriptive ultrasound terminology is used for different tissues. The soft tissue is isoechoic (same as), hyperechoic (brighter than), and hypoechoic (darker than) relative to one another. Correlate with Table 1.1 Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

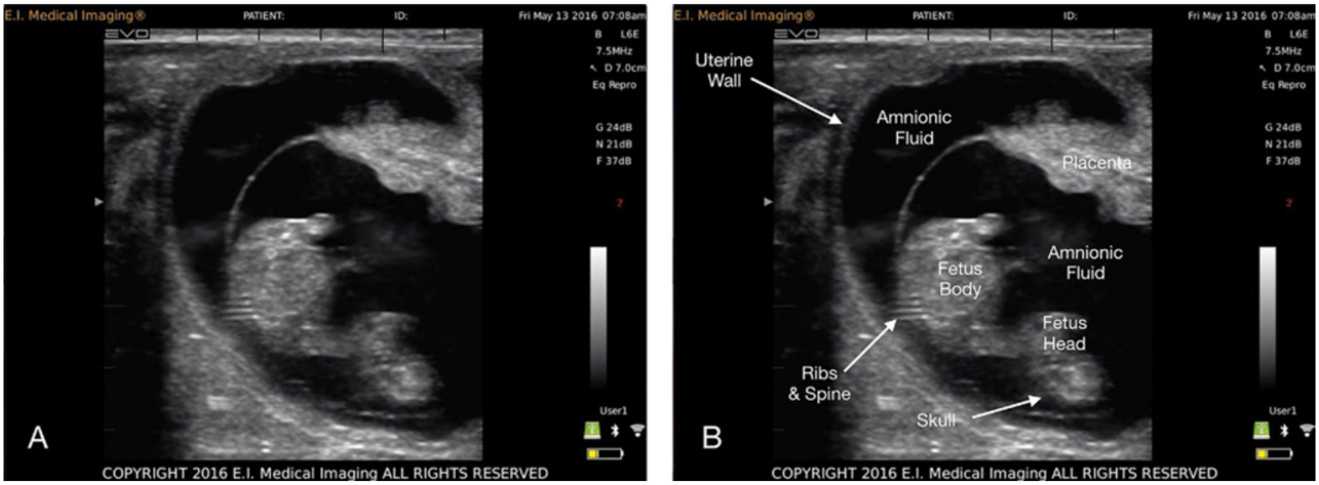

Figure 1.4. This figure is unlabeled and labeled for contrast of what tissue looks like in a gravid female, illustrating the different tissues and structures that correlate with concepts in Figures 1.1 and 1.2. Image used with permission from E.I. Medical, Loveland, CO, USA. www.eimedical.com

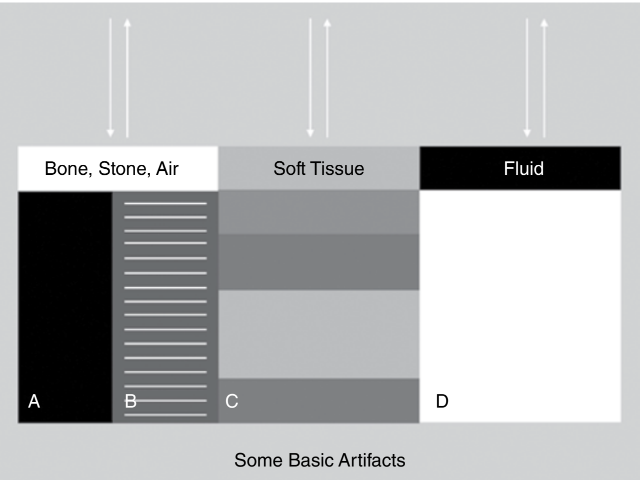

Figure 1.5. Ultrasound and different tissues and elements. Schematic that ties into the previous images showing various elements and the general behavior of ultrasound and its associated artifacts. The arrows represent the ultrasound beam being transmitted and returned to the transducer (probe). In (A) and (B), bone, stone, and air *reflect* because ultrasound (its echoes) does not transmit through them. As a result, they create shadowing of the beam, resulting in (A) "clean shadowing" (anechoic or black past the surface of the structure or element) or (B) "dirty shadowing," including air reverberation called A-lines (hyperechoic horizontal bars past the air). Soft tissues will absorb the ultrasound in different degrees depending on the soft tissue, thus (C) shows different degrees of echogenicity. Lastly, fluid will not absorb much of the ultrasound (echoes pass through the fluid), resulting in (D) acoustic enhancement through the far-field beyond the distal boundary of fluid, making tissues more hyperechoic (brighter) than their adjacent counterparts outside the fluid-related beam. Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

The terms may be used relatively between structures like "X relative to Y" and "Y relative to Z." For example, the spleen is *hyper*echoic (brighter than) to the left kidney. The liver is *hypo*echoic (darker than) to the falciform fat. The feline cortex of the kidney is isoechoic (same as) to the spleen (see Figure 1.3).

- **Anechoic (homogeneous black)**: occurs when *no ultrasound waves* are reflected back to the receiver. Thus, normal urine, normal bile, transudates, and blood all are purely anechoic (black).
- **Hypoechoic (shades of gray)**: occurs when *variable degrees of ultrasound waves* are reflected back to the transducer. Thus, the more echoes reflected back, the brighter gray the structure, and the fewer echoes, the darker the gray. Thus, all soft tissues that are not fully aerated are described relative to other distinct tissues, such that the liver is hypoechoic (darker than) relative to the spleen. Viscus organs (i.e., stomach) cannot be described this way, only their walls (i.e., stomach wall).
- **Hyperechoic (whites, bright whites)**: occurs *when all or nearly 100% of ultrasound waves* are reflected back to the transducer. Thus, bone, stone (metals), and air are strong reflectors resulting in hyperechoic (bright white) interfaces with shadowing, comet tail artifact, ring-down artifact, ultrasound lung rockets, or reverberation artifact projected *distal* to the reflective surface.
- **Isoechoic (same echogenicity)**: occurs when tissues are the same shades of gray. For example, if the liver is isoechoic to the spleen then they are the same echogenicity (same shades of gray).

How Ultrasound Behaves Relative to Tissues and Elements

The knowledge of how ultrasound behaves relative to the structures and elements it encounters is very important. From normal tissues within the body to its various constituents (elements) of fluid, air, and mineralization, ultrasound behaves differently, causing a number of artifacts, which can be learned with diligent study, training, and practice. Foreign materials, such as plastic, metal, bone, stone, glass, and vegetative materials, also cause predictable artifacts. These artifacts will be covered in the next few chapters and throughout the textbook. It is a good idea to consider them every time you look at an image to accelerate your learning process.

Degrees of echogenicity of commonly encountered structures from hypoechoic to hyperechoic structures are listed in Table 1.1.

Ultrasound Screen Orientation

The screen orientation should always be "head to the left and tail to the right," similar to the orientation for radiography (Figure 1.6). Thinking in this manner will help you learn the anatomy you are seeing and help you with the direction you need to go to get to the POCUS and FAST ultrasound structures of interest. The exception to this rule is that most cardiologists *reverse* the screen orientation of the heart, which is very problematic for learning image acquisition when doing a Global FAST approach. Many human institutions have rejected this approach for the noncardiologists performing POCUS and FAST examinations for the aforementioned reason.

Table 1.1.
Degrees of echogenicity of commonly encountered structures.

	Structure
Anechoic – hypoechoic (black)	**Bile, urine**
	Muscle
Darker	Renal medulla
	Renal cortex
	Liver
Shades of gray	Fat
	Spleen
	Prostate
Brighter	Renal sinus
	Vessel walls
Hyperechoic (white)	**Bone, air, gas**

Directional Terms for Orientation

Longitudinal and Sagittal

The term *longitudinal* refers to orientation parallel to the spine *or long axis* of the patient's body (see Figures 4.1, 4.2, 4.3). The term *sagittal* refers to the longitudinal axis of the respective deeper structure being evaluated. For example, the superficial jugular vein is imaged in longitudinal whereas the more deeply located and oblique right kidney (not parallel to the body's long axis) is imaged in sagittal planes (parallel to the right kidney's long axis). The terms are often used interchangeably (or, arguably, misused); however, by appreciating that both terms are in their own right long-axis views, directional communication between veterinarians seems to be clear by use of either term. Thus in longitudinal planes, the probe marker is directed towards the patient's head to maintain the same orientation as radiography, head to the left and tail to the right of ultrasound (and radiographic) image.

Transverse

The term *transverse* refers to orientation 90° to the long axis of the structure being evaluated or the *short axis* of the patient (see Figures 4.1, 4.2, 4.3). The probe marker is turned to the left (or counterclockwise) to the patient's right side. Thus, in transverse planes, the probe marker is directed to the patient's right side to maintain the same orientation as radiography, right side on left side of ultrasound (and radiographic) image.

With that said, let's get on with Dr Fulton's chapters that will cover in more detail the physics of ultrasound, its artifacts, and various pointers on the ultrasound machine features and settings and image acquisition.

It's worth your effort and time investment to learn this core skill – POCUS and FAST improve care and save lives!

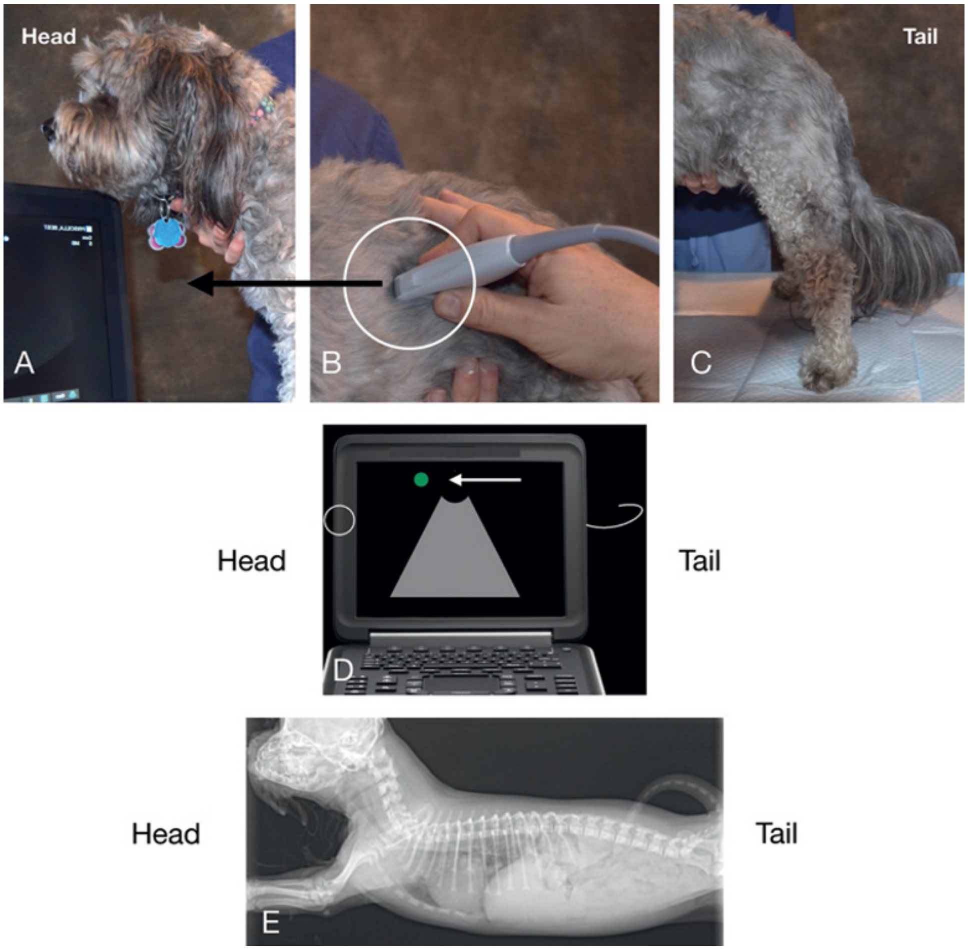

Figure 1.6. Longitudinal (sagittal) planes and orientation. Make the screen marker and the probe marker both consistent with "head to the left and tail to the right," which is the *same* orientation as radiography. (A) shows the head of the dog and (C) its tail. In (B), the probe is placed on the truncal area of the same dog. The white circle highlights the probe marker (can be a notch, a raised line or button, or an LED light). Every probe has its marker. In (D) is a pictorial of the ultrasound screen, and the green dot indicates the screen marker (arrow ←). Make sure that this is to the left of the screen and the probe marker is toward the head of your patient. In (E) is a radiograph showing the *same* orientation used for ultrasound, "head to the left, tail to the right." Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

References

Kirkpatrick AW, Sirois M, Laupland KB, et al. 2004. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the extended focused assessment with sonography for trauma (EFAST). *J Trauma* 57:288–295.

Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2): 104–122.

Lisciandro GR. 2016. The use of the diaphragmatico-hepatic (DH) views of the abdominal and thoracic focused assessment with sonography for triage (AFAST/TFAST) examinations for the detection of pericardial effusion in 24 dogs (2011–2012). *J Vet Emerg Crit Care* 26(1):125–131.

Lisciandro GR, Lagutchik MS, Mann KA, et al. 2008. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 18(3):258–269.

Lisciandro GR, Lagutchik MS, Mann KA, et al. 2009. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma in 101 dogs with motor vehicle trauma. *J Vet Emerg Crit Care* 19(5):426–437.

Lisciandro GR, Fosgate GT, Fulton RM. 2014. Frequency of ultrasound lung rockets using a regionally-based lung ultrasound examination named veterinary bedside lung ultrasound exam (Vet BLUE) in 98 dogs with normal thoracic radiographic lung findings. *Vet Rad Ultrasound* 55(3):315–322.

Lisciandro GR, Fulton RM, Fosgate GT, Mann KA. 2017. Frequency of B-lines using a regionally-based lung ultrasound examination (the Vet BLUE protocol) in 49 cats with normal thoracic radiographical lung findings. *J Vet Emerg Crit Care* 27(3):267–277.

McMurray J, Boysen S, Chalhoub S. 2016. Focused assessment with sonography in nontruamtized dogs and cats in the emegrency and critivcal care setting. *J Vet Emerg Crit Care* 26(1):64–73.

Rozycki GS. 1998. Surgeon performed US: its use in clinical practice. *Ann Surg* 228:16–28.

Rozycki GS, Ballard RB, Feliciano DV, et al. 1998. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg* 228(4):557–567.

Rozycki GS, Pennington SD, Feliciano DV. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50(4):636–642.

Rozycki GS, Knudson MM, Shackford SR, et al. 2005. Surgeon-performed bedside organ assessment with sonography after trauma (BOAST): a pilot study from the WTA Multicenter Group. *J Trauma* 59(6):1356–1364.

Further Reading

Mattoon JS, Nyland TG. 2015. Fundamentals of diagnostic ultrasound. In: *Small Animal Diagnostic Ultrasound*, 3rd edition, edited by Mattoon JS, Nyland TG. St Louis: Elsevier, pp 1–49.

CHAPTER TWO

POCUS: Basic Ultrasound Physics

Robert M. Fulton

Introduction

Turn on the machine. Apply acoustic coupling gel. Start scanning. In the realm of the busy veterinary general practice, emergency clinic, or intensive care unit, that statement really sums up the basic use of ultrasound. Just as it is natural for us to take the stethoscope from around our neck and place it on a patient's thorax, so should be picking up the ultrasound probe and placing it on the patient. No wonder that ultrasonography has been appropriately dubbed both "an extension of the physical exam" and the "modern stethoscope" (Rozycki et al. 2001; Filly 1988). Really, one doesn't need a whole lot of instruction to start scanning; however, as for a lot of things in life, the devil is in the details. Understanding how the ultrasound image is formed (Physics), understanding inherent physical limitations (Artifacts), and knowing how to acquire the image (Technique) are the keys to acquiring and interpreting the diagnostic ultrasound image.

The focus of this and the following several chapters is a brief review of the basic physics and principles of ultrasound, including the more common problematic artifacts. For interested readers, there are more comprehensive textbooks dedicated to the physics and interpretation of ultrasound imaging (Nyland et al. 2002; Penninck 2002; Bushberg et al. 2002).

What POCUS Basic Ultrasound Physics Can Do

- Provide a basic review of ultrasound physics.

What POCUS Basic Ultrasound Physics Cannot Do

- Cannot provide an in-depth discussion of ultrasound physics and principles
- Cannot replace experience and knowledge of your own ultrasound machine.

Indications

- All sonographers performing POCUS and FAST for a basic understanding of the physics and principles of ultrasound imaging.

Objectives

- Provide a basic understanding of ultrasound principles to maximize accurate image interpretation.
- Provide an understanding of the fundamentals of ultrasound physics and how they relate to image formation.

Basic Ultrasound Principles

The ultrasound machine consists of two main parts, the probe and the processor. The probe is the "brawn" and the processor the "brains" of the operation. The probe has two main functions: first, to generate a sound wave (acts as a transmitter), and second, to receive a reflected sound wave (acts as a receiver).

Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition. Edited by Gregory R. Lisciandro.

Companion website: www.wiley.com/go/lisciandro/ultrasound2

The processor, located within the ultrasound unit, takes these incoming signals and turns them into a useful image.

The transmitter and receiver functions of the transducer do not occur simultaneously but rather sequentially. When placed under mechanical stress, the ceramic crystals in the transducer generate a voltage. This process, known as the piezoelectric effect, occurs during the receiving phase, which is when returning sound waves strike the transducer. When an external voltage is applied to the crystals, they exhibit the reverse phenomenon and undergo a small mechanical deformation. The subsequent release of this energy generates the ultrasound wave. This is known as the reverse piezoelectric effect. World War I saw the first practical use of the piezoelectric effect in the development of sonar using a separate sound generator and detectors (Coltrera 2010).

The sound waves generated by diagnostic ultrasound machines are typically in the 3–14 megahertz (MHz) range and are thus too high pitched to be perceived by the human ear. We can hear sounds in the range of 20 Hz (cycles/second) to 20 000 Hz. In contrast, our average canine patient hears sounds in the range of 40 Hz to 60 000 Hz. The high frequencies are in the realm of what is termed the "ultrasonic" range, basically any sound above our ability to hear and hence the name for this clinical imaging tool (Nyland et al. 2002).

The sound waves produced by the transducer penetrate the body tissues and are subject to all the rules surrounding any sound wave, including reflection, refraction, reverberation, attenuation, and impedance. The processor analyzes the transmitted signals and the returning waves, including their quantity, strength, and the time they took to return. By applying preprogrammed algorithms, the processor translates this information into a pixel, gives it an appropriate intensity (its echogenicity), and places it on the monitor screen to give us the image (sometimes being "fooled" into creating artifacts).

Between the transducer and the processor, it is easy to see why the equipment for this modality can be rather pricey. However, by using the variety of POCUS and FAST ultrasound exams outlined in this textbook, we hope that your ultrasound machine will become an asset not only with improved patient care but also with a return on investment.

Velocity

Sound travels at specific known velocities through various materials. Remember from physics that sound travels faster though solids than through liquid or gas, and its velocity through various body tissues is known (Figure 2.1). Notice that velocity is similar through most of the soft tissues; however, current ultrasound machines cannot determine what tissues are being penetrated. Therefore, most ultrasound machines use an average velocity of 1540 m/sec for their imaging algorithms, averaging the speed of sound through fat, liver, kidney, blood, and muscle (Coltera 2010). Some newer machines allow the user to select a different constant for the specific tissue or structure they are imaging.

The first and last columns in Figure 2.1 illustrate that sound passes relatively slowly through air and relatively quickly through bone. Anyone who has picked up an ultrasound probe knows that bone (solid) or lung (air) cannot be adequately penetrated using

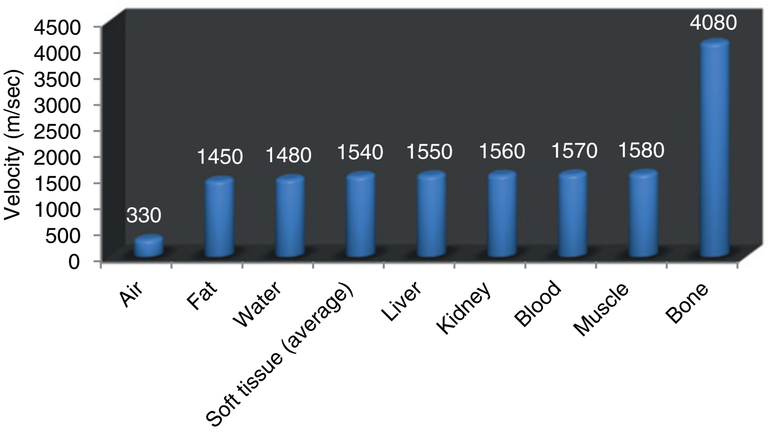

Figure 2.1. Velocity (m/sec) of sound through common body tissues or substances. Note the similar velocity through most soft tissues. This is the basis for using 1540 m/sec as the number in depth calculations by the ultrasound processor (Coltrera 2010).

ultrasound, thus only the surfaces of each are visible. To address this issue, the sonographer must understand the principle of acoustic impedance.

Pearl: Remember the saying: Ultrasound hates bone or stone and is not too fair with air.

Acoustic Impedance

Acoustic impedance refers to the reflection and transmission characteristics of a substance. It is a measure of absorption of sound and the ratio of sound pressure at a boundary surface to the sound flux. Sound flux is flow velocity multiplied by area. If we draw an analogy to electronic circuits, acoustic impedance is like electrical resistance through a wire, sound pressure is like voltage, and flow velocity is like current. The equation that brings it all together is:

$$Z = p / v$$

where Z = acoustic impedance, p = sound pressure (or tissue density), and v = velocity (Nyland 2002).

The amplitude of a reflected sound wave is proportional to the difference in acoustic impedance between two different tissues. Air has a low impedance and bone has a high impedance when compared to soft tissue (Reef 1998) (Figure 2.2). Therefore, when a sound wave comes across a soft tissue–bone or a soft tissue–air interface (large difference in acoustic impedance), nearly all of the sound waves are strongly reflected (and a bright white echogenic line is formed at either interface). Reflection is why the sonographer cannot image through bone (solid) or lung (air) and this points up one of the most common misnomers in clinical ultrasonography: when imaging through the liver into the thorax, we term the bright, curved cranial border as the diaphragm. In reality, the diaphragm is uncommonly imaged except in bicavitary effusions. The bright white (hyperechoic), curved line is actually the strongly reflective surface of the lung (air) at the soft tissue–air boundary or interface serving as a strong reflector.

By comparing the acoustic impedance of most tissues in the body other than bone (solid) and lung (air), we see that they are very similar (there is little difference in acoustic impedance among them). This similarity makes ultrasound a great imaging tool for examining into and through soft tissues (their parenchyma). On the other hand, due to the large difference in acoustic impedance between soft tissue–air and soft tissue–bone interfaces, ultrasound is not an effective tool for examination beyond the surfaces of either aerated lung, gas-containing hollow viscus or bone (Reef 1998).

Absorption, Scatter, and Reflection

Other ultrasound principles that affect our image include absorption, scatter, and angle of reflection. As the sound waves enter the body, some of them are absorbed by the tissues and are never reflected back to the probe. These waves are lost and do not contribute to the image. Furthermore, many of the waves are scattered by the tissues and their surface irregularities and either return to the probe (receiver) in a distorted path or do not return at all. As a result, the ultrasound waves are "misinterpreted" by the processor, and the image and its resolution are affected.

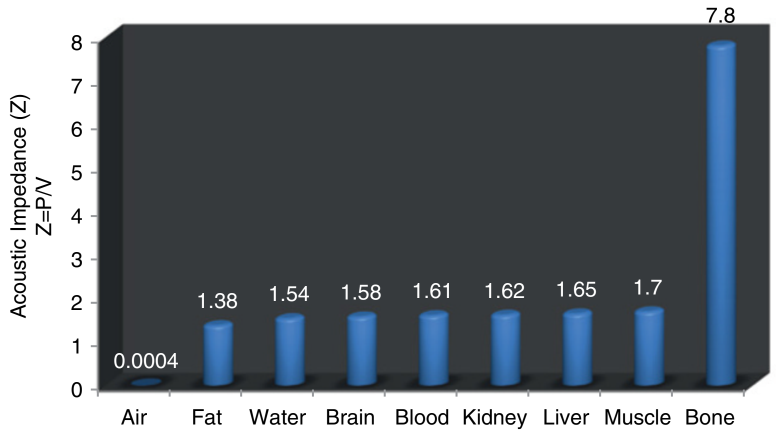

Figure 2.2. Acoustic impedance (106 kg/m^{2}sec) of common body tissues or substances. This figure illustrates the degree of difference in acoustic impedance between substances that helps determine sound wave transmission. The greater the difference, the greater is reflection or loss of transmission. One can see how ultrasound is ideally suited for most soft tissue and why it is not suited for imaging bone or air-filled structures (Reef 1998).

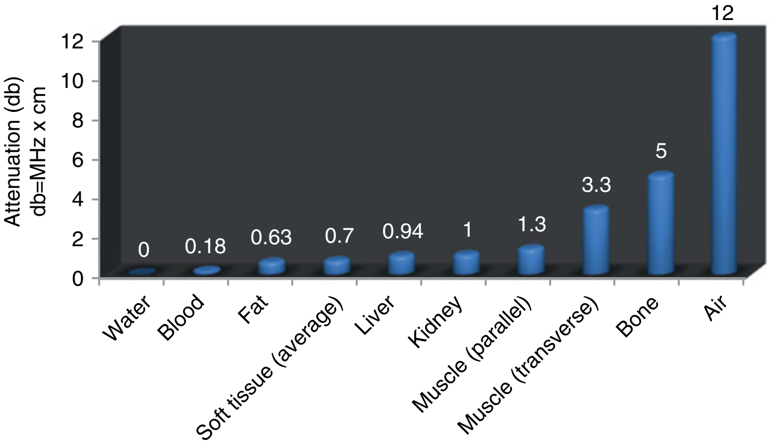

Figure 2.3. Attenuation (db/cm/MHz) in common tissues. Attenuation of sound energy within tissues varies with the frequency of the sound and is affected by reflection, scattering, and absorbance. Note how bone and air have the greatest attenuation values (Reef 1998).

Attenuation

All sound beams lose energy, or become attenuated, during transmission through tissues; therefore, the returning sound wave is weaker than when it started. Different frequencies (MHz) are attenuated to different degrees. Because higher frequency probes send more waves per second, there is greater tissue interaction with the sound waves. This provides improved resolution but undergoes more attenuation. Low-frequency sound waves are less attenuated because of less tissue interaction, and therefore allow deeper tissue penetration. Strategies that include lowering the MHz for better penetration (depth) come at the expense of detail. Conversely, using higher frequency for more detail comes at the cost of less penetration (depth). Furthermore, high-density tissues attenuate the sound waves more than low-density tissues (Figure 2.3).

Pearl: The analogy of hearing a boom box from a distance can help you remember which MHz penetrates more. The bass dominates (low MHz) over higher frequencies (high MHz); thus, low MHz penetrates deeply at the expense of detail, and high MHz give better detail at the expense of penetration.

The Final Say

By understanding the basic physical principles governing sound transmission and the limitations of the ultrasound processor, the ultrasonographer can better understand the image on the screen. Furthermore, this same knowledge is fundamental in understanding ultrasound artifacts covered in the next chapter.

References

Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. 2002. *The Essential Physics of Medical Imaging*, 2nd edition. Philadelphia: Lippincott Williams and Wilkins.

Coltera M. 2010. Ultrasound physics in a nutshell. *Otolaryngol Clin North Am* 43(6):1149–1159.

Filly RA. 1988. Ultrasound: the stethoscope of the future, alas. *Radiology* 167:400.

Nyland TG, Mattoon JS, Herrgesell EJ, et al. 2002. Physical principles, instrumentation, and safety of diagnostic ultrasound. In: *Small Animal Diagnostic Ultrasound*, 2nd edition, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 1–18.

Penninck DG. Artifacts. In: *Small Animal Diagnostic Ultrasound*, 2nd edition, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 19–29.

Reef V. 1998. Thoracic ultrasonography: noncardiac imaging. In: *Equine Diagnostic Ultrasound*, edited by Reef V. Philadelphia: WB Saunders, pp 187–214.

Rozycki GS, Pennington SD, Feliciano DV, et al. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50:636–642.

Further Reading

Volpicelli G, Elbarbary M, Blaivas M, et al. 2012. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med* 38:577–591.

CHAPTER THREE

POCUS: Basic Ultrasound Artifacts

Robert M. Fulton

Introduction

In this chapter, we'll look at the fundamental laws governing wave dynamics and see how ultrasound artifacts are created. Ultrasound machines rely on several physical assumptions to assign the location and intensity of each received echo. These assumptions are that the received echoes have originated from within the main ultrasound beam, an echo returns to the transducer after a single reflection, the depth of an object is directly related to the amount of time for an ultrasound pulse to return to the transducer, the speed of sound in tissue is constant (1540 m/sec), the sound beam and its echo travel in a straight path, and the acoustic energy in an ultrasound field is uniformly attenuated (Feldman et al. 2009). Artifacts may be grouped by the most important principles leading to their formation, including attenuation, velocity or propagation, and artifacts associated with multiple echoes. Many artifacts can be grouped by their association with air or fluid, making learning them easier.

What POCUS Basic Ultrasound Artifacts Can Do

- Provide a basic understanding of how artifacts are formed to allow better interpretation of the ultrasound image.

What POCUS Basic Ultrasound Artifacts Cannot Do

- Cannot provide an in-depth discussion of ultrasound artifacts.
- Cannot account for what artifacts your ultrasound machine's software is most biased towards.

Indications

- Provide a basic understanding of ultrasound principles and common artifacts to maximize accurate image interpretation.

Objectives

- Provide a basic understanding of how common ultrasound artifacts are formed to avoid image misinterpretation of artifacts for abnormalities.

Artifacts of Attenuation: Strong Reflectors (Bone, Stone, Air)

Shadowing, "Clean" and "Dirty"

Clean shadows and dirty shadows result from strong reflectors (bone, stone, and air). We know from differences in acoustic impedance at soft tissue–air and soft tissue–bone (stone) interfaces that most of the sound waves will be reflected, albeit in different degrees (Figures 3.1 and 3.2A).

Bone or Stone Interface: Clean Shadowing

When the ultrasound wave strikes bone (and stone), most of the waves are reflected back so there will be an area of intense hyperechogenicity (whiteness) at the soft tissue–bone (stone) interface. Because the surface of bone is often smooth, there is little scattering or

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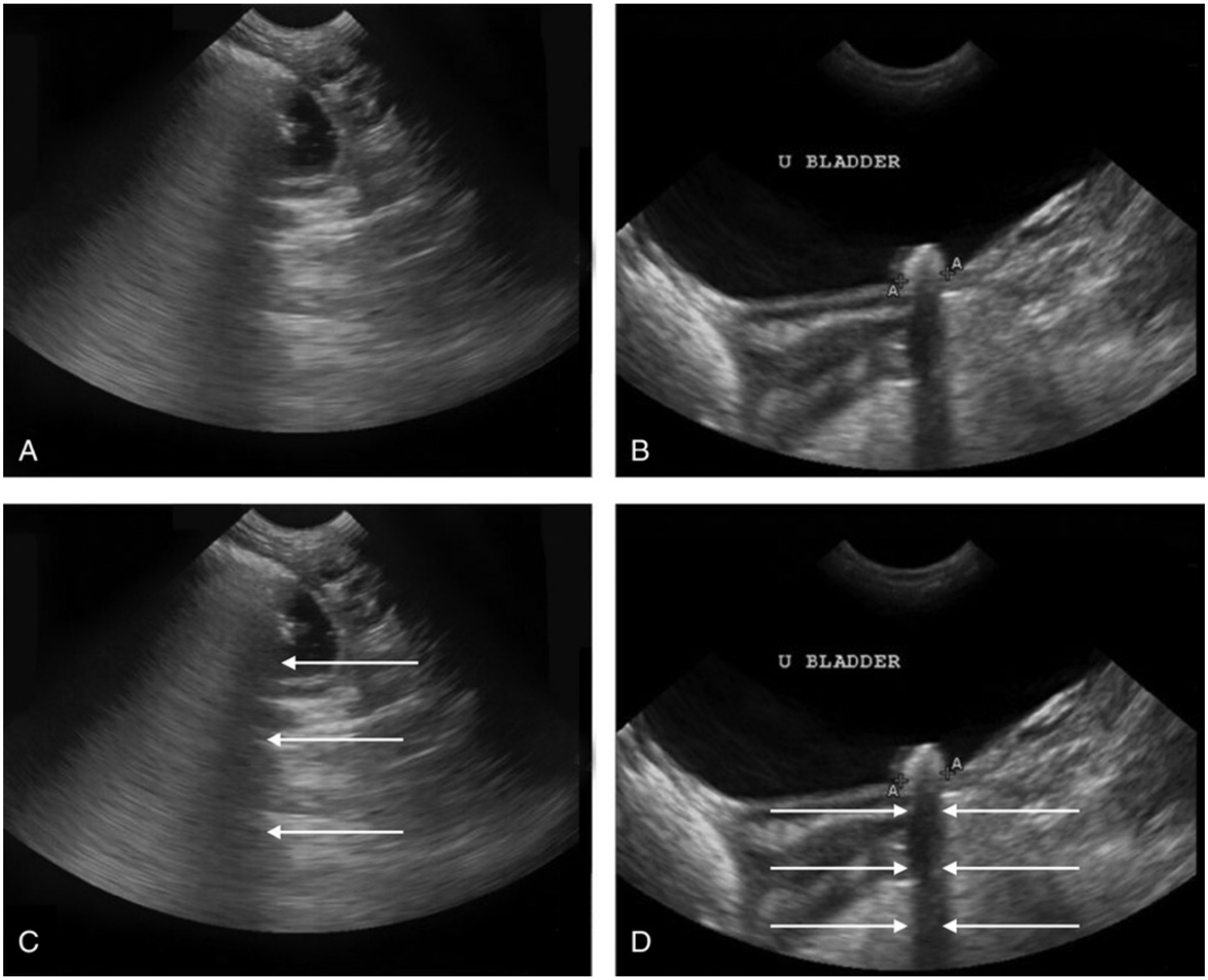

Figure 3.1. Dirty and clean shadowing. (A) "Dirty shadowing" created by air, a gas bubble within a fluid-filled distended loop of small bowel. "Dirty shadowing" is generated because some ultrasound waves pass through the structure. Contrast the "dirty shadowing" with the "clean shadowing" of the cystourolith (urinary bladder stone) in (B) in which all ultrasound waves are reflected back to the transducer. (B) "Clean shadowing." The smooth surface of the cystourolith (urinary bladder stone) generates the "clean shadowing" typical of bone or stone with a hyperechoic (bright white) reflective surface in the near field, completely blocking all echoes and thus resulting in an anechoic (dark or black) shadow extending from it through the far-field. In (C) and (D), the images have arrows (←) pointing out the artifact. Source: Courtesy of Dr Sarah Young, Echo Service for Pets, Ojai, California.

reverberation of the ultrasound wave and a nice, clear-cut, anechoic (blackness) "clean shadow" is produced beyond the reflector (bone or stone) (see Figure 3.1).

Air Interface: Dirty Shadowing

On the other hand, soft tissue–air interfaces are more variable in their degree of reflection, with some of the ultrasound waves incompletely moving through the air-filled structure, unlike the complete reflection at bone (or stone). Thus, reverberations occur distal to the air interface, creating a "dirty shadow" (Penninck 2002) (see Figure 3.1).

Artifacts of Attenuation: Fluid-Filled Structures

Edge Shadowing: Fluid-Filled Structures

When the ultrasound waves strike the edge of a fluid-filled structure with a curved surface (its wall), such as

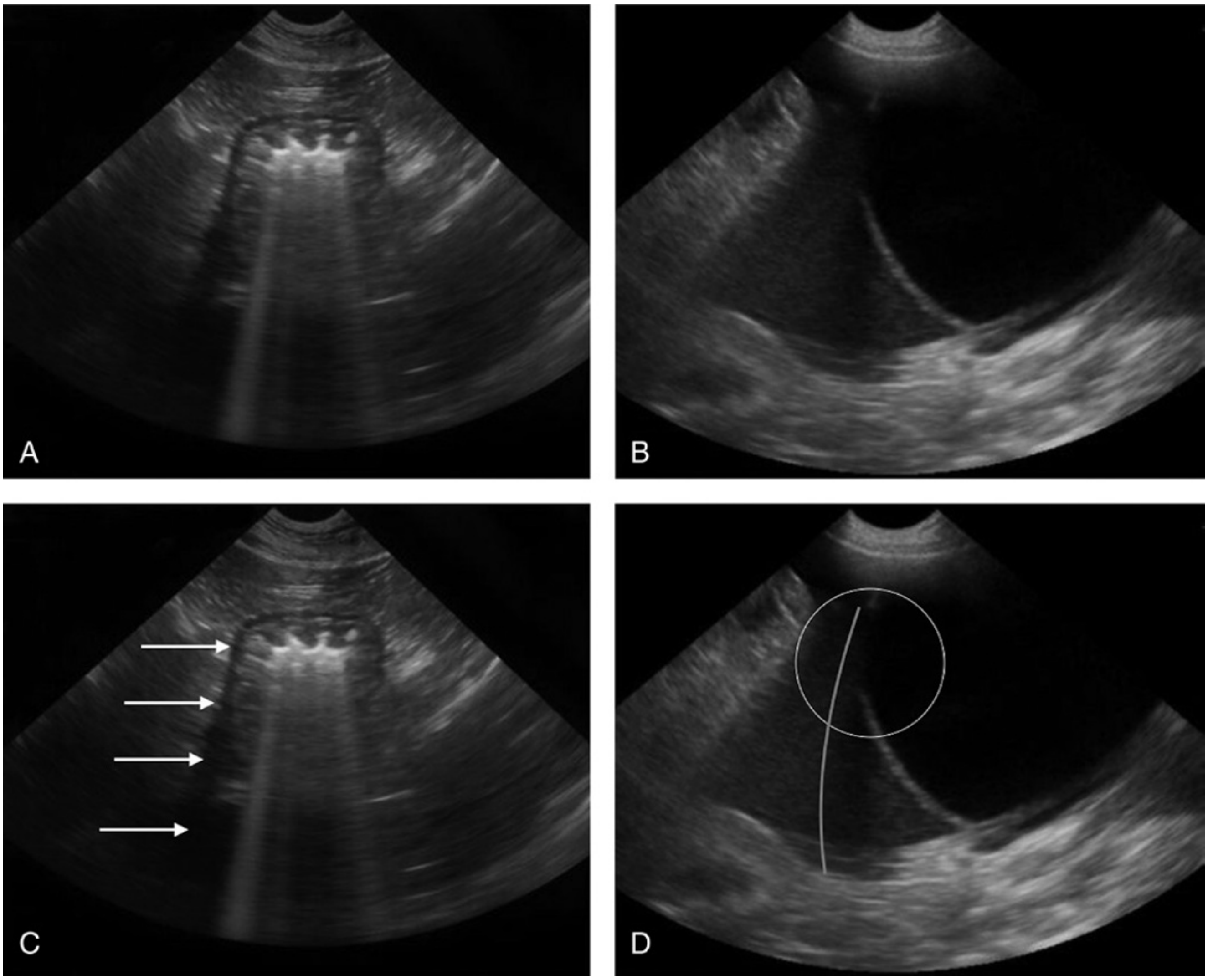

Figure 3.2. Edge shadowing artifact. (A) An edge shadowing artifact is seen arising from the curved edge on the left side of the stomach wall in this image, making its wall appear to extend distally as an anechoic (dark or black) line. A dirty gas shadow is also produced from gas within the stomach lumen that appears as "pseudo B-lines." (B) An edge shadowing artifact at the apex of the urinary bladder makes it falsely appear to have a rent, which can fool the hasty sonographer into thinking the free fluid is from a ruptured bladder; however, note the smooth expected normal contour of the urinary bladder. In (C) the edge shadowing artifact is outlined with arrows (←). In (D) the edge shadowing creates a false rent in the wall of the urinary bladder (*circled*) and the superimposed curved line points out the edge shadowing from the curved surface of the urinary bladder wall extending through the far-field. Source: Courtesy of Dr Sarah Young, Echo Service for Pets, Ojai, California.

the stomach wall, urinary bladder, gallbladder, eye, or cyst, ultrasound waves are reflected to a small degree and these reflected sound waves therefore do not return to the transducer. As a result, a thin hypoechoic (darker) to anechoic (black) area lateral and distal to the edge of the curved structure is formed. For example, the novice may mistake this artifact for a "rent" in the urinary bladder wall when in fact it is an artifact created by the ultrasound machine (Nyland et al. 2002) (see Figure 3.2).

Acoustic Enhancement: Fluid-Filled Structures

When the sound beam passes through a fluid-filled structure, such as the gallbladder, urinary bladder, fluid-filled stomach, eye, or a cyst, ultrasound waves do not become as attenuated as the neighboring waves passing through more solid tissues to either side of the structure. Therefore, the tissues on the far side of the fluid-filled structure appear much brighter than the neighboring tissues at the same depth. Acoustic enhancement is obvious, looking past the fluid-filled gallbladder and urinary bladder (Figure 3.3). On the other hand, by realizing how the artifact is formed, the acoustic enhancement artifact can be useful to the savvy sonographer in determining if a structure of interest is fluid filled (brighter through the far-field having acoustic enhancement) or soft tissue (lacking acoustic enhancement) (Penninck 2002) (see Figure 3.3).

Artifacts of Velocity or Propagation

Mirror Artifacts: Strong Reflector (Air)

When we image a structure that is close to a curved, strong reflector such as the diaphragm (remember this is actually the lung–air interface following the curve of the diaphragm), a sound beam can reflect off the

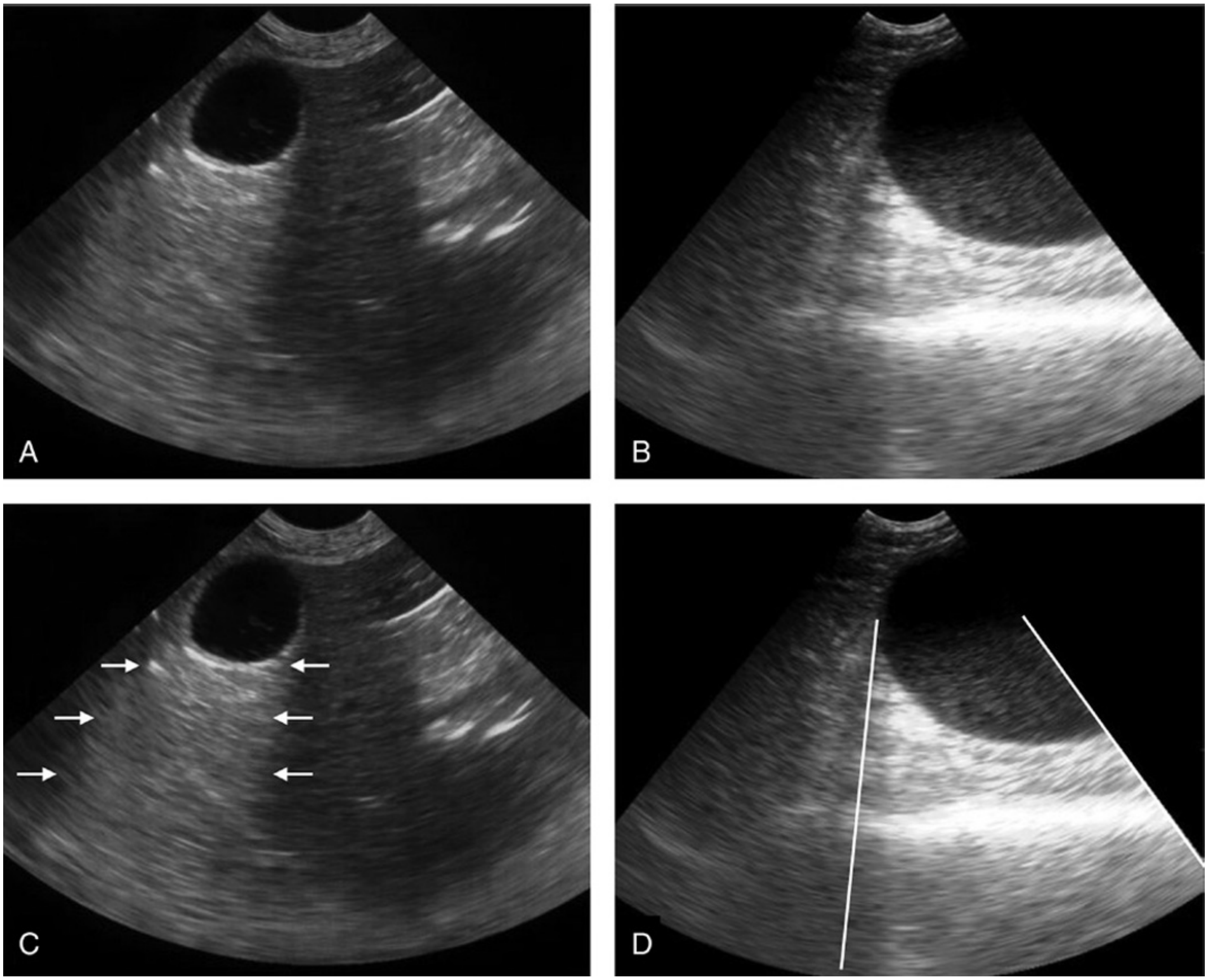

Figure 3.3. Acoustic enhancement artifact. Because there is less attenuation when sound moves through fluid, the area distal to a fluid-filled structure will appear hyperechoic (brighter or whiter) to the surrounding tissue. Note the hyperechoic regions distal to the gallbladder (A) and distal to the urinary bladder (B) that are outlined with arrows (←) in (C) and by white bars in (D).

curved surface, strike adjacent tissues, reflect back to the curved surface, and then reflect back to the transducer. Because the processor only uses the time it takes for the beam to return home and cannot "see" the ongoing reflections, it will be fooled into placing (mirroring) the image on the far side of the curved surface. The classic place for a mirror artifact is at the diaphragm, and the classic mistake is interpreting the artifact as a diaphragmatic hernia (Penninck 2002) (Figure 3.4).

Reverberation or A-Lines: Strong Reflector (Air)

Reverberation occurs when sound encounters two highly reflective layers. The sound is bounced back and forth between the two layers before traveling back to the receiver. The probe will detect a prolonged traveling time and assume a longer traveling distance and display additional reverberated images in a deeper

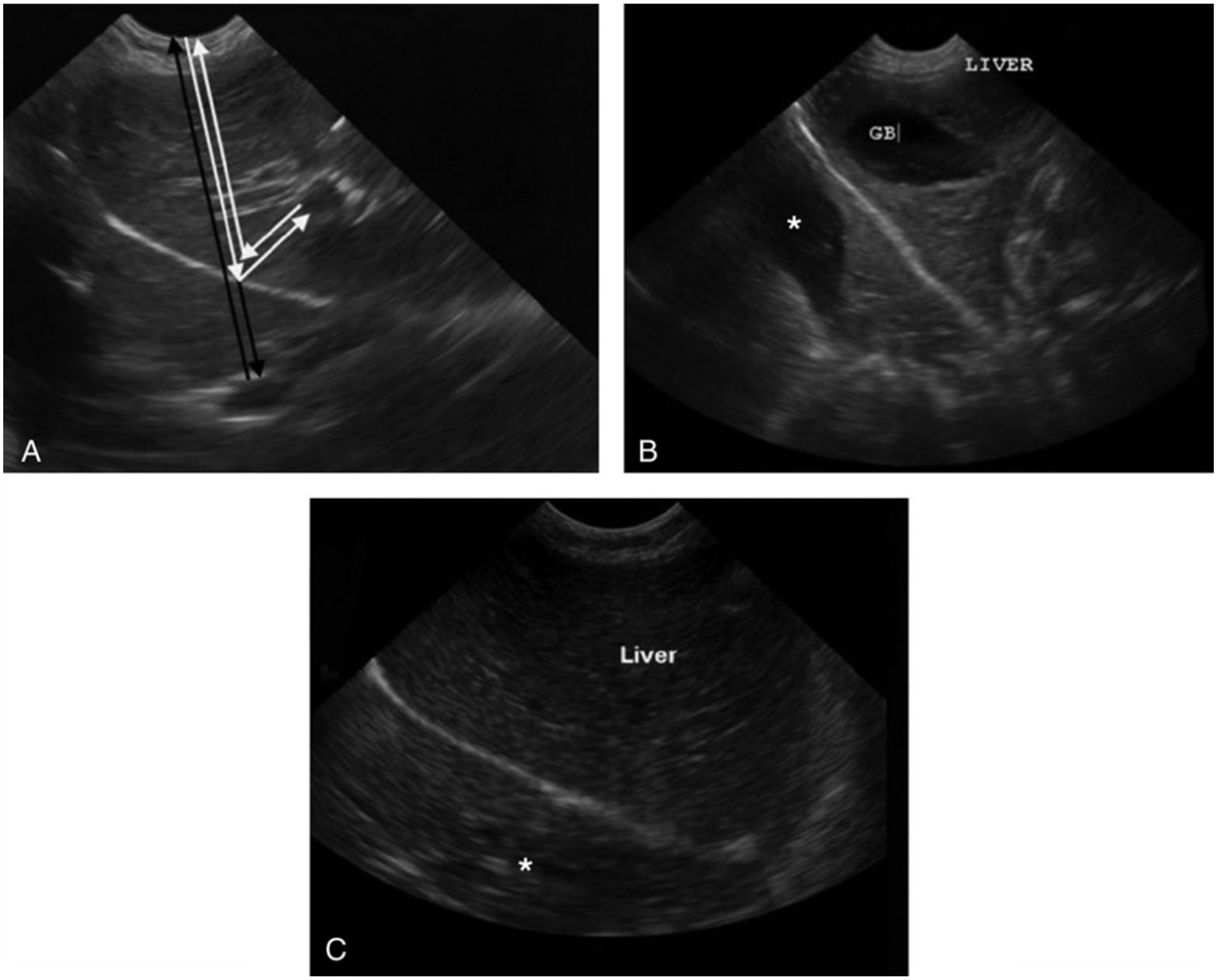

Figure 3.4. Mirror artifact. The gallbladder appearing to be on both sides of the diaphragm is the classic example of mirror artifact, created by a strong soft tissue–air interface. The mirror image artifact also may be generated under similar circumstances when the fluid-filled urinary bladder lies against the air-filled colon. (A) The white arrows illustrate the actual path of the sound beam reflecting off the curved lung–air interface against the diaphragm, while the black arrows illustrate the path perceived by the ultrasound processor. Note that the gallbladder falsely appears as if it is within the thorax, and should not be mistaken for a diaphragmatic hernia. (B) Mirror image artifact in which it appears that the liver and gallbladder are on both sides of the diaphragm (*). (C) Mirror image artifact in which it appears that liver (gallbladder *not* present in this view) is on both sides of the diaphragm (*). Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

tissue layer. The reverberations can get caught in an endless loop and extend all the way to the bottom of the screen as parallel equidistant lines, referred to as A-lines (also see Chapters 22 and 23). This artifact most commonly extends beyond air-filled structures within the thorax, (e.g., lung) and within the abdomen (e.g., gastrointestinal tract), with varying width (Penninck 2002) (Figure 3.5; see also Figures 3.1 and 3.2).

Comet-Tail or Ring-Down Artifact: Strong Reflector (Usually Metal or Bone But Can Be Air)

A comet-tail artifact, also called a ring-down artifact, is similar to reverberation. It is produced by the front and back of very strong reflectors with high acoustic impedance, such as metallic foreign bodies or implants,

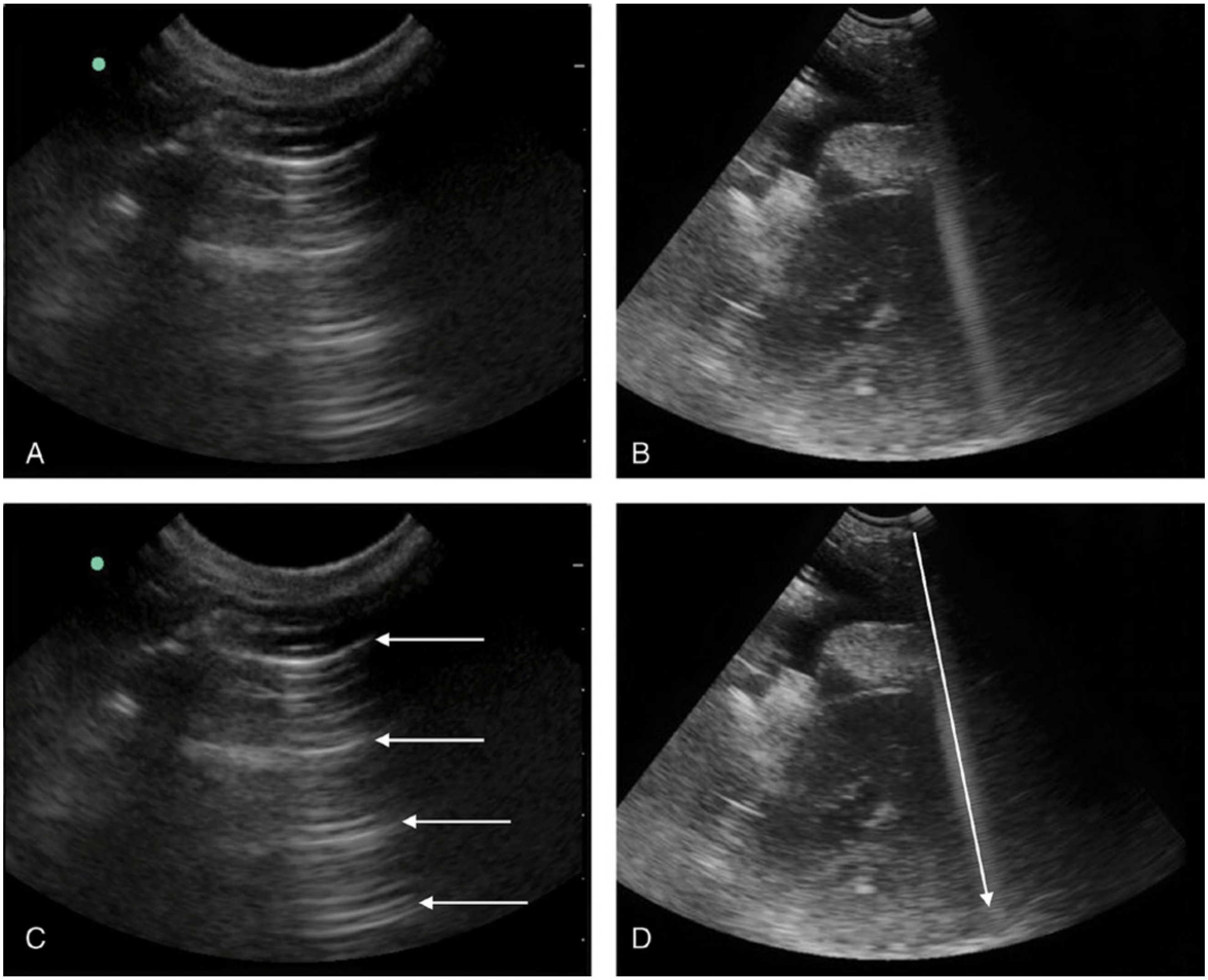

Figure 3.5. Reverberation artifact. (A) Reverberation artifact, also known as A-lines (think of it as "A" for air). A-lines are seen as regularly spaced parallel lines illustrated by the arrows (←) outlined in (C). The most proximal arrow in the near-field denotes the lung's surface, evident within the intercostal space between two ribs on either side (ribs [bone] creating the "clean shadowing" through the far-field). (B) The very tight and distinct band of reverberation artifact, referred to as a comet-tail or ring-down artifact, caused by sound waves reflecting off a metal needle used during abdominocentesis in the near-field. (D) The same image but with an arrow overlay to show the tight band of A-lines as the comet-tail or ring-down artifact. Any strong reflector of ultrasound waves produces this artifact that typically involves bone, stone, or metal, such as implants, needles, and foreign bodies. Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

needles, and stylets during ultrasound-guided procedures (see also Chapters 43 and 44), or strong reflectors with very low acoustic impedance relative to their adjacent soft tissues, such as gas in the lung, gas bubbles, or gas in the bowel. The reverberations are spaced very narrowly and blend into a small band. The greater the difference between the acoustic impedance of the reflecting structure and the surrounding tissues, the greater the number of reverberation echoes (Reef 1998) (see Figure 3.5).

B-Lines: Strong Reflector (Air Immediately Next to Fluid)

Ultrasound lung rockets (ULRs), more recently termed B-lines (Volpicelli et al. 2012), are vertical, narrow-based lines arising from the near-field's pulmonary–pleural line, extending to the far edge of the ultrasound screen, always obliterating A-lines, and moving "to and fro" in concert with inspiration and expiration. Although B-lines are similar to comet-tail artifacts,

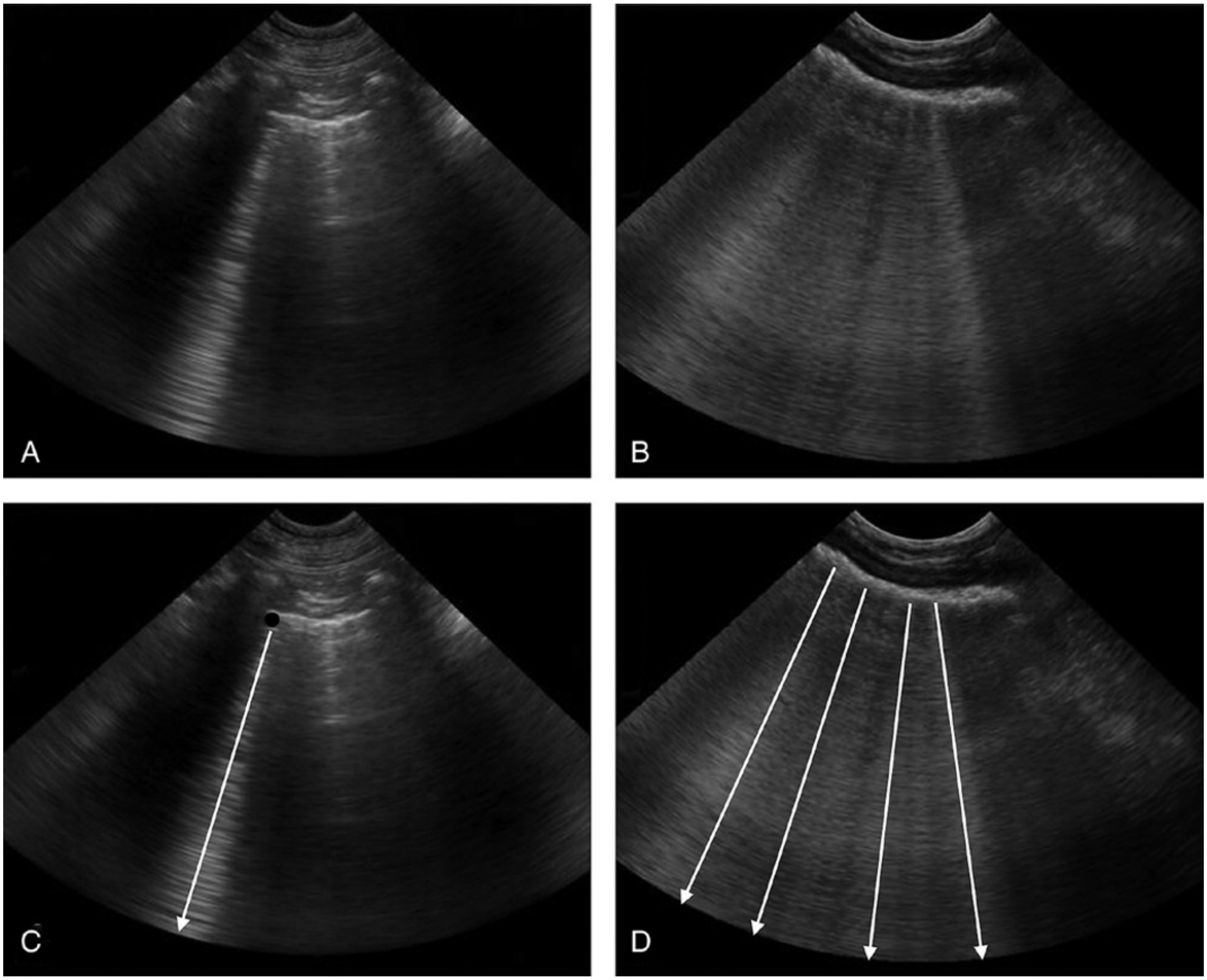

Figure 3.6. Pseudo B-lines. The B-line artifact begins at the lung's pleural surface and continues without loss of intensity through the far-field of the image as a hyperechoic (bright white) streak that obliterates A-lines. In real time, B-lines must oscillate with the to-and-fro motion of inspiration and expiration. Examples and descriptions are found in Chapters 22 and 23. Here, however, are pseudo B-lines. In (A), what appears to be a single B-line is in fact tightly stacked A-lines off the far side of a very small lung nodule. In (B) are multiple pseudo B-lines off the gastric wall. In (C) the nodule is indicated with a solid black circle overlay, and the arrows are over the pseudo B-line. In (D), the pseudo B-lines are indicated by the arrows (←). Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

they are specifically created by the strong difference in impedance of air adjacent to a small amount of water and are the ultrasound near-equivalent of radiographic Kerley B lines (representing interlobar edema). Their clinical relevance is very important and explained later (see Chapters 22 and 23) (Lichtenstein and Meziere 2008; Lichtenstein et al. 2009; Lisciandro 2011; Volpicelli et al. 2012) (Figure 3.6).

Artifacts of Multiple Echoes

Side-Lobe Artifact: Multiple Echoes

We like to think of the ultrasound beam as extending from the probe in a very thin fan or rectangle, and this is exactly what the processor thinks it sees. In reality, there are smaller beams that travel laterally to the main beam.

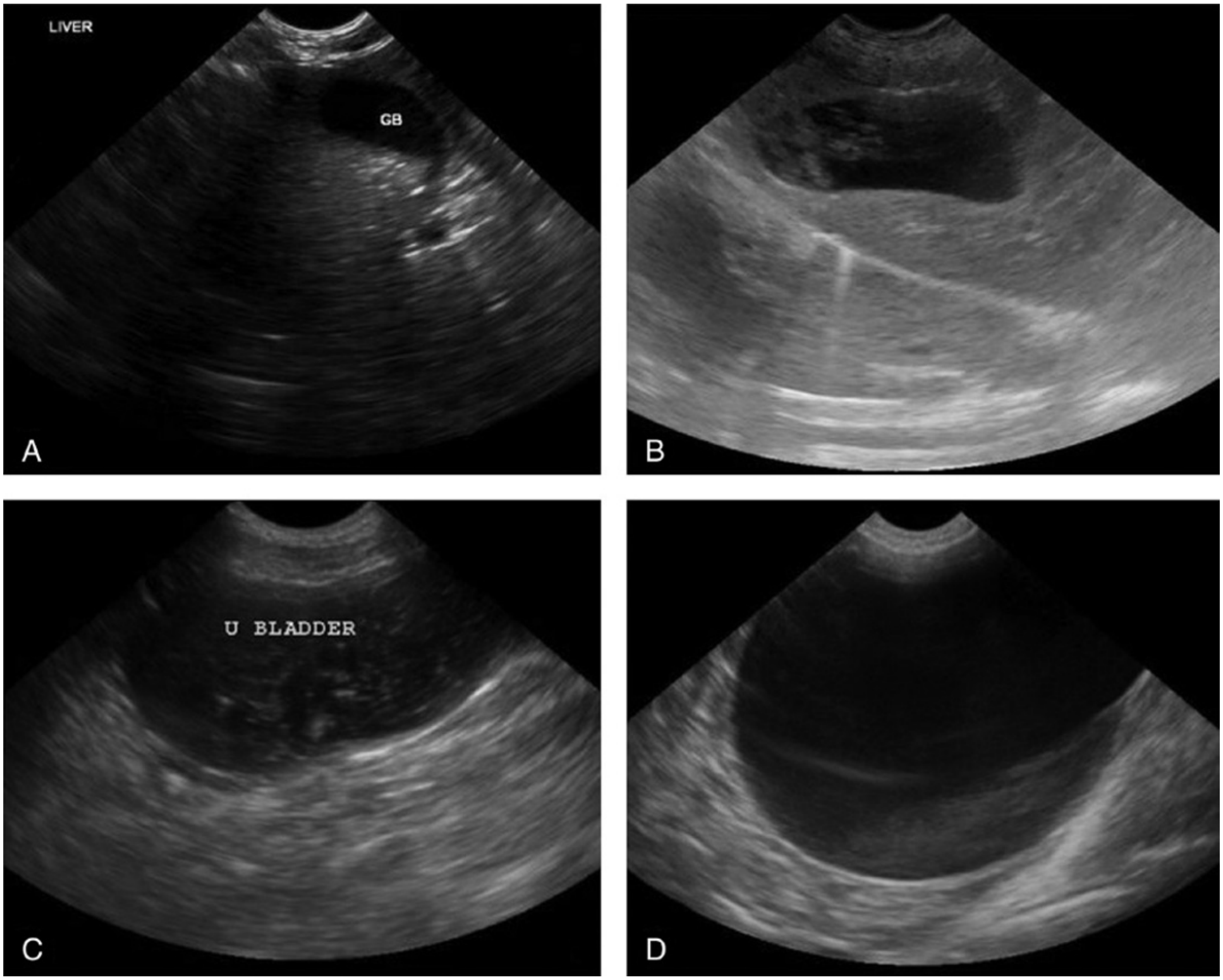

Figure 3.7. Sediment versus side-lobe and slice-thickness artifact. (A) Sediment will be affected by gravity and lead to a flat surface, as seen with the sludge within this gallbladder's lumen. True sediment can be stirred up by repositioning the patient or through ballottement with the ultrasound probe, whereas artifacts mimicking sediment cannot. (B) Slice-thickness and side-lobe artifacts mimic sediment in the gallbladder shown here; however, the artifact will not be altered by moving the patient's position or by ballottement. (C) True sediment in a urinary bladder with ballottement gives a snow globe appearance. (D) In contrast, the slice-thickness and side-lobe artifacts mimicking sediment shown here will fail to ballot (will not "snow globe") or change position to the gravity-dependent side of the urinary bladder when the patient is moved. Other helpful tricks that discriminate true sediment from artifact include lowering the gain and/or moving the focus cursor. Generally speaking, artifacts can be eliminated by these maneuvers, but true sediment cannot. Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

When one of these smaller side beams is of sufficient strength and bounces off a highly reflective surface, such as the wall of the urinary bladder, it will be interpreted as coming from the main beam and the processor will place the resulting image within the main beam image, often mimicking sediment. The resulting image is usually weaker in intensity than the main image. Often, the artifact can be altered by changing probes or lowering the focal point, or lowering the gain setting – all ultrasonographic manipulations that will not remove true pathology (i.e., bladder sediment, bladder stones, etc.) (Penninck 2002) (Figure 3.7).

Slice-Thickness Artifact: Multiple Echoes

Slice-thickness artifact is somewhat like the side-lobe artifact. In the gallbladder and urinary bladder in particular, this artifact mimics sludge or sediment. It occurs when part of the beam's thickness lies just outside a fluid-filled structure. These artifacts typically appear within the lumen of these structures and are somewhat hyperechoic (bright) and curved. They can be differentiated from real sediment by several methods or clues. First, gravity-dependent sediments have a flat surface whereas the artifact will be rounded. Second, by changing the position of the patient, the relative position of true sediment will change as gravity pulls it to the new lower point. Third, the sonographer can use the ultrasound probe to ballot the bladder and stir the sediment up a bit; the artifact will not yield a "snow globe" effect (sediment will) (Penninck 2002) (see Figure 3.7).

Pearls and Pitfalls, The Final Say

By gaining a basic understanding of ultrasound physics and the common ultrasound artifacts, the non-radiologist veterinarian or veterinary sonographer can more clearly interpret the ultrasound image (Table 3.1). Always keep in mind the basic assumptions used to generate the image when scanning or viewing the ultrasound image. Your interpretive and diagnostic skills, and hence your patient, will benefit greatly.

- Knowing the basic assumptions used to generate the image leads to less misinterpretation of the ultrasound image.
- Artifacts are one of the primary pitfalls of ultrasonographic imaging.

Table 3.1.
Summary of common artifacts and examples.

Name of artifact	Fluid-associated	Air-associated	Other	Common examples
Shadowing, clean	No	No	Bone/stone	Cystouroliths, ribs
Shadowing, dirty	No	Yes	Irregular/partial penetration into gas	Lung, stomach, colon, small intestine
Edge shadowing	No	No	Refraction off round structures	Stomach wall, gallbladder wall, urinary bladder wall
Acoustic enhancement	Yes	No	Decreased attenuation	Gallbladder, cysts, eye
Mirror image	No	Frequently	Reflection	Diaphragm/liver Urinary bladder/colon
Reverberation A-lines	No	Yes	Typically used only in reference to lung ultrasound	Lung surface
Comet-tail, ring-down	No	No	Bone/stone/metal	Calculi, surgical clips, tissue mineralization
B-lines, also called ultrasound lung rockets (ULRs)	Yes	Yes	Air–fluid interfaces	Lung
Pseudo B-lines	Yes	Yes	Air–fluid interfaces (gastric luminal contents); strong soft tissue–air interfaces, i.e., lung nodules	Stomach contents, lung nodules
Side-lobe	Yes	No	Multiple echoes	Urinary bladder lumen, gallbladder lumen
Slice-thickness	Yes	No	Multiple echoes	False appearance of sludge in gallbladder, cysts

References

Feldman MK, Katyal, S, Blackwood MS. 2009. Ultrasound artifacts. *RadioGraphics* 29:1179–1189.

Lichtenstein DA, Meziere GA. 2008. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 134(1):117–125.

Lichtenstein DA, Meziere GA, Lagoueyte J, et al. 2009. A-lines and B-lines. Lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. *Chest* 136(4):1014–1020.

Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–122.

Nyland TG, Mattoon JS, Herrgesell EJ, et al. 2002. Physical principles, instrumentation, and safety of diagnostic ultrasound. In: *Small Animal Diagnostic Ultrasound*, 2nd edition, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 1–18.

Penninck DG. 2002. Artifacts. In: *Small Animal Diagnostic Ultrasound*, 2nd edition, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 19–29.

Reef V. 1998. Thoracic ultrasonography: noncardiac imaging. In: *Equine Diagnostic Ultrasound*, edited by Reef V. Philadelphia: WB Saunders, pp 187–214.

Volpicelli G, Elbarbary M, Blaivas M, et al. 2012. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med* 38:577–591.

CHAPTER FOUR

POCUS: Basic Ultrasound Scanning

Robert M. Fulton

Introduction

Ultrasound is a user-dependent imaging modality, with the quality of the image obtained directly dependent on the skill of the ultrasonographer. Many of the POCUS studies are not highly reliant on advanced skill or knowledge. Still, one *must* have a basic understanding of how to manipulate the probe and machine settings to obtain the prescribed images and optimize image quality.

What POCUS Basic Scanning Can Do

- Provide a basic tutorial on ultrasound physics, image acquisition, and storage, and discuss basic ultrasound systematics.

What POCUS Basic Scanning Cannot Do

- Cannot provide an in-depth tutorial on how to learn ultrasound techniques.
- Cannot replace experience and continued learning.

Indications

- Provide a basic understanding of ultrasound principles and image acquisition, including probe type, probe manipulations and orientations, and ultrasound machine features to maximize accurate image interpretation.

Objectives

- Provide a basic understanding of ultrasound image acquisition.
- Provide a review of basic ultrasound techniques and systematics including:
  - image planes
  - image orientation
  - probe maneuvers
  - image optimization
  - image documentation
  - basic machine selection and care.

Understanding Features of the Ultrasound Image

Imaging Planes

Understanding how the two-dimensional image is formed from scanning through a three-dimensional object is crucial not only to image interpretation but also communication of that information. The first piece of information is the imaging or scanning plane. The imaging plane may refer to the whole body, a part of the body (such as a leg or the head), or to a specific structure within the body, the left kidney, for instance (Figures 4.1 and 4.2).

The first of these, transverse, is any plane along the short axis of the structure being imaged.

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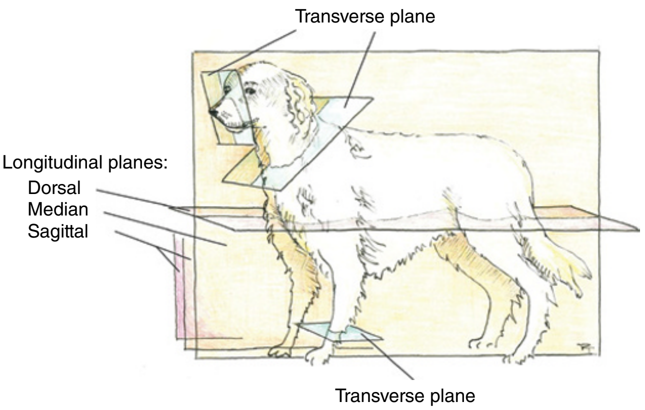

Figure 4.1. Longitudinal and transverse orientation shown on anatomical planes. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

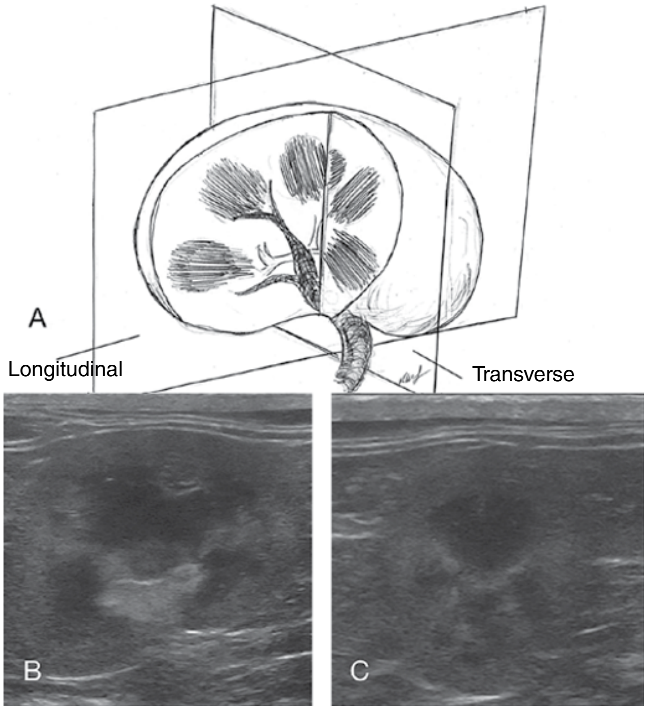

Figure 4.2. Examples of image planes for the kidney. In (A) the kidney is shown with longitudinal (sagittal) and transverse planes. In (B) the longitudinal (sagittal) plane is contrasted to (C) in transverse orientation on actual B-mode ultrasound images. For most nonradiologist sonographers, the kidney is more readily recognized in the longitudinal (sagittal) orientation. Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

The second, longitudinal, is any plane that is perpendicular to the transverse plane or the long axis of the structure. Technically, the longitudinal plane has several specific types.

- *Median* – this plane splits a symmetrical structure into equal left and right halves along the long axis.
- *Sagittal or paramedian* – this plane is any plane that is parallel to the median plane. While technically incorrect, many will use *sagittal* interchangeably with *longitudinal*.
- *Dorsal* – this plane splits a structure into dorsal and ventral segments and is analogous to the coronal plane in biped scanning terminology.

Commonly, veterinary sonographers tend to talk about only two planes, transverse and longitudinal, and this suffices for most communication and image understanding (see Figures 4.1 and 4.2).

Image Orientation

Any part of a medical record must contain the essentials of basic medical communication to have value. As veterinarians, we are taught how to communicate with each other in such a way regardless of our individual personality and training. One veterinarian can describe a lesion to another half a world away and pass along vital information. POCUS exams likewise need to have standard image orientation and recording of findings to give the study meaning.

Ultrasonography Compared to Radiography

For standard flat film radiography, the lateral film is oriented with the patient's head to the left, and the spine or dorsum is at the top of the viewer. This is the same for either a right or left lateral image. For the ventrodorsal or dorsoventral view, the radiograph is positioned with the head pointed up, and the patient's right side toward the left-hand side of the view box.

Ultrasound follows similar conventions. When we scan from the ventral aspect, as when the patient is in dorsal recumbency, the following orientations apply.

- *Longitudinal image*: the ventrum is on the top of the screen, dorsum on the bottom. Cranial (head) is to the left and caudal (tail) is to the right, similar to lateral radiography (Figure 4.3).
- *Transverse image*: ventral and dorsal remain top and bottom, respectively, and the patient's right side is represented on the left side of the screen, and the patient's left side is represented on the right side of the screen similar to ventrodorsal radiography (see Figure 4.3).

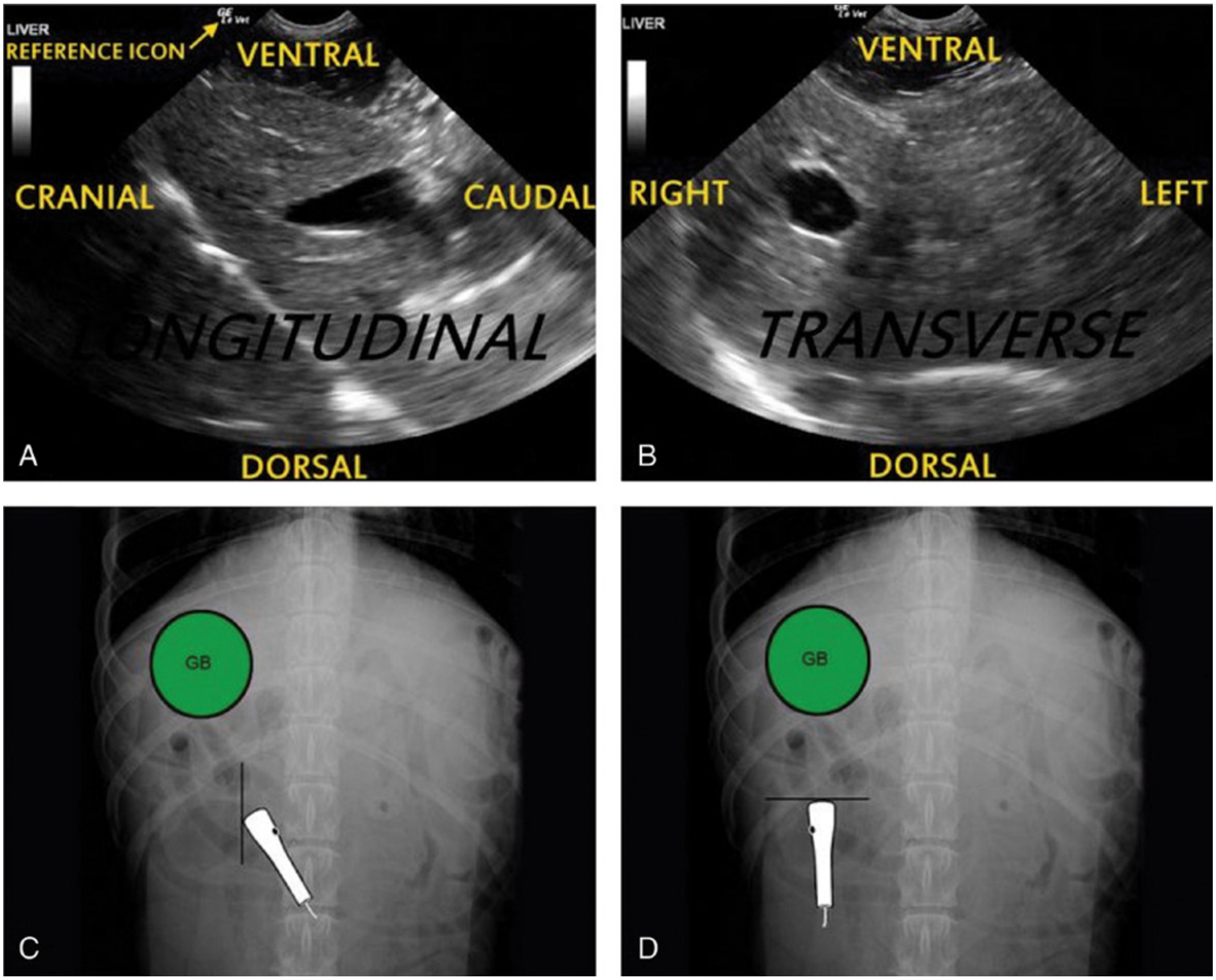

Figure 4.3. Standard ultrasound screen orientation, longitudinal (sagittal) and transverse. The radiograph for each orientation is located below the respective ultrasound image. Figures (A) and (C) illustrate longitudinal (or sagittal) and (B) and (D) transverse orientation with the corresponding probe position during interrogation of the liver and gallbladder via the subxiphoid region of a dog. Note that the reference icon (GELe) corresponds with the probe reference marker (dot on the probe) (labeled with arrow in (A) to the left on the ultrasound image). The best way to make standard ultrasound imaging a habit is to have the probe marker toward the head for longitudinal (or sagittal) orientation (black dot on the probe in (C) and turn (the probe head) left or counterclockwise for transverse orientation (black dot on the probe in (D) with the reference icon to the screen's left, shown at the top of the ultrasound image in (A) and (B)). If your reference icon is to the right of the ultrasound image, most ultrasound machines have a "reverse" button on their keyboard to flip the reference icon back to the standard left side (with the exception of echocardiography orientation; see Chapters 19–21).

Pearl: Ultrasound orientation is the same as radiography: in lateral radiography, the head is to the left and tail to the right when scanning the long axis of the patient; and in ventrodorsal radiography, the left side of the patient is on the right side of the screen when scanning the transverse axis.

This ultrasound image orientation convention is the most intuitive if the patient is positioned in dorsal recumbency with its head facing the same way the sonographer is facing with both toward the machine and its screen. Many emergent patients are not stable enough to be placed in dorsal recumbency and all FAST scans actually prescribe lateral recumbency or sternal or standing positioning because the positioning is safer. So the sonographer may need to do some mental gymnastics at times to orient the image on the screen with the patient. What helps is thinking in terms of gravity dependent (fluid falls) and gravity nondependent (air rises) and each in terms of where the transducer is placed.

Pearl: When imaging, picture the gravity-dependent and gravity-nondependent regions of your patient. Keep in mind that fluid falls (gravity dependent) and air rises (gravity nondependent).

When scanning from the lateral aspect of the patient, that is, in a dorsal plane, the following conventions apply.

- *Longitudinal image*: nonrecumbent side is on top of the screen, recumbent side is on the bottom. Cranial (head) is to the left side of the screen, and caudal (tail) is to the right (see Figure 4.3).
- *Transverse image*: nonrecumbent side is still on top of the screen, recumbent side still on screen's bottom. Ventral is on the left, dorsal is on the right (see Figure 4.3).

Pearl: Develop the habit of having the marker toward the patient's head (longitudinal imaging) and turning left for transverse imaging to maintain proper orientation etiquette, similar to radiography.

Probe Orientation and Reference Markers

All ultrasound probes have a reference marker to allow for proper orientation. The reference marker may be a raised dot or line molded into the plastic, or possibly a small LED light. On the image screen, there will be a symbol, often the company's logo, that corresponds with the probe's reference marker. The marker on the screen is commonly referred to as the "reference icon" (see Figure 4.3).

Sonographers should familiarize themselves with the various types of ultrasound probes (also called transducers): phased-array (also called sector), linear, and curvilinear. Furthermore, they should know that by looking at the shape of the ultrasound image, the probe is readily apparent as follows: pie-shaped pointed near-field (phased-array or sector), rectangular (linear), and pie-shaped with curved concave near-field (curvilinear) (Figure 4.4).

Pearl: You can tell what probe was used for the published image by looking at the image's near-field as follows: pie-shaped pointed near-field (phased-array or sector), rectangular (linear), and pie-shaped with curved concave near-field (curvilinear).

Most veterinarians are taught that when scanning the abdomen in long axis, the probe's reference marker is pointed toward the patient's head. Therefore, to maintain convention, the reference icon on the screen will also be positioned on the left-hand side of the screen (screen left = cranial, screen right = caudal). When the probe is turned into the transverse orientation, the reference marker is pointed toward the patient's right, making a counterclockwise motion ("turning left") if one views the probe from its tail or cable end (screen left = right side of patient, screen right = left side of patient). Again, the orientation is consistent with lateral and ventrodorsal radiographic orientation.

Some veterinarians are trained to orient the reference marker of the probe to be pointed caudally. Therefore, to maintain convention, the reference icon on the screen will be positioned on the right-hand side of the screen. When switching into the transverse orientation, the probe is still rotated counterclockwise. The reference marker will be pointed towards the patient's left, and the reference icon on the screen will still be on the right-hand side of the screen.

No matter which training a veterinarian has received, the image on the screen should follow proper orientation convention with the patient's head to the left (screen left is cranial) and the patient's tail to the right (screen right is caudal) as with a lateral radiograph, and the patient's right is to the left of the screen as with a ventrodorsal radiograph.

Probe Maneuvers

There is one basic concept and six basic probe movements used in acquiring the ultrasound image. *Beginning sonographers often miss their mark because they lack structured movement of the probe when scanning*. Being able to make one type of movement at a time is essential to obtain a good image. To the casual observer, it may appear that the experienced sonographer makes free-flowing and complex moves with the probe; however, the reality is that they are simply integrating the six foundational movements *one movement at a time*.

Pearl: When optimizing image acquisition, a good rule of thumb is to only *perform one probe maneuver at a time*.

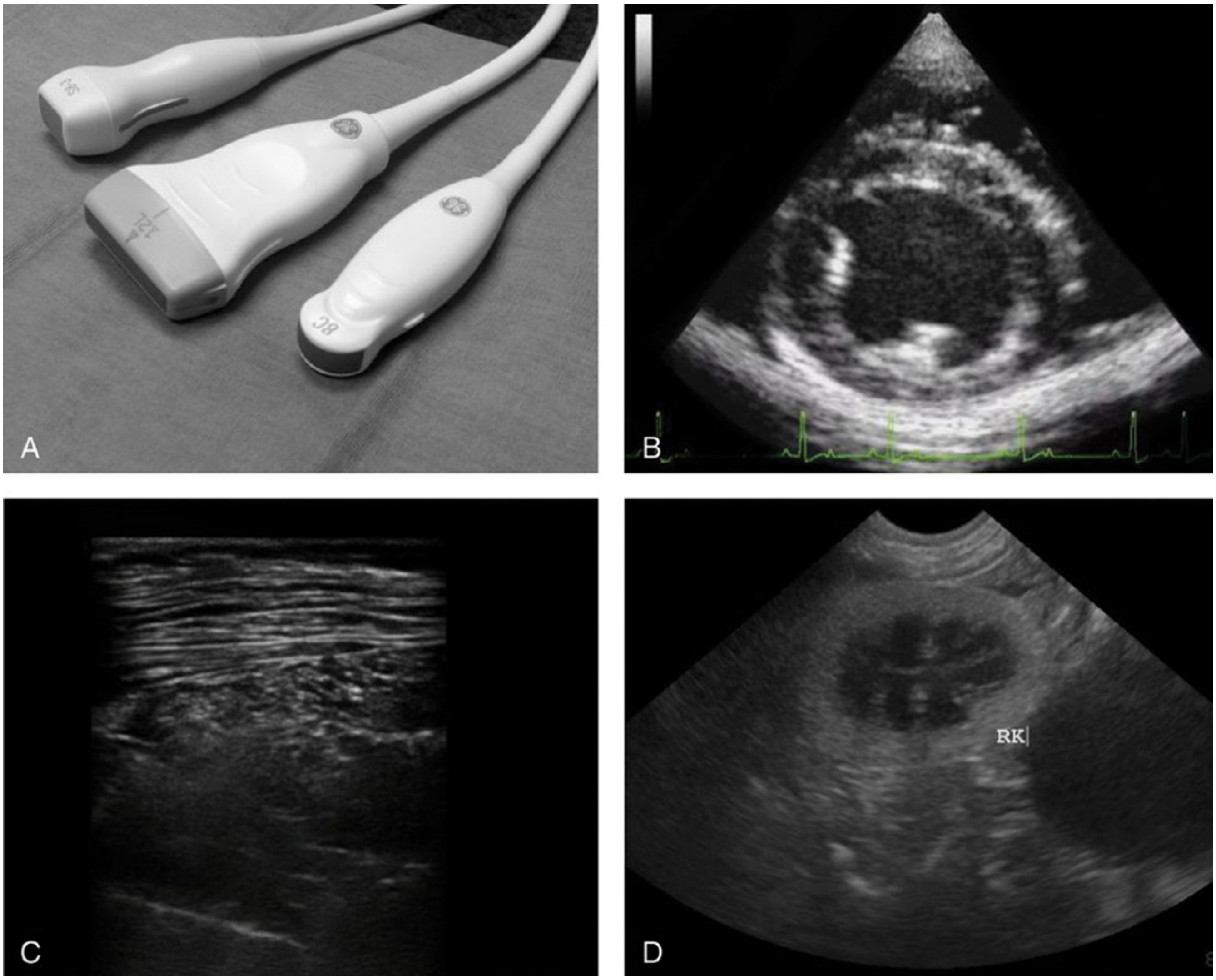

Figure 4.4. Electronic ultrasound probes and their characteristic B-mode images. The probe used for the ultrasound image is easily recognized by the ultrasound image's shape. From left to right in (A) are examples of the following probes (transducers): phased-array (also known as sector), linear, and curvilinear (also referred to as microconvex). A molded reference marker can be seen on all three of these probes. Other probes may use an LED light as the reference marker. The rubber probe heads (gray) represent the "footprint" or contact surface of each probe which differ between probe (transducer) types. (B) The phased-array probe ultrasound image is pie-shaped with a near-field "point." Phased-array is ideal for echocardiography because it best avoids ribs (note no rib shadow). (C) Linear probe ultrasound image with its rectangular shape. Linear is superior in detail because it sends and receives ultrasound waves 90° to the structure(s) of interest. (D) Curvilinear probe ultrasound image is pie-shaped but wide and concave in the near-field. Curvilinear (microconvex) is most commonly used by nonradiologist veterinarians because of its versatility.

Let us take a look at the one concept and the six basic or foundational probe maneuvers (Bahner et al. 2016).

Concept: Angle of Insonation

This concept is very important to understand and be aware of while scanning. The angle of insonation is the angle at which the probe is held in relation to the area of interest. *It defines the angle of incidence at which the ultrasound waves strike the object*.

The clearest image is obtained when the angle of incidence is zero degrees (Figure 4.5). This results in the highest number of sound waves being reflected back to the probe. Much beyond three degrees, the

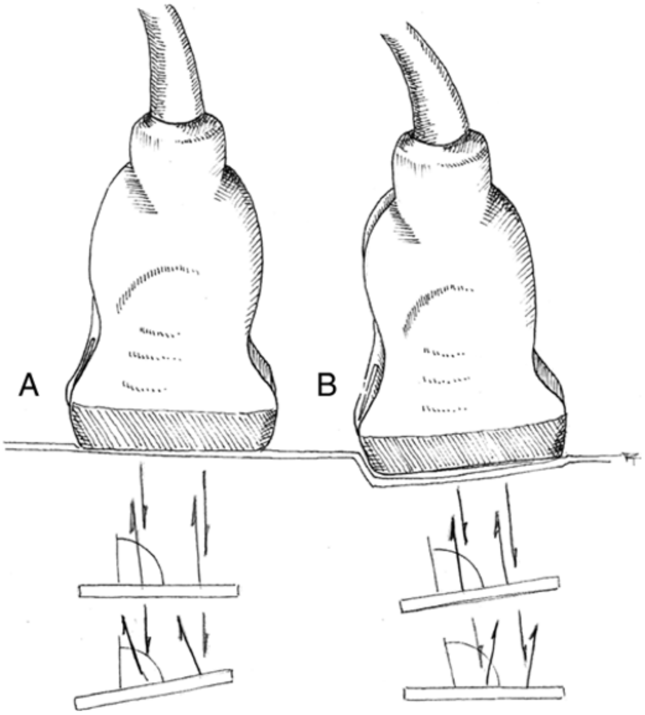

Figure 4.5. Angle of insonation. The angle at which the ultrasound beams strikes the organ or structure of interest is known as the angle of insonation. The best echo quality, and hence the best image quality, is achieved when the angle of insonation equals the angle of reflection. In (A), if the structure of interest is parallel to the transducer footprint, it will be best imaged. In contrast, in (B) if the area of interest is oblique then the probe must be adjusted for the optimal angle of insonation. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

image quality will diminish (Bahner et al. 2016). A curvilinear probe will lead to numerous different angles of incidence with the same angle of insonation. This is one reason why curvilinear probes do not produce as detailed an image as a linear probe. While the curvilinear probe can be considered the workhorse in veterinary ultrasound, adding a linear probe to the line-up can significantly improve your images. In terms of POCUS and FAST scans, however, the more maneuverable curvilinear probes remain the most commonly prescribed.

Maneuvers: Basic Probe Movements and Effects on Angle of Insonation

Rocking (Figure 4.6)

Rocking is best visualized with a curvilinear probe, a back-and-forth movement of the probe. Imagine a rocking horse or rocking chair. The position of the probe is not moved on the patient and the angle of insonation is changed only in the longitudinal plane. The rocking movement allows an object being visualized to be in the center of the screen (Bahner et al. 2016). A simple way of determining which way to rock the probe is this: if the object in the longitudinal plane is towards the cranial side of the screen (left side), rock the probe to direct it more cranially, and conversely, if the object is towards the caudal side of the screen (right side), rock the probe to direct it more caudally. Similar motions apply when scanning in the transverse plane.

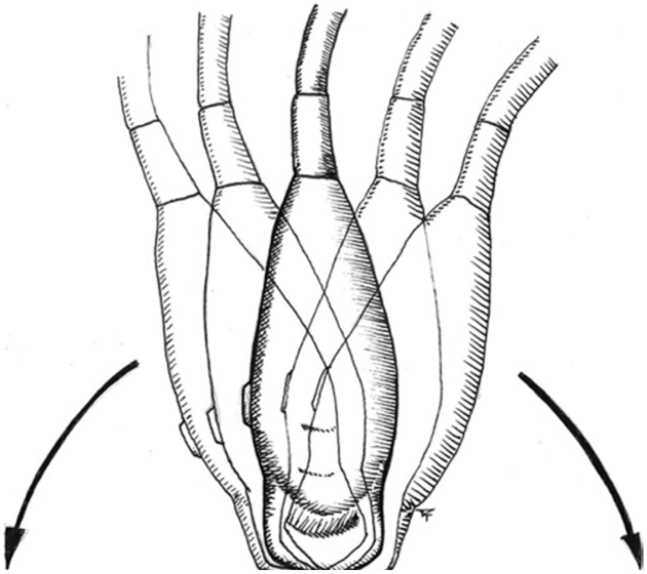

Figure 4.6. Rocking. The position of the probe is not moved on the patient and the angle of insonation is changed only in the longitudinal (sagittal) plane. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

Fanning (Figure 4.7)

Fanning is on the same focal point as rocking but moved in the perpendicular plane to rocking. During fanning, like rocking, the probe *stays on the same external point of* the patient, but the angle of insonation now changes in the transverse plane (side-to-side) in contrast to rocking. This motion allows for scanning a region and looking for the area of interest (Bahner et al. 2016).

Rotating (Figure 4.8)

Rotating is another movement where the probe stays on the same external point on the patient; however, the angle of insonation is *not changed* in any plane. The probe is turned about its long axis. Picture a clock dial

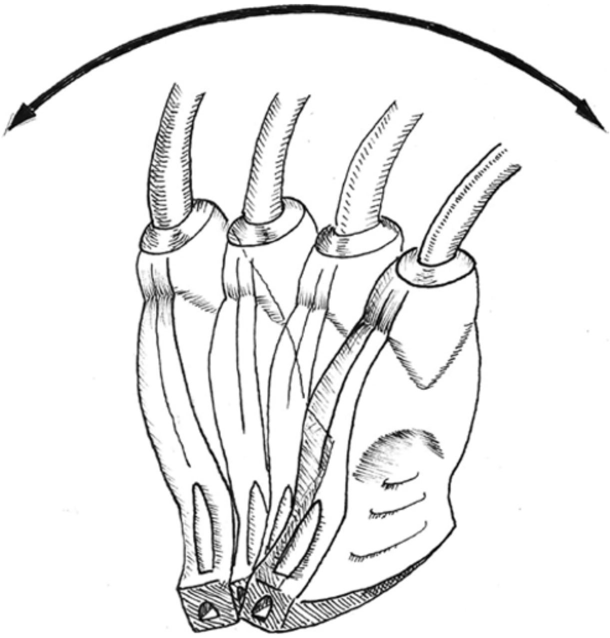

Figure 4.7. Fanning. The position of the probe is not moved on the patient and the angle of insonation is changed only in the transverse plane. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

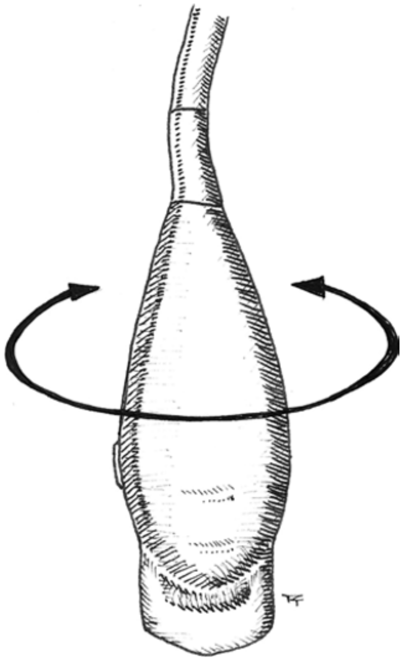

Figure 4.8. Rotating. The probe remains on the same focal point of the patient as with rocking and fanning. During rotating, the angle of insonation is not changed in any plane. The probe is turned about its axis in either a clockwise or a counterclockwise direction. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

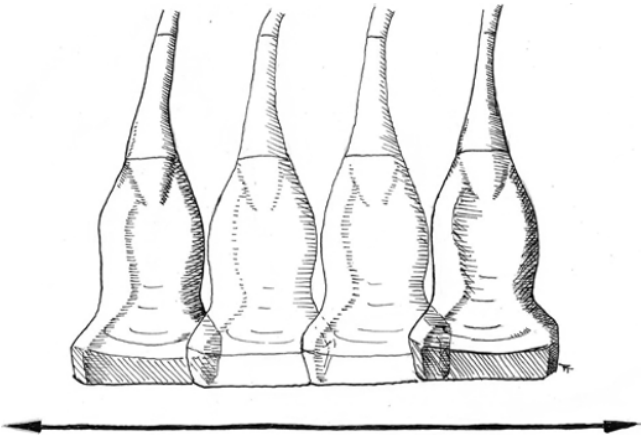

Figure 4.9. Sliding. The probe is moved across the body in the longitudinal axis of the patient, and the angle of insonation in relation to the patient's body is not changed. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

with the probe perpendicular to the face. The probe may be rotated either clockwise or counterclockwise (Bahner et al. 2016); however, to maintain the same imaging as a ventrodorsal radiograph, rotate counterclockwise (to the left).

Pearl: Rocking, fanning, and rotating are on the *same fixed external point* on the patient; however, the angle of insonation is changed with rocking and fanning (but not rotating).

Sliding (Figure 4.9)

During sliding, the angle of insonation in relation to the patient's body is *not* changed as the probe is moved across the body in the *longitudinal axis* of the patient (Bahner et al. 2016).

Pearl: Gradual increase in probe pressure is much better tolerated by the patient than a quick stabbing motion.

Pearl: Excessive pressure can push or move the area of interest out of view.

Pearl: There are three major reasons to use probe pressure knowing that your patient may not like the maneuver: reduce contact and air-trapping artifact, push structures out of the way, such as gas-filled small intestine, and gain more depth by moving the transducer closer to the area of interest.

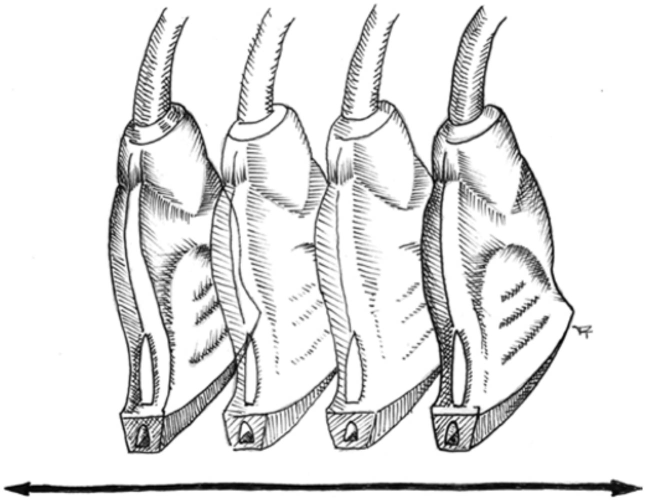

Figure 4.10. Sweeping. The probe is moved across the body in the transverse axis of the patient, and the angle of insonation in relation to the patient's body is not changed. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

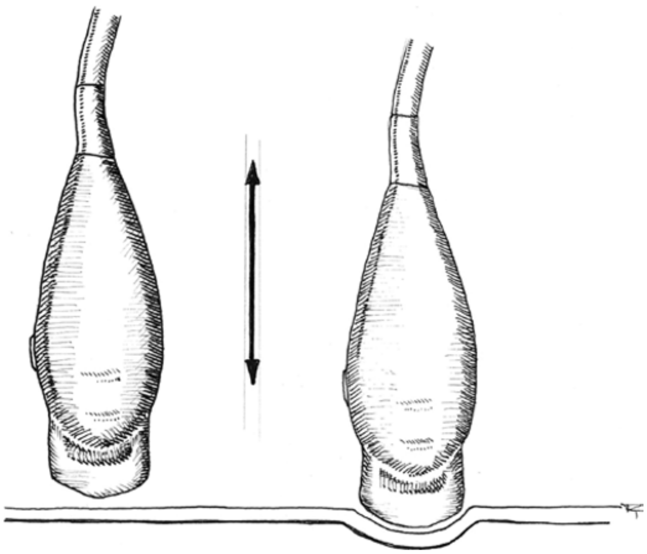

Figure 4.11. Pressure/Compression. Neither the probe position on the body nor its angle of insonation is changed. Rather, the probe is pushed into the body, compressing the underlying tissues. Source: Illustration courtesy of Randi Taggart, Richmond, VA.

Sweeping (Figure 4.10)

Like sliding, during sweeping the angle of insonation in relation to the patient's body is *not* changed as the probe is moved in the *transverse axis* of the patient (Bahner et al. 2016).

Pressure/Compression (Figure 4.11)

During pressure/compression, the probe is pressed or pushed into the body, causing compression of body tissues. The pressure/compression maneuver may help to reduce contact and air-trapping artifact, push structures out of the way, such as gas-filled small intestine, and gain more depth by moving the transducer closer to the area of interest. Uncontrolled pressure may result in moving the intended target (area of interest) out of the field of view. This effect commonly occurs with the feline spleen and kidney and at the AFAST spleno-renal (SR) view.

Cardiac Orientation

See Chapters 17–21 for detailed information on cardiac orientation.

Pearl: For the POCUS and FAST ultrasound scans, begin with an intermediate setting of 8 MHz as a general rule of thumb. That being said, most chapters in this textbook provide probe frequency recommendations.

Image Optimization: Using the "Big 4" Knobs of Depth, Gain, Frequency, and Focus

For an ultrasound image to have meaning, it must have adequate detail. The best rule of thumb is that the image should simply look "nice." This idea may be a little different from one person to another but they should all be relatively similar. Always keep in mind the angle of insonation. The ideal angle of ultrasound reflection for generating the best image is 90° on the surface of the organ of interest (see Figure 4.5). In fact, this is why linear probes, while not used by most small animal practitioners, provide superior detail when compared to curvilinear probes, which are more commonly used among small animal practitioners.

Although there are numerous buttons and knobs on the ultrasound machine that can be used to improve, or worsen, the image, the "Big 4" are depth, gain, frequency, and focus position and number. See also Chapter 5 for additional examples.

Pearl: Know the "Big 4" knobs: depth, gain, frequency, and focus position and number.

Depth

When reviewing a radiograph, the clinician can become narrow-sighted by focusing on one area and not looking at the rest of the film. With ultrasound, however, the goal is to focus on one area. Adjust the depth to the area of interest. Filling up the screen with the area of interest will result in a better diagnostic ultrasound image and this strategy is used for detailed parenchymal assessment. However, during AFAST and TFAST target organs are usually reduced to 25–33% of the screen, depending on the target organ and the respective view.

Every sonographer performing ultrasound has a responsibility to know where the ultrasound scale is located; usually values are in centimeters and are displayed along the side of the machine's screen. The awareness of depth within the image is often overlooked by beginning sonographers. However, recognizing depth is of the utmost importance because what looks large on ultrasound may in fact be small. Attention to the centimeter scale on the screen also allows for eyeballing not only the depth but also the dimensions of structures in view.

Gain

Gain is the overall brightness of the image. The ideal is not too bright and not too dark. The gain knob is the one that will adjust the overall gain setting. After first setting the overall gain, minimize dark or light bands across the screen by using the time gain compensation (TGC) knobs. These are usually sliders that adjust brightness along discrete bands across the image, although some machines have reduced the numbers of sliders to near- and far-field. The goal is to have a consistent brightness from top to bottom of the screen, in other words, gain extending through the far-field.

Frequency

Find a happy medium between penetration and resolution. Use the highest frequency (MHz) possible yet still see as deeply as needed. The smaller the patient, the higher the frequency and the larger the patient, the lower the frequency. High MHz provides detail at the expense of penetration and low MHz provides penetration at the expense of detail. In addition to the frequency, the focus position and focus number also have a major impact on the image. Frequency is also affected by presets. Smaller parts, pediatric and smaller abdominal and cardiac presets generally increase the frequency automatically and adult and larger abdominal and cardiac presets decrease the frequency automatically.

Focal Position and Number

The ultrasound beam has a focus position where the beams narrow to give a more detailed image at a certain depth. The beams do not converge, as we may think of light focusing on the retina, because they will again diverge beyond the focal position. The physics of this can be found in additional references (Nyland et al. 2002). Both the focus position and number of focal points can be set and adjusted by the sonographer. However, the processor can only handle a certain amount of information and by asking it to do more, it will reduce other items, normally the frame rate or how many times/second the image is refreshed. High frame rates make for a smooth image but take a lot of processing power. Low frame rates give a choppy image. Ask the processor to do more and it will respond by giving you a lower frame rate, a choppier image.

Pearl: For the POCUS and FAST scans, generally keep the focal point number at 1, and set the focal point's position at, or just deep to, the area of interest.

Presets, Abdominal, Cardiac, Small Parts, etc.

Even with just these four settings, that's still a lot of knobs to be adjusting in the emergent situation. Modern ultrasound machines have a collection of imaging settings which the user may select, based upon the area of interest, such as cardiac vs abdomen vs small parts and others, and patient size, adult versus pediatric. Trying to image an abdominal structure if the machine is on the small parts preset will lead to frustration until the sonographer realizes that the preset must be changed first to be able to adjust and manipulate the Big 4 knobs.

Alternate Imaging Tools

Up to now, we have been talking about B-mode, or standard two-dimensional, ultrasonography. A-mode has no practical bearing on the emergency scans outlined in this book and therefore will not be discussed. However, M-mode and color flow Doppler imaging are used in many of the POCUS and FAST protocols and during ultrasound-guided procedures.

M-Mode

The "M" in M-mode stands for "motion." This mode has also been called the "ice pick" mode because it reflects a small column of ultrasound waves but follows it over time. Cardiac ultrasound is where M-mode is best known. It can be a little challenging to understand what is being displayed on the screen but using the B-mode view to show just where that "ice pick" is cutting through is helpful. M-mode is used not only for certain cardiac studies but also in certain lung and pleural space studies, vascular measurements for volume assessment, and fetal imaging. Importantly, M-mode speed may be adjusted to slow, medium, and fast, and the M-mode speed setting can significantly impact what you are attempting to interrogate, depending on the area of interest.

Color Flow Doppler

Color flow Doppler is used in combination with B-mode ultrasonography. It allows you to see blood flow within a vessel and helps to determine the direction of that flow. Doppler is best when the flow is *parallel* with the sound beam. Color signatures are usually set up so that flow toward the probe is red – remember by "you are getting warmer" – and flow away from the probe is blue – remember by "you are getting colder" or that "blue" and "away" have the same number of letters – although this can be set on most machines to user preference. Color flow Doppler has its limitations, with low velocities and is also affected by patient movement, a phenomenon called "jumping" (see Chapter 25).

To maximize accurate image acquisition and proper interpretation, the sonographer should be familiar with settings that affect color flow Doppler (Pozniak et al. 1992). Briefly, the Big 3 are gain, pulse repetition frequency, and wall filter setting, and their effects are as follows.

- *Gain*: the overall sensitivity to flow signals.
- *Pulse repetition frequency* (also known as PRF, scale, or velocity scale): user-defined setting. Use a lower PRF with low velocities; use a higher PRF with higher velocities to correct aliasing. If too high a PRF is selected, low velocities may not be recorded, and a vessel may appear as if thrombosed (no flow); conversely, too low a PRF will lead to overlap of the signal on the image.
- *Wall filter*: removes unwanted low-velocity Doppler signals; however, if set too high, it will remove important low-velocity signals.

For more information, the reader is referred to more detailed texts (Nyland et al. 2002; Evans et al. 1989) and the machine's technical support team.

An alternate form of color flow Doppler, called power Doppler imaging (PDI), can be employed. Similar to color flow, this shows flow of fluid but at much lower velocities. The trade-off is a lack of directionality. Blood flowing at 0.5 cm/sec away from the probe will have the same color signature as blood flowing at 0.5 cm/sec toward the probe. Consider using PDI for small vessels in POCUS studies such as the optic artery and vein

Pearl: Color signatures are usually set up so that flow toward the probe is red and flow away from the probe is blue – remember "red is getting warmer and toward you" and "blue is away from you and getting colder" or that "away" and "blue" have the same number of letters.

Pearl: Color flow Doppler is optimized by understanding its settings and their effect on the image: gain, pulse repetition frequency, and wall filter setting.

On the Horizon

Single Crystal Probes

Single crystal probes emit a large bandwidth of sound beams instead of just one, thereby combining the benefits of high-frequency resolution and low-frequency penetration. The learning curve for imaging is generally quite different from that of traditional multicrystal ultrasound probes.

Smartphone Applications

At the time of this writing, there are several smartphone-powered ultrasound devices approved by the Federal Drug Administration. Technology is advancing quickly and ultrasound machines may now be carried around in the healthcare provider's pocket. One must wonder what the future holds for the ease and availability of ultrasound imaging.

Documentation of POCUS and FAST Ultrasound Examination Findings

Save and label the images. A medical record is not complete with just a written description of an image, whether that is a radiograph, an ultrasound image, computed tomography (CT), or magnetic resonance imaging (MRI). The image must be there to back up the interpretation. Furthermore, the other imaging modalities contain information to indicate exactly where an image was obtained. For example, the radiograph has anatomical landmarks and for both CT and MRI, there is a pilot image that records where all the remaining images are obtained. For ultrasound images, there may not be any definitive markers.

An ultrasound image that makes sense to the sonographer when it was recorded may make no sense when under review two days or even two hours later. One of the most common mistakes sonographers make is not labeling their images. Label the organ or structure of interest and label your orientation as longitudinal versus transverse, if it is not evident from the image. There will be times when there are no anatomical landmarks evident on the image and labeling is your only guide (Figure 4.12).

Most ultrasound machines have some sort of body pattern that can be placed on the image with an icon to show the approximate location of the probe (see Chapter 2). Put all labels outside the image, too. Placing words across the image can potentially hide diagnostic information. If you must write across the ultrasound image, first save a picture of the unadulterated image and then save a second picture of the annotated image. Short (3–10 second) video clips can also be saved on most ultrasound machines.

For recording ultrasound findings in medical records, see suggested goal-directed templates in the respective chapters throughout the textbook.

Ultrasound Machine and Probe Care

Not all ultrasound machines were designed for the battlefield with parts that can sustain a six-foot drop. Most were designed for the relative quiet and safety of a hospital. Ultrasound machines and their components can be easily damaged or broken by rough handling and improper use, and replacement can be costly, especially if you drop an ultrasound probe and damage its crystals. Dropping the probe is the most common cause of probe damage and machine misuse.

The second most common form of misuse involves probe head damage (Figure 4.13). There are two major forms of probe head abuse: needle damage and chemical damage. With the use of POCUS as standard of care for many invasive procedures on the human side, now fast spilling over into veterinary medicine, needle damage, in other words stabbing or catching the rubber probe head with the point of the needle, quickly leads to severe probe head damage. In the haste of the moment, the attending sonographer will often grab a bottle of isopropyl alcohol, wet down the fur with only the alcohol, and apply the probe, leading over time to chemical damage. Many ultrasound manufacturers list alcohol as an inappropriate liquid to place in direct contact with the probe head because alcohol, over time through desiccation, can cause probe head damage.

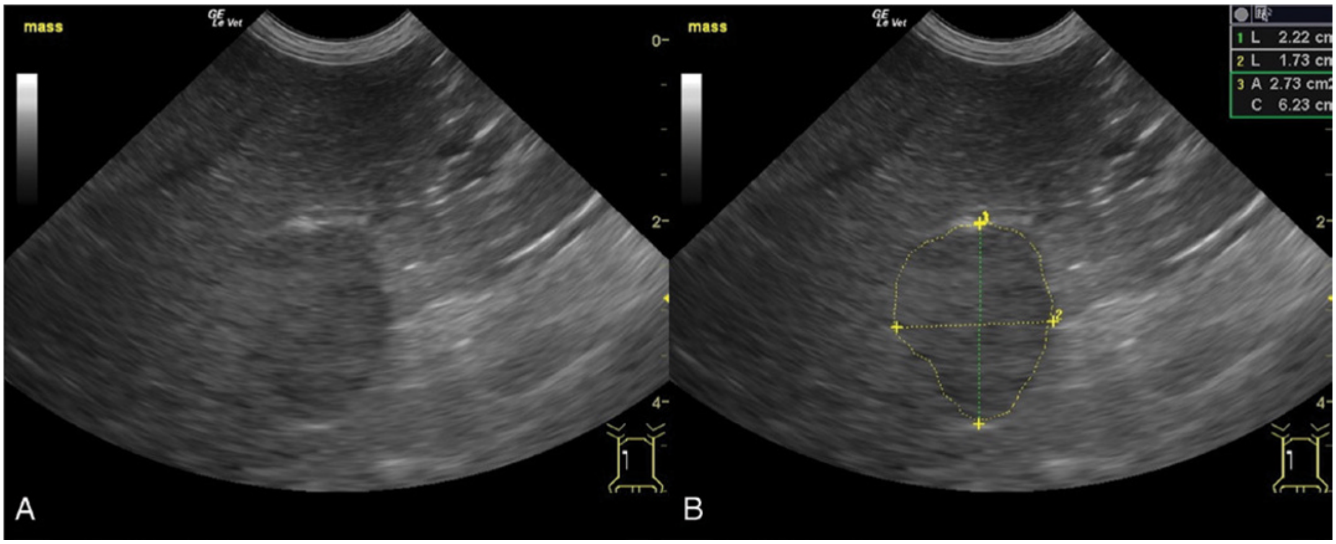

Figure 4.12. Labeling the image. The same image in (A) and (B) of a liver mass. The location cannot be determined by the image itself and thus the use of the body icon helps point out where the image was taken. The mass itself is circled using the various measurement features of the ultrasound machine. The measurements of the mass are displayed in the upper right of image (B). Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

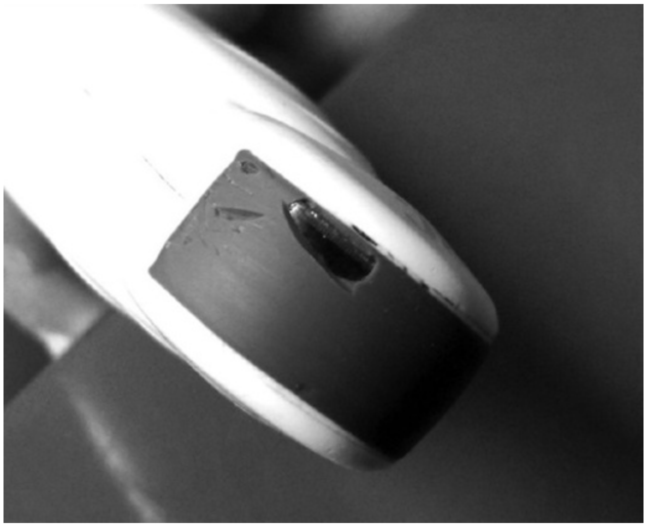

Figure 4.13. Probe head damage. The damage to the surface of this probe was attributed to a combination of repeated or prolonged contact with isopropyl alcohol and needle trauma. The contact layer is clearly lost over a portion of this probe, negating its ability to serve as an electrical insulator between the probe and patient. It is possible for potentially serious electric shock to occur through the damaged area. Source: Courtesy of Robert M. Fulton, DVM, Richmond, VA.

Pearl: Always use acoustic coupling gel on the probe head and be familiar with the guidelines provided by the ultrasound machine's manufacturer.

Importantly, it should be noted that the rubber probe head accomplishes two things. First, it acts as a coupling medium to transmit the sound wave out of the probe. Second, it is part of an electrical insulator serving as an electrical ground between the patient and the electricity being sent from the ultrasound machine to the transducer's crystals. There are currently no reports of electrocution via a damaged ultrasound probe but theoretically it's possible.

Pearl: Avoid probe head damage by using an acoustic coupling medium on the probe head as a barrier to alcohol, and avoid stabbing the probe head with needles during ultrasound-guided procedures.

Deciding on an Ultrasound Machine

Selecting the Machine

There are three main types of ultrasound machine: consoles, portables, and hand-helds. The console machines are big and bulky, but they have stronger processors and thus give a better image. The portables, often laptop format, are easy to move to the exam table or cage side and their image quality is constantly improving. There are several small hand-held machines now on the market. Some have adequate depth and resolution capabilities. Just make sure they don't "walk out of your clinic" or get tossed into the laundry or dropped or stepped on. It's very easy to put these hand-held devices in a lab jacket pocket and forget about them.

You may be limited to whatever you currently have in your veterinary practice, but if you are thinking of buying a new unit, consider what your main use is going to be and get the best ultrasound machine you can afford for that purpose. The axiom holds true: the better the machine, the better the image, and hence the better the diagnostic information.

Selecting the Probe: Linear, Curvilinear, and Phased-array

Probes, or transducers, come in two basic types, mechanical and electronic. Mechanical probes are on many counts considered outdated but there are still some around with their working parts visibly rotating or rocking under their translucent covers. Newer ultrasounds have electronic probes as standard. Electronic probes come in various arrangements. Probes are generally described by the size and shape of their face, referred to as their "footprint," which is represented by the gray rubber probe covering (see Figure 4.13). Selecting the right probe is essential to getting good images, although there may be times when more than one probe may be appropriate for a given exam.

Three basic types of probes are used in general practice, emergency, and critical care POCUS: linear, curvilinear, and phased-array (also known as sector) (see Figure 4.4). Linear probes are typically of higher frequency and have a rectangular footprint. Curvilinear probes are arranged along a convex face and are typically of lower frequency than linear probes. A phased-array (sector) probe generates an image from an electronically steered beam in a close array, generating an image that comes from a point and is good for getting between ribs, such as in cardiac ultrasound. Both curvilinear and phased-array probes generate sector or pie-shaped images, narrow in the near-field and wide in the far-field. Phased-array probes are typically lower frequency. Because of their smaller footprint, "pie-shaped" image, and commonly used frequencies, curvilinear probes are generally the most versatile and ideal for POCUS and FAST studies.

Probes are generally named for the primary frequency they emit. For example, a General Electric (GE) 8C probe indicates that 8 MHz is its primary frequency and the C represents the probe's curvilinear footprint. A GE 9L probe indicates a 9 MHz primary frequency in a linear (L) probe, and a GE 7S has 7 MHz as its primary frequency in a sector (S) probe. However, modern probes are capable of emitting a range of frequencies, known as bandwidth. In choosing the best frequency, we need to go back to basics. Remember that higher frequencies are attenuated more and that means less penetration but better detail. Lower frequencies are attenuated less and that means deeper penetration but less detail. Another rule of thumb is that the smaller the patient or area of interest, the higher the frequency (MHz) versus the larger the patient or area of interest, the lower the frequency (MHz).

Setting Up an Ultrasound Program

See Chapter 45 for additional information.

Pearls and Pitfalls, The Final Say

In summary, these first four chapters have briefly covered some of the ultrasound basics. Other textbooks are available that go into more detail regarding ultrasound principles and artifacts, and many courses sponsored by ultrasound companies are available throughout the year to enhance learning. FASTVet.com is an online Global FAST education company. Another resource is the International Veterinary Point-of-Care Ultrasound Society's website www.IVPOCUS.org

It is important to be familiar with some of the basic principles, artifacts, and nuances associated with ultrasound as an imaging modality for your busy general practice, emergency room, or critical care unit to minimize misinterpretations. POCUS and FAST ultrasound are truly an "extension of the physical examination" and "the modern stethoscope" (Rozycki et al. 2001; Filly 1988).

So there you have it. Turn on your ultrasound machine, apply your coupling medium, and start scanning. Get POCUS and FAST and better pick your next test, more accurately treat, and better keep alive your patients for gold standard testing and treatment. POCUS and FAST save lives!

References

Bahner DP, Blickendorf JM, Bockbrader M, et al. 2016. Language of transducer manipulation. *J Ultrasound Med* 34:183–188.

Evans DH, McDicken WN, Skidmore R, Woodcock JP. 1989. *Doppler Ultrasound: Physics, Instrumentation, and Clinical Applications*. Chichester: Wiley.

Filly RA. Ultrasound: the stethoscope of the future, alas. *Radiology* 167:400.

Nyland TG, Mattoon JS, Herrgesell EJ, et al. 2002. Physical principles, instrumentation, and safety of diagnostic ultrasound. In: *Small Animal Diagnostic Ultrasound*, 2nd edition, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 1–18.

Pozniak MA, Zagzebski JA, Scanlan KA. 1992. Spectral and color Doppler artifacts. *Radiographics* 12:35–44.

Rozycki GS, Pennington SD, Feliciano DV, et al. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50:636–642.

CHAPTER FIVE

POCUS: Top Ultrasound Mistakes During Global FAST

Gregory R. Lisciandro

Introduction

Having trained close to 1000 veterinarians from around the world in Global FAST, AFAST, TFAST, and Vet BLUE, we have come up with our top list for image acquisition and interpretation mistakes made during Global FAST that will help synthesize the previous three excellent chapters by Dr Fulton. Whichever machine you work with, you must understand its software, how it interprets artifacts, and what its strengths and weaknesses are to gain full confidence in its imaging potential. You also need to know how to optimize image acquisition by taking advantage of external patient features and the role your hands should play. This takes time, repetition, and critical thinking during image acquisition and a sonographer who dares to use the different buttons and controls on the machine.

We strive to perform the entire Global FAST using the abdominal preset with the same curvilinear (microconvex) probe for the abdomen and thorax, including heart and lung. However, in time the sonographer may come to prefer different presets (cardiac, small parts) and probes (phased-array, linear), depending on the structure(s) of interest, the stability of the patient and the clinical questions being addressed. However, the curvilinear (microconvex) probe is absolutely acceptable for the entire Global FAST examination.

What POCUS Top Mistakes Can Do

- Make the sonographer aware of the most common mistakes which occur during Global FAST image acquisition.
- Make the sonographer aware of the most common air and fluid-associated artifacts and where they commonly occur during Global FAST.
- By raising awareness of these mistakes during Global FAST, the sonographer will carry over these principles to other ultrasound studies.

What POCUS Top Mistakes Cannot Do

- Cannot replace proper ultrasound training and experience.

Indications

- For all sonographers performing Global FAST for a basic understanding of how to optimize image acquisition and avoid mistaking artifacts for abnormalities.

Objectives

- Provide a basic understanding of Global FAST ultrasound image acquisition to help accelerate the learning process.

Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition. Edited by Gregory R. Lisciandro.

Companion website: www.wiley.com/go/lisciandro/ultrasound2

- Provide a practical approach for image optimization and artifact identification as they pertain to the standardized examination of Global FAST and its 15 acoustic windows, and to help make your ultrasound interpretation more accurate.

Image Acquisition Mistakes

Not Recognizing Air Trapping

Ultrasound does not transmit through air. Air reflects your ultrasound beam from its path from the probe head to your areas of interest. Optimizing image quality relies on eliminating the phenomenon of "air trapping," especially the air trapped between the probe head and its contact with the patient's skin (Figures 5.1 and 5.2). Air trapping is potentially more problematic when not clipping hair, and hair is rarely clipped for Global FAST, AFAST (abdomen), TFAST (pleural cavity, heart, and lung), and Vet BLUE (lung). So be sure to part the hair, part the hair, part the hair! Parting the hair gets the probe in direct opposition to skin and the best image is optimized with the probe head directly on skin, with no hair in between, and with ample acoustic coupling medium. So what do we recommend?

- 70% isopropyl alcohol helps strip out air and lipids from hair follicles and is used for that reason. We use 70% isopropyl alcohol unless electrical defibrillation is anticipated (it's a burn/fire hazard in the presence of electrical current and 100% oxygen) followed by alcohol-based hand sanitizer, a brilliant trick of the trade given to me several years ago by the Mississippi State radiologist Dr Jennifer Gambino. Note that saline and water, although more gentle, lack the aforementioned properties of 70% isopropyl alcohol.
- Alcohol-based hand sanitizer is an excellent coupling medium and has advantages over both 70% isopropyl alcohol and commercially available acoustic coupling gel.

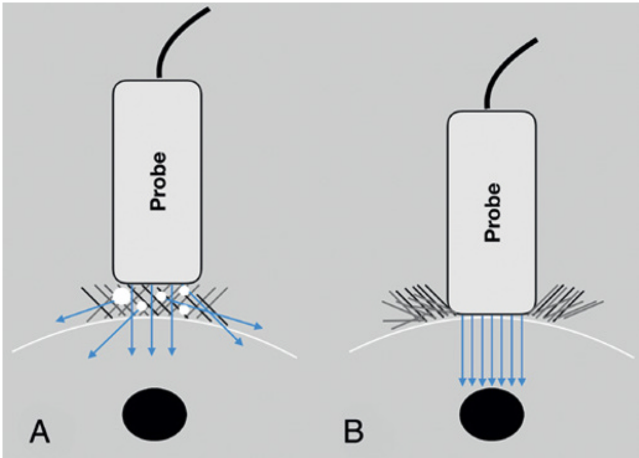

Figure 5.2. Air trapping. In (A) the probe head is placed on a wetted mat of fur in which air is trapped between the hairs. Air trapping attenuates the beam by its reflection and scattering of echoes (*blue arrows*) off the small pockets of air (*white circles*). In (B) the hair is parted and thus the probe head is coupled directly to the skin for best image acquisition in an unshaved patient. Note all the beam is transmitted with no reflection or scatter of echoes (*blue arrows*). Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

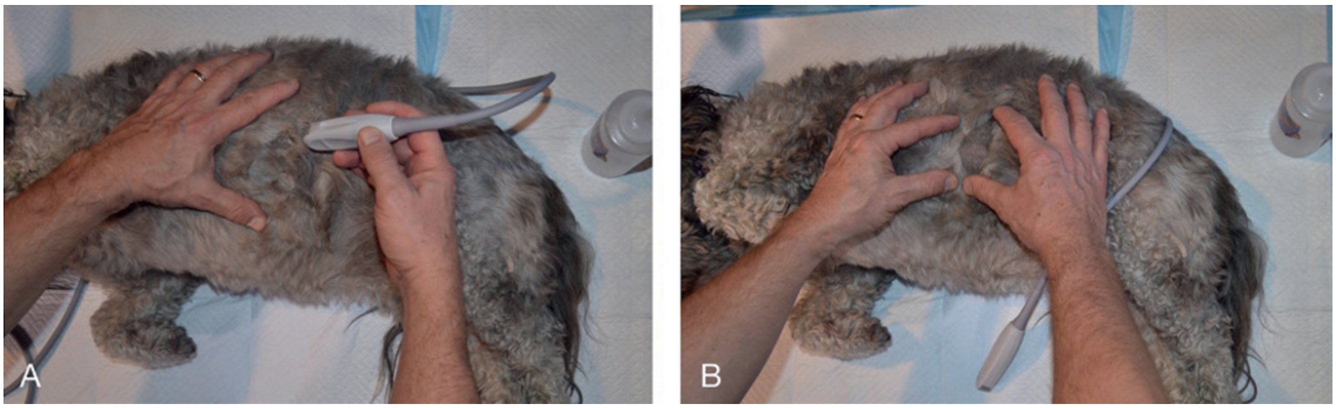

Figure 5.1. Wet and part the hair. In (A) the area is wetted without parting the hair. By doing so, the image will not be optimized because of all the air trapping (see Figure 5.2). In (B) the wetted hair is parted to optimize the coupling of the probe head directly to skin to produce the best image in unshaved patients. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

- Alcohol-based hand sanitizer when compared to 70% isopropyl alcohol is not as noxious on skin or indirectly by its fumes. The coldness associated with isopropyl alcohol is not only objectionable to your patient, but also contributes to their cooling (hypothermia) which may be detrimental for a critical patient. The fumes are also problematic for patients placed in closed environments such as an oxygen cage. My personal experience is that our patients associate the coldness with the anticipation of something painful if they have had previous blood draws and catheter placements. Try smaller volumes of 70% isopropyl alcohol and larger amounts of alcohol-based hand sanitizer.
- When compared to acoustic coupling gel, alcohol-based hand sanitizer not only wipes off your patient more readily than the gooey consistency of commercially available gel but also evaporates off the hair and skin. The final benefit is that your hands are clean after scanning!

Pitfall: Placing the probe on a wetted mat of hair leads to marked air trapping and poor image quality. Part the hair and get the probe head in direct opposition with the skin with an appropriate acoustic coupling medium.

Pearl: The alcohol-based hand sanitizer is better than 70% isopropyl alcohol because it is not noxious to the patient, either directly on the patient's skin or indirectly via fumes in closed environments. Moreover, alcohol-based hand sanitizer is not nearly as cooling as 70% alcohol, which can lead to hypothermia especially in smaller and critically ill patients.

Failure to Keep the Patient's Head and Ultrasound Screen in the Same Sightline

The danger of not having the head of the patient and the ultrasound screen in the same sightline is twofold (Figure 5.3). First, if the patient decompensates or is critical, you have no idea if they are becoming distressed, cyanotic, having open-mouth breathing, etc. when you and the technician are focused on the ultrasound screen in the *opposite* direction to your patient's head. Second, by not having the patient's head and ultrasound screen in the same sightline, you and your assistant are vulnerable, leaving your face, hands, and body open to bites and scratches without defense, while focusing on the screen. And finally, spatial orientation is better learned and established even by experienced sonographers by having the machine and head of the patient in the same sightline, and you will likely be more comfortable rather than craning your neck to look at a screen in an uncomfortable direction.

Understanding Your Hands

Your two hands will function differently while scanning. One is your "probe hand" (Figure 5.4). The probe hand always holds the probe and you may change which hand is your probe hand depending on where and from which side of your patient you are imaging. However, this hand's function is to work the probe. Your other hand is your "helper hand" which is used to palpate external landmarks and physically stabilize the patient or the probe on the patient, which is explained subsequently. Briefly, in standing patients, your helper hand is your "V trough" during TFAST and Vet BLUE, cupping the sternum to keep your patient from swaying (every time you lose contact, you prolong the study, which is not always in the patient's best interest) (see Figure 5.4). While performing AFAST, your helper hand is used to move less haired skin over your probe placement site for such views as the splenorenal (SR) and hepato-renal (HR) in flank areas, and the cysto-colic (CC). For TFAST recumbent views, the helper hand can lift the sternum off the table top for less weight on the probe head, which allows for finer movements and less pain because of less pressure on your patient's intercostal space. Finally, during Vet BLUE, the acoustic window you acquire may be moved together with skin, dependent on the mobility of your patient's skin, caudal and cranial over intercostal spaces at each Vet BLUE region.

Consistently Maintaining the Screen Orientation of Head to the Left and Tail to the Right

When imaging in longitudinal and sagittal planes, including short- and long-axis views of the heart, maintain the head to the left and tail to the right on the screen. If the area of interest is to the left of the screen, you learn to slide or rock toward the patient's head to center the image and vice versa if to the right of the screen, slide or rock toward the patient's tail whether you are doing AFAST, TFAST or Vet BLUE (see Figure 1.6). In human medicine, physicians performing cardiac FAST and POCUS examinations will not necessarily reverse orientation, but stay consistent with all other imaging, with cranial to the left and caudal to the

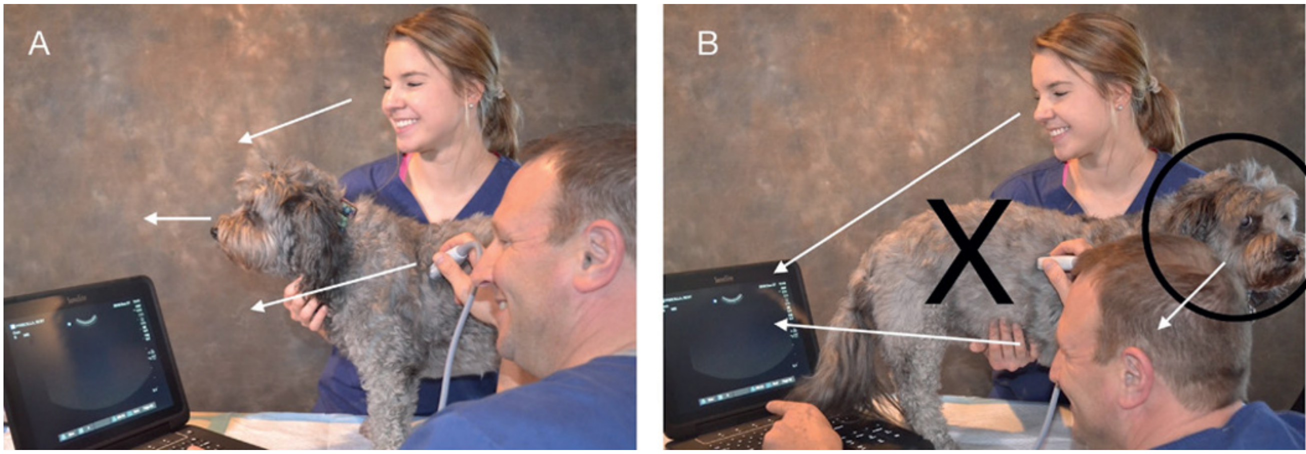

Figure 5.3. Best practice is the head of the patient and machine in the same sightline. In (A), the assistant, the scanner, and the patient are all facing the ultrasound screen (*arrows*). This is safest because the patient can be observed for any stress and decompensation while imaging. In (B) the head of the patient is away from the ultrasound screen. Both the assistant and scanner are focused on the screen and thus cannot readily appreciate any stress or decompensation of the patient, and cannot quickly react if the dog turns to bite them. The large "X" denotes that this is risky practice. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

Figure 5.4. The helper hand and probe hand make a difference. In (A) the helper hand moves less haired skin and can help spread the hair for optimal probe head to skin coupling. In (B) and (C) the helper hand in essence V troughs the standing patient, preventing swaying and better stabilizing the probe for maneuvering in small increments, especially important for cardiac imaging. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

right of the screen (Walker and Mohabir 2014). I like to call this the "rogue way" in which to capture echocardiography views, but maintaining orientation whatever the region of interest is advantageous for localizing abnormal findings, and the noncardiologist doesn't have to do any mental spatial adjustments because the cardiac ultrasound orientation is now the same as everywhere else (abdomen and lung).

Fan, Rock Cranially, and Return for AFAST Views

As a result of work by Boysen et al. in the original FAST translational study from humans to dogs, we have simplified and standardized the probe maneuver for AFAST as "fan, rock cranially, and return to your starting point" because 397/400 views matched for detecting free intraabdominal fluid when comparing longitudinal to transverse orientation (Boysen et al. 2004). And most abdominal organ anatomy during AFAST is easier to recognize in longitudinal and sagittal planes. Consider transverse orientation as an add-on skill (Figure 5.5).

Playing on the Short-axis and Long-axis TFAST Lines

In contrast to many echocardiography courses that begin with the long-axis cardiac views, we begin TFAST with short-axis views. Importantly, if the sonographer can grasp the "short-axis line" and "long-axis line" concept and fan the probe while *staying* on these lines, echocardiography views are learned more quickly and acquired more consistently by the noncardiologist sonographer (Figure 5.6). Without even looking at the screen, knowing you are on these TFAST

Figure 5.6. Short-axis and long-axis lines for echo views. If only someone had told me this back in 2005, to religiously keep the probe head parallel to the short-axis (cardiac) and long-axis (cardiac) lines while fanning, I would have gained proficiency so much faster. Trust these lines and fan while staying on them to achieve your echo views. We can tell from across the room whether or not you are successful by seeing if you are on these lines using a clockface orientation approach (see Figures 17.25 and 17.26). Wander from them and everything gets goofy. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

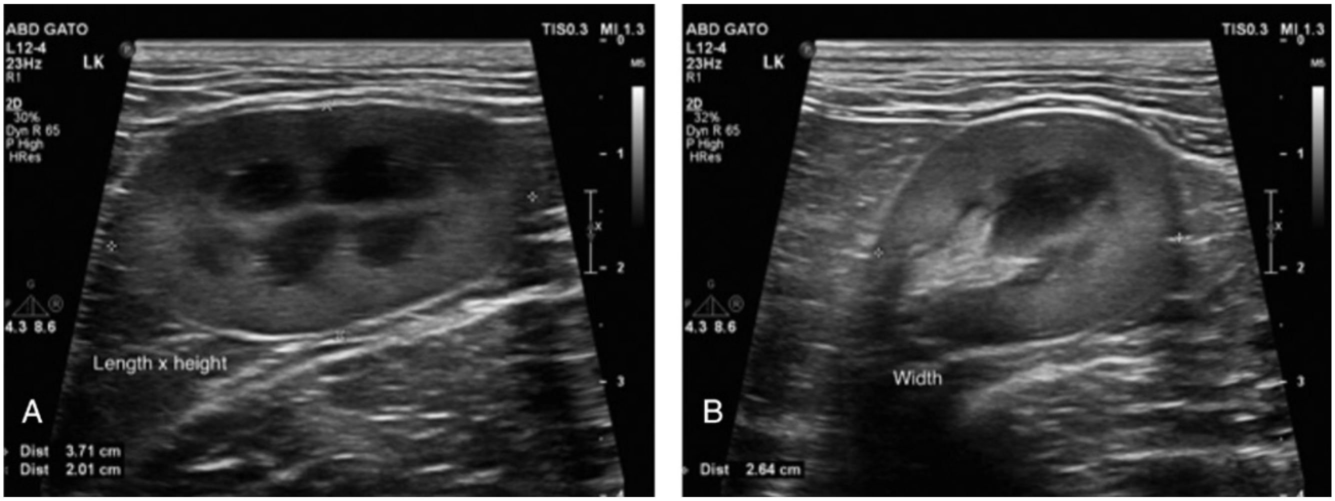

Figure 5.5. Anatomy generally better recognized in longitudinal (sagittal) orientation than transverse. In (A) the kidney is generally better recognized and then interrogated by fanning through longitudinal planes than in (B), showing the kidney in less recognizable transverse orientation. Source: Courtesy of Dr Daniel Rodriguez, Mexico City, Mexico.

cardiac lines will optimize success. We could literally teach you from across the room, without any screen knowledge, by just seeing whether or not you are maintaining the ultrasound beam on these lines while fanning from the apex to the base on short-axis, and from side to side on long-axis using our clockface approach (see Figures 17.25 and 17.26).

Failure to Maintain Probe–Skin Contact with the Patient

Every time you lose probe–skin contact with your patient, you delay the imaging and have to reestablish your acoustic window, losing precious time and potentially increasing risk in hemodynamically fragile (and stressed) patients. There are several recommendations that involve your nonprobe "helper hand," placed into two broad categories: (1) maintaining probe–skin contact (acoustic window) by moving your patient's loose skin with the probe, and (2) maintaining probe–skin contact (acoustic window) by keeping your patient from swaying and at the same time stabilizing the probe against your patient's body.

We have found that the sonographer may take advantage of the patient's loose skin by moving the probe and skin together, and moving nearby less haired skin over the external landmark for your desired acoustic window. An example would be while doing Vet BLUE lung ultrasound, without losing probe–skin contact and your acoustic window, slide the probe together with the loose skin one intercostal space caudal and one intercostal space cranial when possible to cover the respective intercostal spaces at each respective Vet BLUE region. Another example is at the SR and HR views where the skin ventral to these views is often more sparsely haired, so your helper hand's thumb can lift or move this region dorsally over your external landmark of the costal arch and sublumbar muscles. By taking advantage of the sparsely haired area, imaging quality is markedly improved, especially in a thickly coated golden retriever, border collie or Siberian husky (see Figures 5.1 and 5.4). Another AFAST location is the CC view. Placing the probe laterally but closer to the midline where there is obvious sparsely hair coated skin markedly improves the image.

Regarding maintaining probe–skin contact, we have some pearls. First, when your patient is standing during the Global FAST approach, use your helper hand to "V trough" the patient by holding both sides of the sternum (Figure 5.7). This is especially helpful for evaluating your TFAST pericardial site (PCS) views but may also be used during Vet BLUE. Second, use your helper hand to brace your probe against the thorax or abdomen for better control of fine probe maneuvers.

Figure 5.7. V trough your patient with your nonprobe helper hand. Your nonprobe helper hand is used as a V trough to keep your patient from swaying and maintaining probe to skin contact. Every time you lose contact, you potentially lose your good acoustic window and precious time. As much as possible, keep all four legs of your patient on the table. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

Third, as often as possible, let the patient have all four legs on the exam tabletop (see Figures 5.4 and 5.7). The only time a three-legged approach is mandatory is for the Vet BLUE cranial lung region for defining the cranial transition zone of soft tissue of the neck and then sliding caudally to image the first three intercostal spaces. Most of the time, the standing TFAST PCS views and imaging the heart may be done with all four legs on the exam table. By this approach, the patient is not swaying and feels more secure than lifting and extending a foreleg off the table. Fourth, when lifting and extending a foreleg, we lift and extend near the patient's elbow, especially for dogs. Many dogs do not like their paws being handled and associate it with the unpleasant experience of having their nails trimmed (Figure 5.8). Thus, by handling the paws, your patient becomes restless, wary, and tachycardic and may try to bite you!

Other Probe–Skin Contact Issues

Not Being Aware of Drifting

Drifting is the phenomenon of looking intensely at the ultrasound screen and not realizing that the weight of your hand and gravity has taken you to a place where no man (or woman) has gone before – a bit of an exaggeration which will hopefully help you remember this very common mistake. The *Star Trek* phrase sounds funny but you started at the costal arch and hypaxial muscles looking for the left kidney, not realizing the probe has made it to the midline at the umbilicus (by drifting). No wonder you cannot find the left kidney! If you double-check yourself by frequently looking at the screen and then at the probe's external location on your patient, you will get to where you want to go much faster! This also occurs commonly while performing Vet BLUE in standing patients. You think you are at the Caudodorsal Vet BLUE lung region but the weight of your hand has brought you close to the Middle Vet BLUE lung region.

Figure 5.8. When extending the foreleg, don't touch the paw! Gently extend the foreleg with your helper hand placed near the elbow and away from the paw. The paw is sensitive and you may create an uncooperative patient (e.g., may bite, may become resistant to restraint, may become tachycardic) by triggering a negative response. Stay near the elbow. Shown is the acquisition of the right Vet BLUE cranial lung region view. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

The best way to prevent drifting is to routinely "kickstand" out a finger that solidly touches your patient's body wall (or have another comfortable part of your hand against the patient's body wall) (Figure 5.9).

Not Checking Where the Probe is Externally on the Patient

This is really Part 2 of the previous paragraph. A few years ago, while I was performing Global FAST imaging on dolphins, the concept proved most helpful. Without goggles showing the ultrasound screen, two people were needed for imaging – one on the dock monitoring the ultrasound screen and directing the sonographer who was in the water with the dolphin, unable to see the ultrasound screen. Paying attention to external landmarks helped guide the sonographer to the AFAST target organs (and all of Global FAST) efficiently and confidently.

The same holds true with our small animal and exotic patients. Pay attention to where the probe is

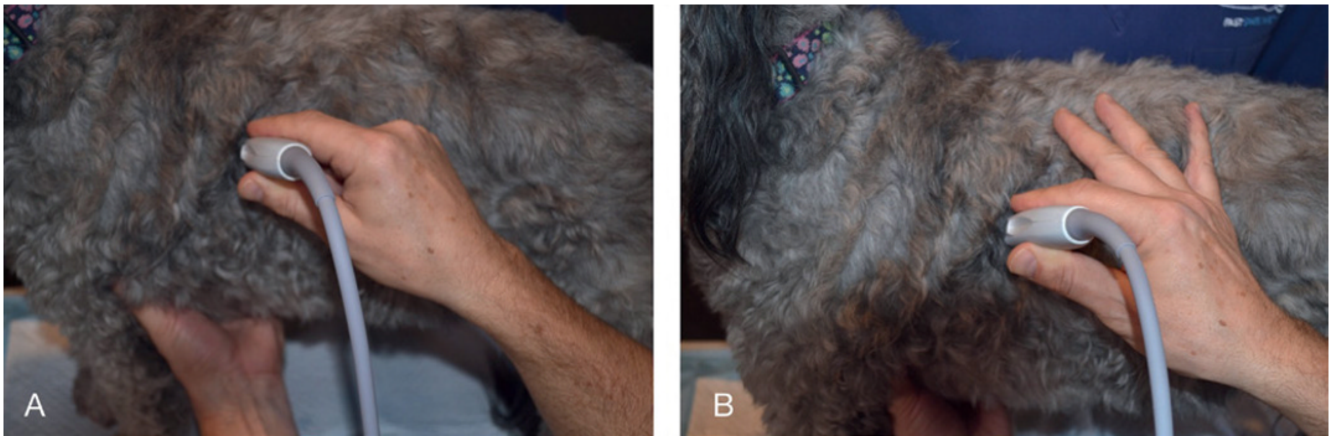

Figure 5.9. "Kickstand" your probe hand to prevent drifting. Having some part of your probe hand in contact with the patient will prevent drifting, which is when the sonographer is focused on the screen and unaware that the weight of their probe hand has moved the probe to a different acoustic window. In (A) the probe hand is not braced against the patient, so the sonographer is susceptible to drifting. In (B) the fingers are comfortably spread in contact with the patient's body, thus preventing drifting. Common views for drifting are especially during Vet BLUE and the least gravity-dependent SR and HR views. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

externally on your patient, double-checking between the ultrasound screen and the probe's external location. Look at your patient! For example, if you can't find the urinary bladder then slide toward the patient's pubis slightly off midline in lateral recumbency or along midline when standing or sternal. Some other examples – the gallbladder is right of midline in both dogs and cats so the probe has to be directed to *that side* of your patient; the TFAST chest tube site (CTS) view generally takes you to the caudodorsal transition zone, thus helping to prevent mistaking abdominal structures for lung pathology; and the kidneys are close to the caudal vena cava and aorta attached by their short renal artery and veins.

Not Visualizing the Path of the Beam from the Probe Head

Mental visualization of success prior to a motor skill performance such as an athletic event is important and so is mentally visualizing the path of the ultrasound beam from the probe head (Figure 5.10). To get the "cardiac bump" at the diaphragmatico-hepatic (DH) view, the probe's beam must be directed toward the muscular apex of the heart which requires the probe being rocked far cranially and the beam approximating being parallel to the sternum. The AFAST CC pouch is in the most gravity-dependent region of that view so the probe should be directed toward the tabletop (when in lateral recumbency), not at the spine! Visualizing the direction in which the ultrasound beam is projecting from the probe head will contribute to your imaging success, save time, and build confidence in locating structures of interest.

Losing Track of the Probe Orientation Marker

Make it a habit to have a finger or thumb on the probe marker or be able to clearly see the probe marker (Figure 5.11). It is easy to lose track of the probe marker without making this habitual while imaging. It not only helps with orientation but also prevents creating confusing planes through structures by the sonographer's awareness of being in longitudinal, sagittal, transverse, and short- and long-axis planes. Moreover, keep the screen orientation marker to the left so you maintain the "head to the left, tail to the right" orientation, which is the same as radiography (see Figure 1.6).

Using More than One Probe Maneuver at a Time

One of the main rules of imaging is only performing *one probe maneuver at a time*. The five major maneuvers are rocking, fanning, rotating, sliding, sweeping and pressure/compression (see Figures 4.5–4.11). Performing only a single maneuver at a time while optimizing your image should become habitual. When you perform multiple maneuvers at the same time, you are really doodling and nothing productive typically results. This is very common with "flashing" the

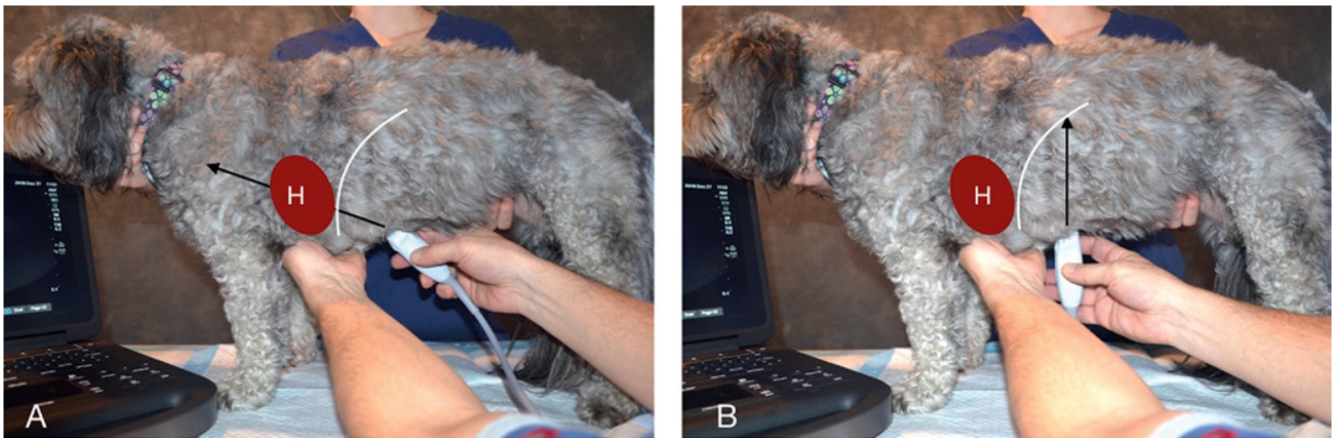

Figure 5.10. Paying attention to the direction of the beam. If the sonographer is to image the heart and its cardiac bump at the DH view, then the beam must be directed where the heart would be. In (A) the beam is directed in the correct direction whereas in (B) the heart will never be imaged. The "H" and red oval represent the heart; the black arrow the ultrasound beam; and the white curved line the diaphragm. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

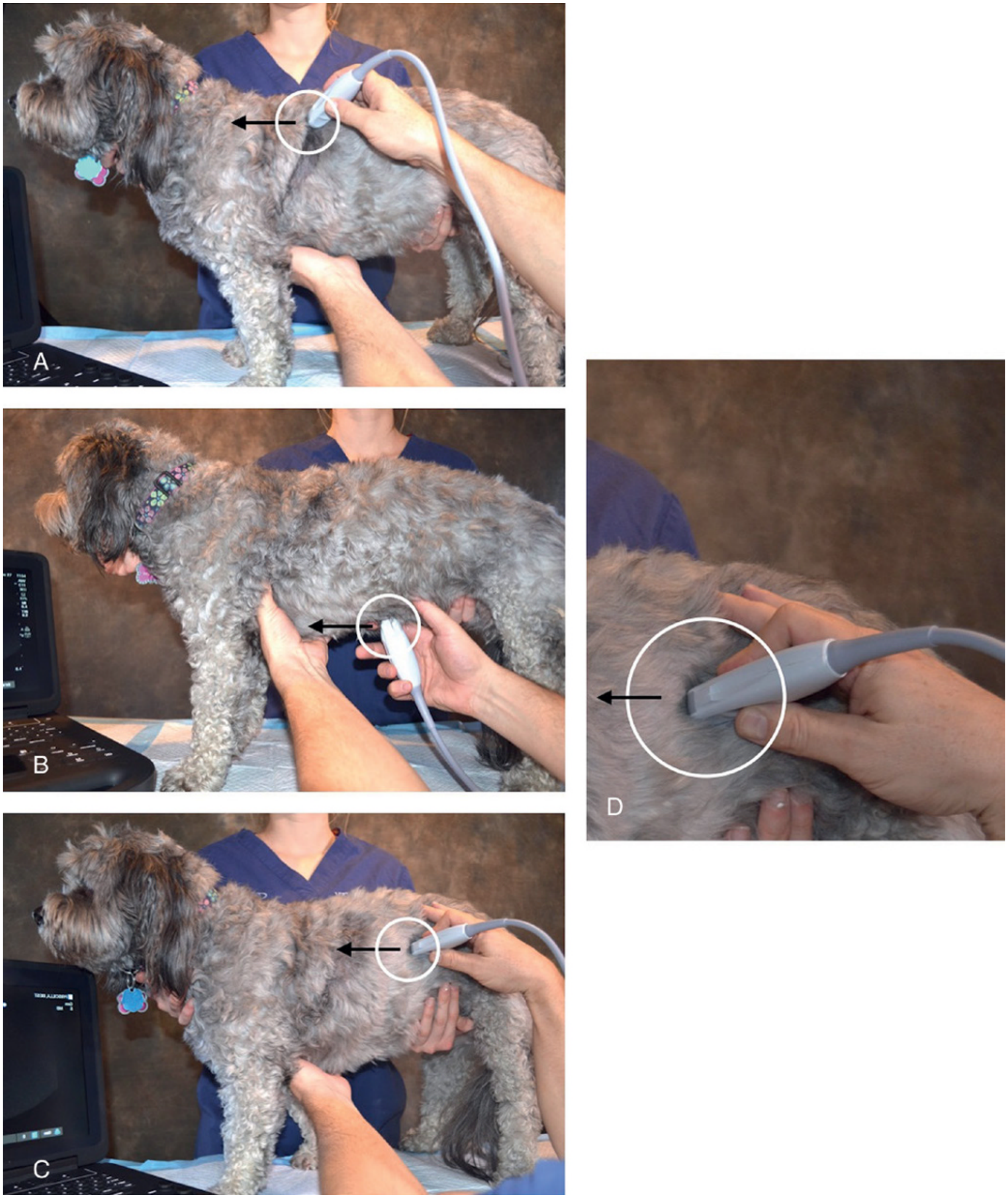

Figure 5.11. Be aware of the probe marker. Every probe has a marker or notch that serves as its orientation marker. Always keep track of the marker and when in longitudinal or sagittal orientation, keep it directed toward the patient's head. Getting into the habit of holding the probe with your index finger or thumb on the marker or be able to clearly see the probe marker keeps you from making mistakes and getting confused during image acquisition and interpretation. Screen orientation is also important (see Figure 1.6). Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

abdomen, thorax, and lung (see Preface). We strongly discourage flashing but rather stick with the exact clarity of the 15 acoustic windows of Global FAST.

Ultrasound Machine Optimization

A trouble-shooting algorithm is provided that incorporates the following major image optimization features of your machine (see Figure 5.15).

Failing to be Aware of the Focus Cursor

The position of the focus cursor can have profound effects on image quality (Figure 5.12). Most sonographers are familiar with gain, and its effect on making the image brighter or darker; and frequency, lower for better imaging of the larger patient and higher for more detail and imaging the smaller patient. However, the focus cursor is often forgotten. It is usually an arrow or an icon that moves along the centimeter scale. It can be increased from one to two or three or more on some machines, but generally it's best to have only one, a single focus cursor, on your screen. Think of it as when having more focus cursors than just one, you are dividing up the energy in your ultrasound beam and the image will not be as high quality as a result.

The focus cursor should be directly across from the area or region of interest. A common mistake is moving the focus cursor to the "lung line" during Vet BLUE and then leaving the cursor in the very near-field when you then image deeper thoracic, like heart, and abdominal structures. The deeper structures will often not look good no matter what you do to the gain and frequency *until you move the focus cursor back to the center of the screen*. Conversely, you may have the focus cursor in the center of the screen while imaging abdominal and thoracic structures that may be less than optimum for lung, in which the focus cursor placed in the near-field across from the "lung line" could make a big difference in image quality (see Chapters 22 and 23). In some machines, the focus cursor actually moves on its own as depth settings are changed, and it may move to a less than optimal level within your image, so learn what your machine does to the focus cursor when you change the depth.

Not Paying Attention to the Centimeter Scale

Every machine has a centimeter (cm) scale (Figure 5.13). Be familiar with where the maximum depth is on the screen, and how the marks are set up – as one hash mark every centimeter or are the hash marks every 5 mm or even every 2.5 mm? This will help you to locate the area of interest; for example, starting the FAST DH (subxiphoid) view at a depth of 5 cm even in medium-sized dogs is too superficial (shallow or magnified) and won't properly image the diaphragm and

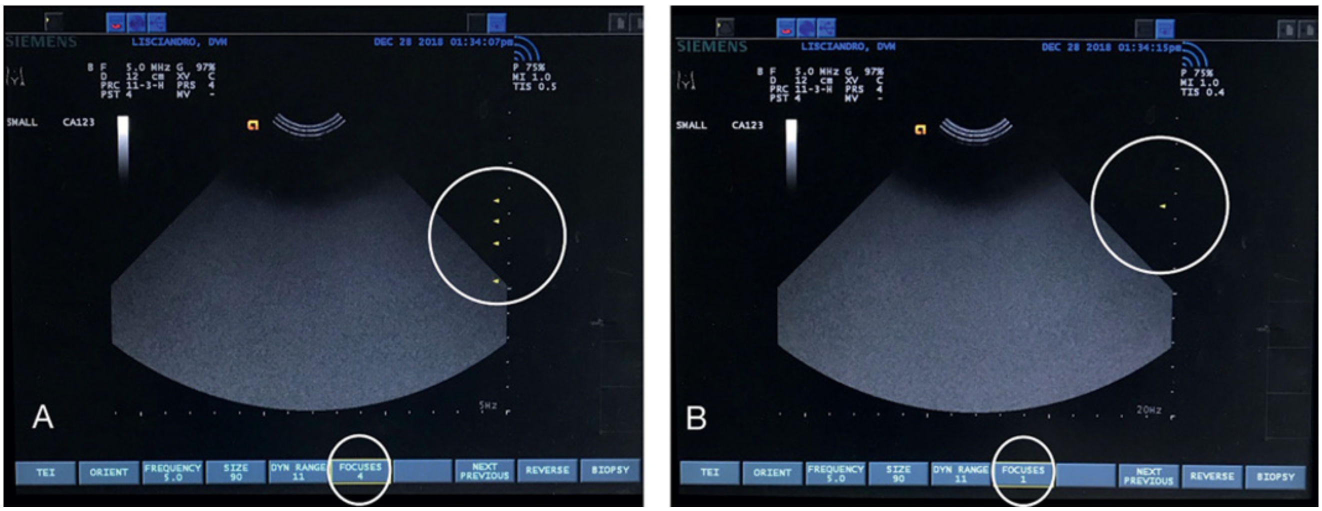

Figure 5.12. Focus cursor and depth. In (A) there are four focus cursors (*upper right circle*) and in (B) a single focus cursor (*upper right circle*). The best image is usually obtained by having a *single* focus cursor directly across from the area of interest so generally in the middle of the screen, unless imaging the lung in which a position directly across from the "lung line" is best. The number of focus cursors on this machine is also noted at the bottom of the screen (*circled*). Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

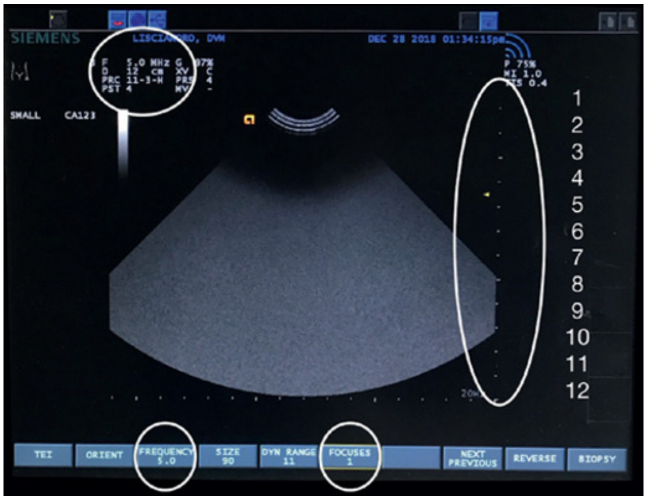

Figure 5.13. Depth setting and the centimeter scale. The image is the same as Figure 5.12B with the focus cursor near center. The image has the centimeter scale to the right of the screen and then added numbers by the author for the depth of 12 cm. See how the hash marks correlate with 1 cm increments. Every ultrasound screen has a centimeter scale. Individual hash marks are often 1 cm (10 mm) on abdominal presets but can be every 0.5 cm (5 mm) or less. Find your cm scale and be aware of its depth scale. The screen itself has the depth (cm) and frequency (5 MHz), circled upper left and also at the screen's bottom along with number of focus cursors (1), plus other parameters noted (including the preset). Take the time to look over all the information provided on your machine's screen. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

gallbladder. The wise sonographer knows to start with a depth between 9 and 13 cm, get a feel for the four DH targets – diaphragm, gallbladder, cardiac bump, and caudal vena cava – and then magnify (decrease depth) once the targeted structures are identified from afar (see Chapters 6 and 7). On the other hand, lung is imaged at more shallow depths between 4 and 8 cm for smaller and larger patients, respectively.

Not Using the Centimeter Scale

What looks really large on ultrasound may in fact be quite small. This is especially true with pleural effusion that looks like a lot on ultrasound but the maximum dimension is only 2 cm (or less than an inch), and merely a fissure line on the thoracic radiograph (TXR) or is missed altogether by TXR. As for masses, the seemingly large splenic mass that deforms the spleen, a serious finding, is really only 3 × 3 × 3 cm (or approximately 1¼ × 1¼ × 1¼ inches), easily missed by palpation during your physical exam and on abdominal radiography; and the lung lesion that appears so obvious is in fact a mere few millimeters (<1/3 inch) being missed or occult by thoracic radiography (and possibly CT) (Figure 5.14). Don't get me wrong, these findings may have a significant clinical bearing on your case, but a small pocket of pleural effusion in a stable case requires a calm and collected mind for decision making, and not overresponding.

Pearls: Trouble Shooting a Poor Image

See the trouble-shooting algorithm (Figure 5.15).

- *Check your frequency*. In small dogs and cats, you can get away with higher frequencies such as 7–9 MHz; however, in large dogs (and other patients), the image will not be optimized until you lower the frequency to the 4–6 MHz range. You may have to change your preset, for example from small abdomen to medium or large abdomen, to change your frequency on some machines. Get used to looking at the frequency setting when starting to image the patient (see Figure 5.13).
- *Check your gain*. Generally, the time gain compensation (TGC) should be a gentle curve from the near-field to the far-field (Figures 5.16 and 5.17). Then, only the overall gain is used for the rest of the Global FAST ultrasound examination. However, using the TGC sliders is another strategy, depending on what level of the image needs to be brighter or darker. A common mistake when moving from AFAST and TFAST to Vet BLUE is having too much gain, in other words too bright in the near-field for lung because you needed more gain for soft tissue than lung surface imaging. Thus, the "lung line" is now too bright, lacking the contrast you need for Vet BLUE. Conversely, moving from Vet BLUE to AFAST or TFAST, you are now too dark (undergained) because the "lung line" imaging did not need as much gain as the soft tissue of abdominal and cardiac structures.
- *Check your depth*. Depending on the area of interest and the size of your patient, paying attention to the depth will help you to get where you want to go more quickly (see Figure 5.13). Generally, it's best to start with too much depth to gain an overview of what you are imaging, and to survey for recognizable landmarks prior to magnifying (decreasing the gain). And time is valuable on many fronts,

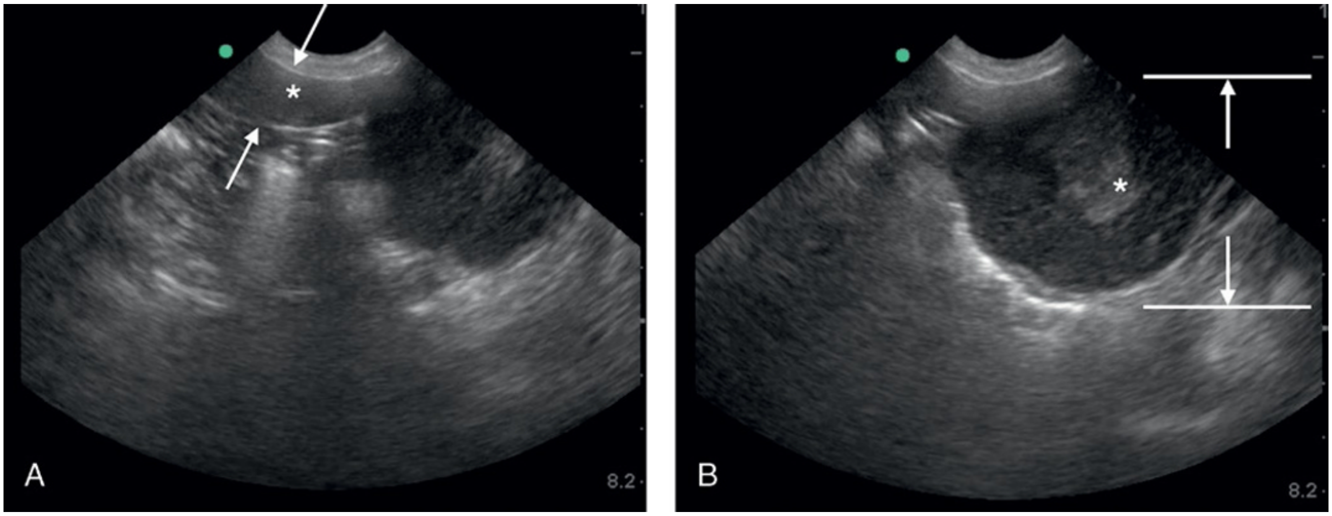

Figure 5.14. Splenic mass and estimating size from the centimeter scale. These images were captured during a POCUS spleen following AFAST. In (A) is the spleen (*) and arrows showing its borders. The spleen is sonographically recognized by its hyperechoic (bright white) capsule, and its splenic vessels splitting the capsule (not shown). In (B) the mass detected is eyeballed at approximately 4 × 4 cm using the centimeter scale. The mass appears large when in fact it is quite small. The finding is important and concerning because the mass *deforms* the capsule of the spleen. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

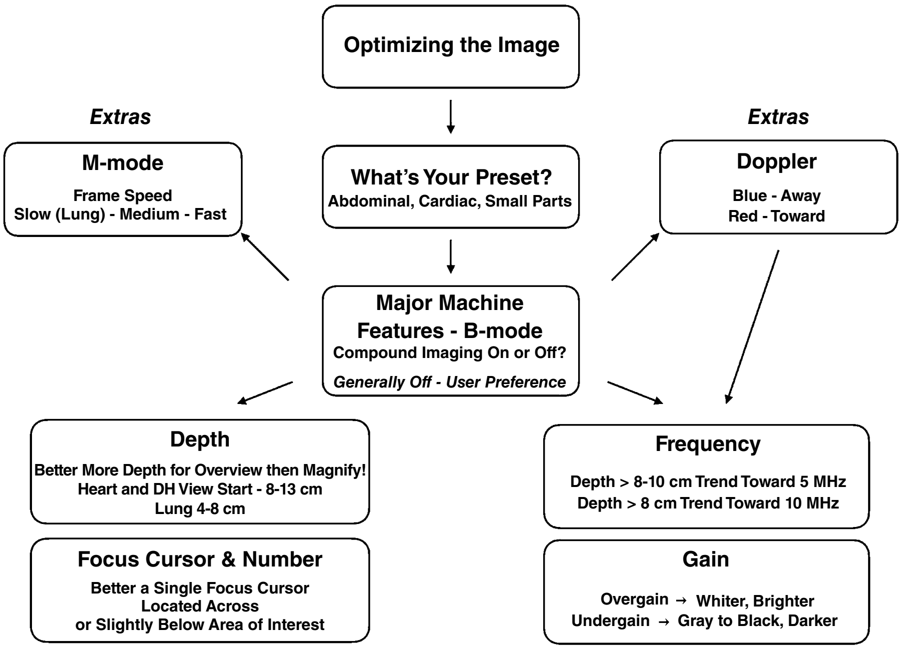

Figure 5.15. An algorithm for trouble shooting image acquisition with some clinical pearls and descriptors. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

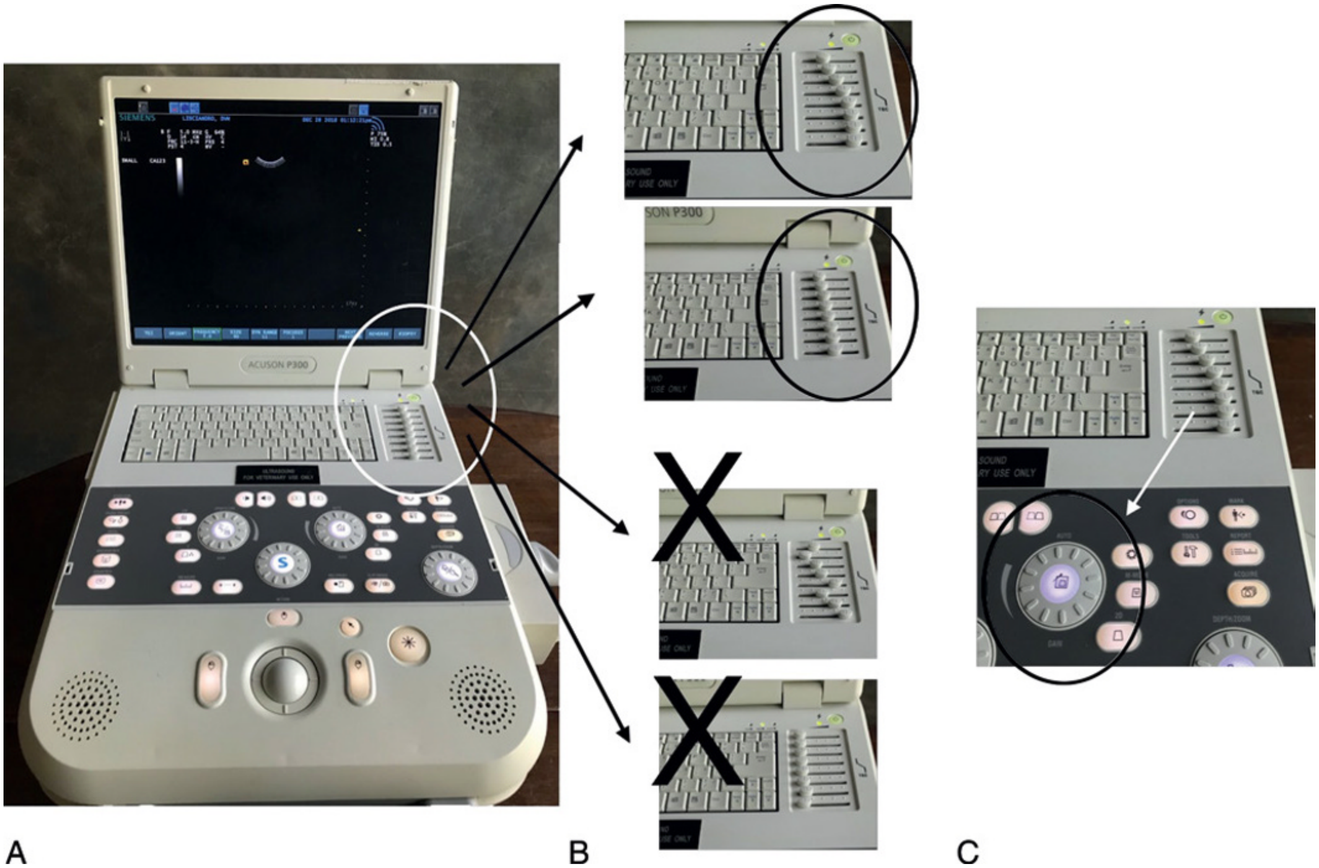

Figure 5.16. Time gain compensation (sliders) and the overall gain (wheel). Shown in (A) is an ultrasound machine with its keyboard and screen. The time gain compensation (TGC) is in the upper right on this keyboard. These TGC sliders can be intimidating but gain adjusts your gray scale when in B-mode. The sliders represent the different levels from the near-field to the far-field. In general, they should look like the circled upper two images in (B) and not like the lower two images (marked with an "X"). In (C) is the overall gain (circled wheel with arrow pointing to it) that may be turned clockwise and counterclockwise that alters the overall picture. If your sliders are adjusted as in (B) then you should mostly only be using the overall gain thereafter. If the image still doesn't look good then go through the trouble-shooting algorithm (see Figure 5.15). Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

including the patience of your patient and its tolerance of your physical and chemical restraint.

- *Check the location and numbers of your focus cursor(s)*. Generally, a single focus cursor is best that is centered on the screen or directly across your area of interest.
- *Check your probe–skin contact (coupling)*. Is the probe head directly on skin? Do you have ample acoustic coupling medium?
- *Check your probe hand placement and beam direction*. Make sure that you are in the right region, using external landmarks as well as considering the direction and path of your ultrasound beam (see Figures 5.10 and 5.11).
- *Default back to original settings*. If you still cannot figure out why the image looks so wrong, push the B-mode button first and then go to presets and change to a different preset or return to the original preset, as many machines will default back to the original settings. The reality is sometimes you have no idea what you did to make everything look so bad.

See Chapter 4 for additional explanation and examples.

Not Knowing How to Freeze and Roll the Cine Ball

You will need to know how to freeze the image on the screen. This is especially helpful when you have short-duration images of the region of interest.

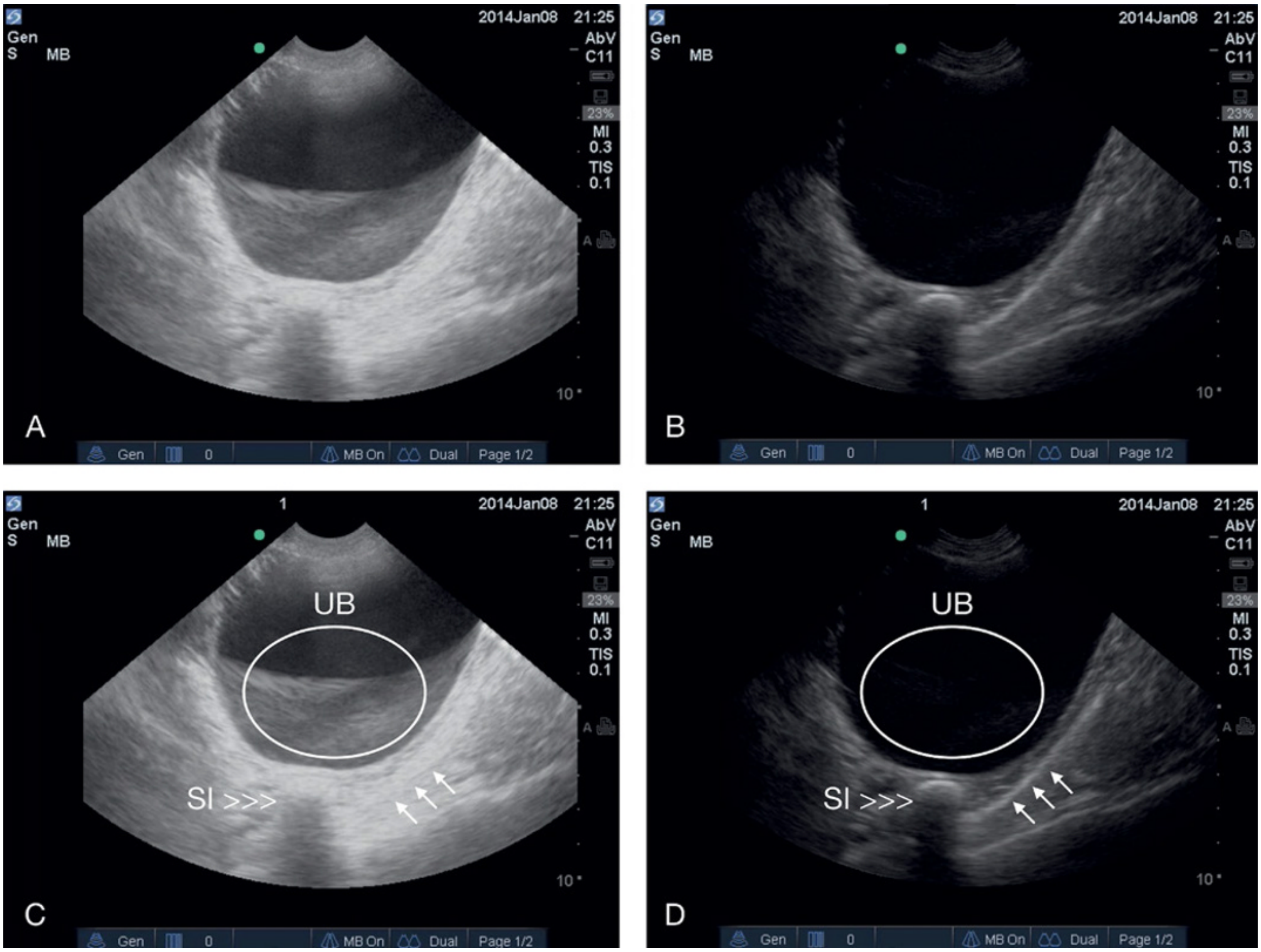

Figure 5.17. Slice-thickness artifact at the AFAST CC view. (A) and (B) are the same images within the same cine loop that have been extracted to show how much gain settings affect the image. In (A) is a slice-thickness artifact that is circled in (C). In (B) the gain is turned down, eliminating the artifact (true sediment would persist in gravity-dependent regions). Color flow Doppler is another technique used to look for flow (mass versus thrombus versus sediment versus artifact). (C) and (D) are labeled images of (A) and (B) respectively. Note how the loop of small intestine outside the lumen of the urinary bladder could mimic a bladder stone (cystic calculi) with a hyperechoic line (reflective air) and clean shadowing through the far-field. Note also that the screen provides a lot of information including a depth of 10 cm, an abdominal preset (Abv) in the upper right. Note, there is uniquely *no* focus cursor on machines from this manufacturer (SonoSite). Arrows indicate the body wall in the CC pouch. SI, small intestine; UB, urinary bladder. Source: Courtesy of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

Examples include air (lung) interference of cardiac views in a panting patient, the tachycardic patient with normal higher heart rates (cats) in which the eyeball method is error prone; or you caught a quick glimpse of a structure you want to measure. Freezing the image on the screen and then rolling the cine ball through preceding frames allows you to evaluate better than in real time.

Image Interpretation

Lacking Awareness of Most Common Locations for Artifacts

In Chapter 3, Table 3.1 lists the common ultrasound artifacts and the most common locations and examples for each. Briefly, we will list here some strategies to create better awareness of these artifacts, especially during the Global FAST approach. This leads to another major point…

Saving images is important not only for archiving patient information but for learning by reviewing studies and being able to compare to other modalities, future studies, and clinical course and outcome. For learning artifacts and how your machine interprets them, you can go through studies playing the "artifact game." For example, look at the AFAST views for mirror image artifact at the DH view on the pleural cavity side of the diaphragm, the CC view and the other side of the abdominal wall, and TFAST echo views for mirror image artifact on the far side of the pericardium. This can also be done with other artifacts in their most common locations, such as edge shadowing off the curved surface of the stomach wall, renal cortex, urinary bladder, etc.

Mirror Image

This most commonly occurs at the diaphragm but the most problematic is the mirroring of the gallbladder into the thorax, especially when it's a partial mirror image. In this case, the gallbladder can mimic pleural and pericardial effusion to the hasty sonographer.

Other places for mirror image, where generally a strong air–soft tissue interface exists, are on the far side of the heart when aerated lung is in direct opposition to the pericardium, and the urinary bladder against the colon or thin body wall. See Chapter 3 for more explanation and examples.

Side-lobe, Slice-thickness

This artifact occurs where there is a curve within a fluid-filled structure and is especially associated with the urinary bladder and gallbladder mimicking sediment and a mass. To differentiate artifact from sediment, consider where the gravity-dependent region is within the lumen of these structures. If "sediment" appears in nongravity-dependent regions, you should consider the possibility of artifact. Other techniques to differentiate artifact from true pathology include eliminating the artifact by turning down the gain and ballottement or changing the patient's position. Finally, some hasty sonographers will misinterpret an artifact for a mass. Simply place color flow Doppler on the suspect region for differentiation because a mass generally has pulsatile blood flow and an artifact (and thrombus) does not. See Chapter 3 for more explanation and examples.

Edge Shadowing

The edge shadowing artifact is created when the ultrasound beam strikes a curved surface, creating a dark shadow that extends from that curved surface through the far-field. Edge shadowing most commonly occurs at the curved surfaces of stomach wall, renal cortex, gallbladder and urinary bladder and can be mistaken for free fluid along the stomach wall and renal cortex or defects in the wall of the gallbladder and urinary bladder, the latter especially when ascites is present on the AFAST CC view. See Chapter 3 for more explanation and examples.

Pearls, Pitfalls, and The Final Say

The paradigm change of POCUS and FAST rests on expediting the learning process and we hope that this chapter will help accelerate your learning process by highlighting factors in a different way from other chapters in this textbook. The material in the chapter is based on training more than 1000 veterinarians in these techniques over the past 15 years as well as leading in clinical studies.

- Take the time to go through the major knobs on the machine - depth, gain (TGC and overall), focus cursor, frequency, and preset. Know where these buttons are located and play with images to get used to how to efficiently adjust their settings. Using stickers on your machine is another way to train yourself on where these buttons are located.
- Use our algorithm for trouble shooting. By doing so, you will have a way to efficiently review the most common image optimization features of your machine. *Depth, frequency, preset, focus cursor, gain (TGC and overall), probe–skin contact, direction of the beam, then default back to original settings*.
- Save images and then go through the views and play the artifact game; look through AFAST studies and see how many mirror image artifacts you see and then choose another artifact and do the same.

References

Boysen SR, Rozanski EA, Tidwell AS, et al. 2004. Evaluation of a focused assessment with sonography for trauma protocol to detect free abdominal fluid in dogs involved in motor vehicle accidents. *J Am Vet Med Assoc* 225(8):1198–1204.

Walker C, Mohabir PK. 2014. Orientation. In: *Point-of Care Ultrasound*, edited by Soni N, Arntfield R, Koy P. Philadelphia: Elsevier Saunders, pp 25–31.

Further Reading

Blanco P, Volpicelli G. 2016. Common pitfalls in point-of-care ultrasound: a practical guide for emergency and critical care physicians. *Crit Ultrasound J* 8(1):15.

Boivin M. 2014. Basic operation of an ultrasound machine. In: *Point-of Care Ultrasound*, edited by Soni N, Arntfield R, Koy P. Philadelphia: Elsevier Saunders, pp 32–37.

Brietkrutz R, Uddin S, Steiger H, et al. 2009. Focused echocardiography entry level: new concept of a 1-day training course. *Minerva Anesth* 75(2):285–292.

Chiem AT. 2014. Transducers. In: *Point-of Care Ultrasound*, edited by Soni N, Arntfield R, Koy P. Philadelphia: Elsevier Saunders, pp 19–24.

Goodgame B, Debesa O, Lee A, et al. 2014. Imaging artifacts. In: *Point-of Care Ultrasound*, edited by Soni N, Arntfield R, Koy P. Philadelphia: Elsevier Saunders, pp 38–48.

Hempel D, Stenger T, Campo Dell Orto M, et al. 2014. Analysis of trainees' memory after classroom presentations of didactical ultrasound courses. *Crit Ultrasound J* 6(1):10.

Hock GH, Widmer WR. 2010. Apearance of common ultrasound artifacts in conventional vs. spatial compound imaging. *Vet Radiol Ultrasound* 51(6):621–627.

Mattoon JS, Nyland TG. 2015. Fundamentals of diagnostic ultrasound. In: *Small Animal Diagnostic Ultrasound*, 3rd edition, edited by Mattoon JS and Nyland TG. St Louis: Elsevier, pp 1–49.

Mayette M, Mohabir PK. 2014. Ultrasound physics. In: *Point-of Care Ultrasound*, edited by Soni N, Arntfield R, Koy P. Philadelphia: Elsevier Saunders, pp 9–18.

SECTION II

Abdomen

CHAPTER SIX

POCUS: AFAST – Introduction and Image Acquisition

Gregory R. Lisciandro

Introduction

In 2004, a focused assessment with sonography for trauma (FAST) exam was prospectively validated in traumatized dogs, translating the four acoustic windows described in human medicine (Boysen et al. 2004) (Figure 6.1). Interestingly, intraabdominal injury, more specifically hemoabdomen, was far more prevalent than previously reported with a prevalence of 38–45% versus a pre-FAST rate of 12–23% (Boysen et al. 2004).

In 2005, the original FAST examination was modified in the following ways, including renaming the study AFAST (Lisciandro et al. 2009) (Table 6.1).

- The probe was directed into the gravity-dependent regions of each acoustic window.
- The views were renamed by their target organs rather than external anatomy.
- The probe was maneuvered differently, making the major orientation longitudinal with fanning and rocking of the probe at each AFAST acoustic window *without* rotating.
- The patient was not shaved but rather the hair was parted to maximize probe–skin contact.
- A simple AFAST-applied fluid scoring system (0–4) was developed for semiquantitating volume of the effusion, with more recent modifications.
- Serial AFAST examinations were performed as standard of care for all admitted patients four hours post admission and sooner if questionable or unstable patient status.
- AFAST investigated many important clinical questions rather than a single binary question of fluid positive or negative.

The AFAST study documented that its simple abdominal fluid scoring system (0–4) reliably predicted the degree of anticipated anemia in dogs with hemoabdomen. The abdominal fluid score (AFS) differentiated lower scoring small-volume bleeders (AFS 1 and 2) from higher scoring large-volume bleeders (AFS 3 and 4). Moreover, the study answered what was implied in the original FAST study, that the historical use of radiographic abdominal serosal detail was an *unreliable test* for the presence or absence of free peritoneal fluid and its volume (Boysen et al. 2004; Lisciandro et al. 2009). In fact, 24% of dogs with normal abdominal radiographic serosal detail were AFAST positive, and 32% with decreased abdominal radiographic serosal detail were in fact AFAST negative (Lisciandro et al. 2009). Thus, in summary, not only was abdominal radiographic serosal detail *unreliable* for the presence and absence of free fluid, but abdominal serosal detail also *could not* reliably estimate the volume of free fluid present (see Figure 7.9).

The repeating of at least one more AFAST and assigning an AFS allowed the attending clinician to not only screen for the presence of free fluid that may have been missed or absent on the first AFAST examinations, but also to reassign an AFS and evaluate the urinary bladder (Lisciandro et al. 2009; Lisciandro 2011, 2012; Boysen and Lisciandro 2013). AFAST and the use of the patient's AFS were shown to be invaluable

Point-of-Care Ultrasound Techniques for the Small Animal Practitioner, Second Edition. Edited by Gregory R. Lisciandro.

Companion website: www.wiley.com/go/lisciandro/ultrasound2

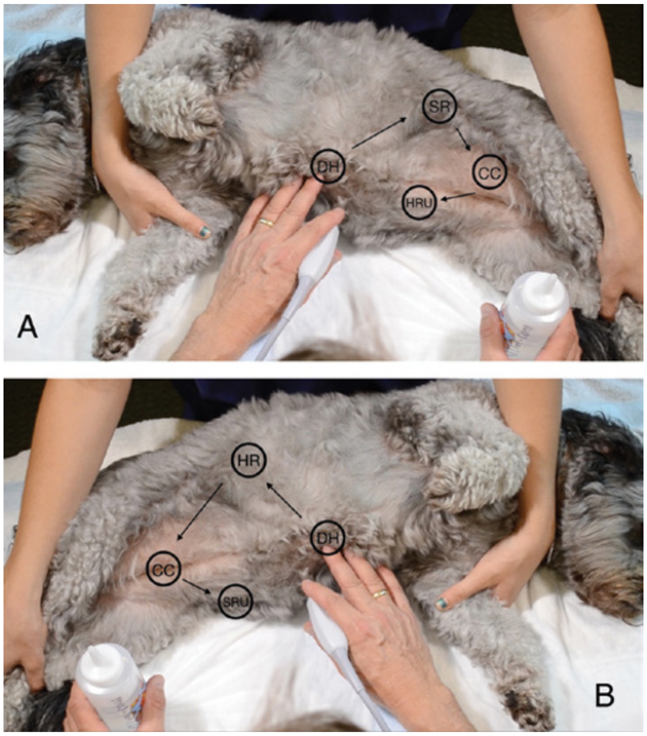

Figure 6.1. AFAST on a dog in right and left lateral recumbency. In (A) AFAST is shown on a dog in right lateral recumbency and in (B) left lateral recumbency. Sites are named by their target organs. The AFAST order is always the same. In right lateral, (1) DH view, (2) SR view, (3) CC view, (4) HRU view. In left lateral recumbency, (1) DH view, (2) HR view, (3) CC view, (4) SRU view. These AFAST views are part of the abdominal fluid scoring (AFS) system and the order ends at the most gravity-dependent view where abdominocentesis is likely to be performed in higher-scoring patients. Note that the 5th AFAST bonus view is not shown in these images. The AFAST views are nearly identical sonographically no matter the positioning (lateral recumbency versus standing-sternal). AFAST target organs are imaged in the same standardized manner regarding probe maneuvering with the "fan, rock (cranially) and return to your starting point" approach. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

for the detection of developing hemoabdomen (initially negative [AFS 0] turned AFAST positive [AFS 1-4]), the detection of ongoing hemorrhage (increasing fluid score), and evidence-based resolution of hemoabdomen (decreasing fluid score) (see Figure 7.9). Interestingly, the American College of Emergency Physicians has advocated the use of a serial four-hour postadmission FAST examination for all at-risk human patients since 2001 yet at the time of writing this chapter, the number one cause of death in hospitalized

Table 6.1.
Changes in methodology from FAST to AFAST.

Parameters	FAST (Boysen 2004)	AFAST (Lisciandro et al. 2009)
Shaving patient	Shaving	No shaving
Primary probe orientation	Longitudinal and transverse	Only longitudinal
Primary probe maneuver	Sliding, rotating and sweeping	Fanning and rocking
Main probe direction	Toward spine	Gravity-dependent pouches
Lateral[a]	Left	Right
Fluid scoring	No	Yes
Naming acoustic views	External locations	Target organs
Timing of examination (median time presentation to ultrasound examination)	Post resuscitation (median 1 hour)	Presentation and serially post resuscitation (median <5 minutes)

[a]Lateral recumbency was a brilliant proposition, being markedly safer than dorsal recumbency (see Figure 6.5).
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human trauma patients surviving traumatic brain injury during their first 48 hours of care remains ongoing, unrecognized bleeding (Bilello et al. 2011; Sobrino and Shafi 2013).

More recently, a human study showed that in people with prehospital hypotension, the only intervention that prevented the "crump factor," the phenomenon of a patient decompensating unexpectedly, was the liberal use of FAST examinations (Bilello et al. 2011). The upshot is veterinarians have a better tool, the AFAST and its applied fluid scoring system, to determine within minutes of presentation or during hospitalized care when patients are becoming unstable, to not only "see" if the patient is positive or negative for free fluid, but also the degree of bleeding (or effusion) by easily calculating the patient's AFS (0–4 scale). AFAST and AFS are the missing link to traditional trauma, triage and tracking algorithms, and by adding the target organ approach, a huge amount of clinical information is easily gained within minutes, *when minutes count*.

The comparison of the original FAST to the subsequent AFAST study is fascinating and some important differences are noted (see Table 6.1) (Boysen et al. 2004; Lisciandro et al. 2009). Remarkably, degree of trauma was very similar, including numbers of pelvic fractures and pneumothoraces

(Table 6.2), suggesting that the overall degree of trauma between studies was comparable and thus inferences may be loosely drawn (Boysen et al. 2004; Lisciandro et al. 2009).

One involves the case management and decision making for blood transfusion(s), and that knowing if the dog at triage was AFS positive affected fluid therapy administration strategies. In other words, intravenous fluid resuscitation was likely titrated more closely to low normal endpoints, such as mean arterial pressure, thus mitigating exacerbation of hemorrhage by lessening the probability of "popping the clot" and diluting clotting factors through overresuscitation in bleeding dogs (Lisciandro et al. 2009). The differences in median time from trauma to FAST/AFAST, median time presentation to FAST/AFAST (240 versus <5 minutes), and numbers of transfusions FAST/AFAST (9 versus 3) support this conclusion. AFAST was performed as part of the physical exam versus FAST, which was a second line test after initial assessment, intravenous fluid resuscitation, and blind abdominocentesis possibly to the dog's detriment by the much higher positive rate (45% versus 27%).

The original FAST study lacked a fluid scoring system, and as simple as the AFAST system is, with a range of 0–4 (AFS 0 negative all AFAST views to a maximum of four being positive for fluid at all four AFAST views), AFS provides an effective tool for decision making (see Table 7.3). This decision making, ranging from intravenous fluid resuscitation strategies to administration of blood transfusion products to the need for exploratory surgery, importantly carries the potential to improve outcome and decrease complications, as shown in people (see Chapter 7) (Blackbourne et al. 2004; Ollerton et al. 2006; Bilello et al. 2011).

Of note, dogs with pneumothorax (55%), pelvic fractures (40%), and high alanine transaminase (ALT) (>400 U/L) were also more likely to concurrently have or develop hemoabdomen detected by either their initial or serial AFAST examinations than dogs without these findings (Lisciandro et al. 2009; Lisciandro 2014c). The serial use of AFAST is helpful in determining the integrity of the urinary bladder, estimating urinary bladder volume and urine output during resuscitation (Lisciandro et al. 2009; Lisciandro 2011; Lisciandro and Fosgate 2017). Both FAST and AFAST studies documented that when the urinary bladder was imaged with an expected, smooth, rounded contour, it was unlikely to be ruptured, holding advantages over traditional means of palpation, characterization of urine post micturition, and plain radiography (Boysen et al. 2004; Lisciandro et al. 2009; Boysen and Lisciandro 2013).

More recently, a urinary bladder estimation formula for use during AFAST has been published and provides a noninvasive way to estimate urine output when serial calculations are made over time (Lisciandro and Fosgate 2017). AFAST additionally remains useful to survey for intrathoracic trauma, pleural and pericardial effusion, and lung conditions, through the acoustic

Table 6.2.
Comparison of FAST and AFAST in dogs.

Parameters	FAST (Boysen et al. 2004)	AFAST (Lisciandro et al. 2009)
Primary presentations	65%	96%
FAST positive cases	45%	27%
Low-scoring (AFS 1 and 2) small-volume bleeders	NA	13
High-scoring (AFS 3 and 4) large-volume bleeders	NA	14
Cases of abdominocentesis prior to AFAST/FAST examination	16	0
Median time trauma to AFAST/FAST examination	240 minutes	60 minutes
Median time presentation to AFAST/FAST examination	60 minutes	<5 minutes
	FAST was a secondary evaluation post initial resuscitation	AFAST was a first-line screening test
Median time for AFAST/FAST examination	6 minutes	3 minutes
	Shaved sites	No shaving
Pelvic fractures	20	22
Pneumothorax	21	22
Appendicular fractures	15	25
Diaphragmatic hernia	NA	2
Number of blood transfusions	9	3

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window of the liver and gallbladder by imaging cranial to the diaphragm in every patient, dependent on patient size, coupled with depth limitations of the ultrasound machine (Boysen et al. 2004; Lisciandro et al. 2009; Lisciandro 2011, 2016a; McMurray et al. 2016).

Lastly, AFAST was never meant to be a "flash exam," meaning that it was never meant to only answer a single binary question of whether free fluid was present or absent (Table 6.3). AFAST provides much more clinical information by:

Table 6.3.
What clinical questions are answered using AFAST? Binary? Qualitative-quantitive?.

	Binary	Qualitative-quantitive	[a]Sensitivity (Se) [a]Specificity (Sp)
• Does the patient have free fluid in the abdominal cavity?	√ Yes or no	√ Use AFAST-applied fluid scoring system (1–4)	Se – High Sp – High
• Does the patient have free fluid in the retroperitoneal space?	√ Yes or no	√ Trivial, mild, moderate, severe	Se – High to variable Sp – High
• Does the patient have any obvious AFAST target organ abnormalities?	√ Yes or no	√	Se – Variable, operator dependent Sp – High
• Does the patient have pleural effusion?	√ Yes or no	√ Trivial, mild, moderate, severe via its DH view	Se – High Sp – High
• Does the patient have pericardial effusion?	√ Yes or no	√ Trivial (<0.5 cm), nild (>0.5 and <1.0 cm), moderate (>1.0 and <2 cm), severe (>2 cm) via its DH view (Candotti and Arntfield 2015)	Se – High Sp – High
• Does the patient have lung pathology along the pulmonary–diaphragmatic interface?	√ Yes or no	√ Vet BLUE B-line scoring Vet BLUE 6 lung ultrasound signs (Lisciandro 2014b,c; Lisciandro and Fosgate 2017)	Se – Unknown, operator dependent Sp – Likely high
• What is the patient's volume status?	√ Unremarkable or abnormal	√ Characterizing the dynamic changes in height of caudal vena cava (bounce, fluid responsive; FAT, fluid intolerant; or flat, hypovolemic) (see Figures 36.7, 36.10–36.12); coupled with hepatic venous characterization (presence or absence of the "tree trunk sign" – see Figure 36.8); and absolute maximum CVC height measurements (see Table 36.3)	[a]Hypervolemia Se – Likely high Sp – Likely high [a]Hypovolemia Se – Likely variable Sp – Likely high [a]Euvolemia Se – Variable Sp - Variable [a]Integrating TFAST echo and Vet BLUE pulmonary information likely improves both Se and Sp
• What is the patient's urine production?		√ Length (cm) × width (cm) × height (cm) × 0.625 = volume estimation (mL)	Unknown

[a]Clinical experience, limited veterinary studies, human studies.
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- having a fluid scoring system
- looking cranial to the diaphragm into the thorax at the DH view for pleural and pericardial effusion and lung conditions
- examining the gallbladder wall for signs of intramural edema
- characterizing the caudal vena cava and its associated hepatic venous system
- observing the urinary bladder for its expected rounded contour and measuring it (when applicable) for bladder volume estimation and urine output
- calculating the AFS to better make sense of the volume of blood in hemorrhaging small animals
- serving as monitoring tool for any and all effusive conditions
- taking advantage of its target organ approach.

In other words, an AFAST not only provides a highly sensitive and specific means to detect intraabdominal and retroperitoneal effusions, but also serves as an abdominal soft tissue screening test for obvious target organ pathology. Patient information is acquired rapidly during AFAST (<3–4 minutes) with low patient impact (minimal restraint, no shaving) and point of care (Lisciandro et al. 2009; Lisciandro 2012, 2016a; Boysen and Lisciandro 2013; McMurray et al. 2016).

Abbreviations and terminology are listed in Table 6.4.

POCUS abdominal, thoracic, ocular, neurological, and musculoskeletal examinations are more extensively described in their respective chapters; however, the POCUS approach should always include minimally an AFAST, with its target organ approach, and AFS, and, much better, the Global FAST approach, as an extension of your physical exam for best practice. Global FAST has been advocated by the author as an extension of the physical examination for virtually any small animal patient since 2005 (Lisciandro 2011, 2012, 2014a–c, 2016a,b; Lisciandro et al. 2019), with a similar approach more recently advocated in human medicine (Lichtenstein 2010; Narasimhan et al. 2016).

What AFAST Can Do

- Can detect free fluid in small amounts superior to physical examination and abdominal radiography and comparable to the gold standard of computed tomography (CT).
- Can detect clinically significant pleural and pericardial effusions in most cases by imaging past or cranial to the diaphragm at the AFAST DH view.
- Can detect retroperitoneal effusion when imaging at the AFAST spleno-renal (SR) and hepato-renal (HR) views and the HR5th and SR5th bonus views.
- Can anticipate degree of anemia in different patient subsets by using its easily applied abdominal fluid scoring system.
- Can be used to screen for canine anaphylaxis through the detection of sonographic striation of the gallbladder wall as the “double rim effect” or “halo effect” or “halo sign” at the AFAST DH view, referred to as the “anaphylactic gallbladder,” coupled with the finding of a flat caudal vena cava (CVC) (see Figure 36.9).
- Can be used to screen for right-sided congestive heart failure through the detection of sonographic striation of the gallbladder wall as the “double rim effect” or “halo effect” or “halo sign” at the AFAST DH view, referred to as the “cardiac gallbladder,” coupled with the finding of a FAT CVC (see Figure 36.7).
- Can be used to assess volume status and right-sided cardiac function by evaluating CVC size and for the presence of hepatic venous distension, the “tree trunk sign,” at the AFAST DH view (see Figure 36.8).
- Can screen for concurrent target organ injury or pathology for basic soft tissue conditions of the liver, gallbladder, kidneys, urinary bladder, spleen, and gastrointestinal tract.
- Can assess urinary bladder integrity at the AFAST cysto-colic (CC) view especially when there are concerns regarding rupture in trauma cases.
- Can noninvasively estimate urinary bladder volume and thus urine output at the AFAST CC view using the formula of length (L) × width (W) × height (H) (cm) × 0.625 = estimation of urinary bladder volume (mL) (Lisciandro and Fosgate 2017).

What AFAST Cannot Do

- Cannot sonographically characterize fluid, thus sample acquisition via abdominocentesis is required when fluid is safely accessible; and fluid analysis should be performed.
- In penetrating trauma, AFAST lacks sensitivity (in contrast to blunt trauma where it has high sensitivity) but likely is highly specific for intraabdominal and retroperitoneal injury similar to human studies (Udobi et al. 2001).
- In penetrating trauma, AFAST should *always be repeated* post resuscitation as long as necessary until assured that the patient is not a surgical candidate

Table 6.4.
Abbreviations and terminology. As lengthy as the list seems, the abbreviations and terminology allow for more rapid communication verbally and in medical records.

Terminology for standardized ultrasound exams	
Abdominal FAST	AFAST
Thoracic FAST	TFAST
Veterinary Bedside Lung Ultrasound Exam	Vet BLUE
Global FAST	AFAST, TFAST and Vet BLUE combined as a single ultrasound examination
Complete Detailed Abdominal Ultrasound	
Complete Detailed Echocardiography	
Serial Examination	Repeating the standardized protocol and recording your findings. Serial examinations have also been referred to as "secondary examinations." We prefer the term "serial" (Blackbourne et al. 2004; Lisciandro et al. 2009)
Ultrasound signs and characterizations used during AFAST	
AFAST views: DH view = diaphragmatico-hepatic view SR view = spleno-renal view HR view = hepato-renal view CC view = cysto-colic view HRU view = hepato-renal umbilical view SRU view = spleno-renal umbilical view HR5th bonus view = the final view of small animals when in right lateral recumbency imaging the right kidney and adjacent right liver (not part of the abdominal fluid scoring system) SR5th bonus view = the final view of small animals when in left lateral recumbency imaging the left kidney and adjacent spleen (not part of the abdominal fluid scoring system)	
CC pouch = most gravity-dependent region where free fluid would accumulate at the CC view HRU (SRU) pouch = most gravity-dependent region where free fluid would accumulate at the HRU (SRU) view Pouch = most gravity-dependent region at that acoustic window	
Gallbladder "halo sign," also called "halo effect," "double rim effect"	Occurs with the presence of intramural gallbladder edema, recognized as sonographic striation, and supports the diagnosis of canine anaphylaxis (along with acute collapse and gastrointestinal signs and a flat CVC) versus right-sided heart failure/generalized systolic dysfunction, pericardial effusion (along with a FAT CVC) versus right-sided volume overload (FAT CVC) in collapsed, weak, hypotensive dogs (see Figures 36.7 and 36.9). There are other causes for gallbladder wall edema (see Table 7.5 and Chapter 8), however, canine anaphylaxis and heart conditions present more emergently with acute weakness or collapse in a previously healthy dog (Lisciandro 2014a)

Table 6.4.
(*Continued*)

Caudal vena cava (CVC) characterization by assessing maximum heights in the longitudinal orientation at the FAST DH view	1. Bounce: expected ~35–50% dynamic respirophasic changes in CVC height during the respiratory cycle; also called a “fluid-responsive CVC”; an expected maximum height in longitudinal at the DH view is available for dogs of various weights and cats (see Tables 7.6 and 36.3 and Figures 36.9–36.12). 2. Flat: lacks respirophasic dynamic change (<10%) in CVC maximum height and having an abnormally *small* maximum height; also called “hypovolemic CVC” or “fluid starved CVC”; maximum heights of <0.25 cm, <0.35 cm, <0.50 cm for dogs weighing <9 kg, >9 kg, <15 kg and >15 kg, respectively (modified by Lisciandro from Darnis et al. 2018). 3. FAT: lacks respirophasic dynamic change (<10%) in CVC diameter during inspiration and expiration having an abnormally large maximum height (Ferrada et al. 2012a,b); also called a “fluid-intolerant CVC”; maximum heights of >1.0 cm and >1.5 cm for dogs weighing <9 kg and >9 kg, respectively (modified by Lisciandro from Darnis et al. 2018).
Cardiac bump	Observation at the FAST DH view where the muscular apex of the heart is beating and often indenting along the diaphragm; helps rule in and rule out pericardial effusion through presence or absence of the “racetrack sign” (Lisciandro 2014a,b, 2016a) (see Figures 7.13, 7.14 and 39.5)
Racetrack sign	Sign indicative of pericardial effusion at the FAST DH view through the observation of free fluid rounding the apex of the heart being contained within the pericardial sac (Lisciandro 2014a,b, 2016a) (see Figure 7.13)
Tree trunk sign	Observation of distended hepatic veins as they drain into a distended (FAT) caudal vena cava (abnormal finding); represents conditions impeding blood flow from the liver to the right heart, most commonly right-sided failure, pericardial effusion, and dilated cardiomyopathy (DCM), and right-sided volume overload during fluid resuscitation (Lisciandro 2014a,b; Nelson et al. 2010) (see Figure 36.8)
Urinary bladder volume estimation formula (mL)	Length (cm) × width (cm) × height (cm) × 0.625 (Lisciandro and Fosgate 2017)

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by repeating at 2–4 hours post admission as standard of care and then continued at eight hours, 12 hours, 24 hours, two days, three days, five days, etc. post trauma at any time the patient is not doing well, for example to detect a septic abdomen or pyothorax that would otherwise be missed.

- AFAST misses peritonitis in some dehydrated and hypotensive patients, so should *always be repeated* post resuscitation and rehydration, with continued serial (repeat) exams as long as necessary until assured that the patient is not a surgical candidate.
- The AFAST AFS system is effective in cats, but cats as a species lack a large splenic blood reservoir and thus felines generally do not survive large-volume bleeds, and larger volume intraabdominal effusions are more likely to be due to uroabdomen.
- Understand that serial (repeat) exams using the Global FAST approach is an even better strategy because the thorax, heart, and lung are also surveyed.
- Cannot replace a complete detailed abdominal ultrasound.
- Cannot replace proper training.

Indications

- All blunt and penetrating trauma cases as standard of care for screening for indirect evidence of intraabdominal and retroperitoneal injury.
- All collapsed both recovered and unrecovered cases with unexplained hypotension, tachycardia, or mentation changes.
- All anemic cases.
- All "ain't doing right" (ADR) cases.
- All postinterventional cases including intravenous fluid therapy, postsurgical cases, postpercutaneous procedures, etc. that are at risk for bleeding, infections, vascular complications.
- All peritonitis suspects, including acute abdomen, for expedient diagnosis through the detection of free fluid (and subsequent sampling, fluid analysis testing as deemed appropriate) and free air.
- Preanesthetic screening test.
- Extension of the physical exam for patients presenting once or twice a year for routine care.

Objectives

- Be able to perform the AFAST views and apply its fluid scoring system.
- Be able to recognize basic abnormalities of the AFAST target organs in each of its views.
- Know how to assign an AFS during AFAST.
- Be able to recognize sonographic striation of the gallbladder wall, referred to as the "halo effect" or "double rim effect" or "halo sign," that can be present in both dogs and cats from different causes.
- Be able to recognize retroperitoneal free fluid and distinguish it from intraabdominal fluid.
- Know common artifacts at each AFAST view.
- Know the major pitfalls at each AFAST view.
- Know how to do a focused (POCUS) spleen examination and its importance following the completion of AFAST and after assigning an AFS.
- Understand why best practice would be to add on the Global FAST approach for all AFAST and POCUS exams (abdomen, thorax, eye, brain, musculoskeletal, etc.) to make sure that forms of peritonitis and pleuritis, presence of bleeding, and cardiac and pulmonary conditions are not being missed.

How to Perform an AFAST Exam

Ultrasound Settings and Probe Preferences

- Standard abdominal settings, presets, with adequate depth to be able to visualize the target organs of each AFAST view.
- Curvilinear (microconvex) probe with a range of 5–10 MHz and a maximum depth of 12–15 cm is acceptable for most dogs and cats.

Optimizing Image Quality and Probe–Skin Contact

Hair is generally not shaved but rather parted for the best probe–skin contact with the use of isopropyl alcohol, and/or alcohol-based hand sanitizer, and/or acoustic coupling gel. The author prefers the use of minimal amounts of isopropyl alcohol to effectively part the hair followed by alcohol-based hand sanitizer. The strategy is much less noxious to your patient by minimizing the cold wetness of isopropyl alcohol and its fumes, especially when moved to an oxygen cage. Alcohol-based hand sanitizer has the added benefit of being easily wiped off and it also evaporates quickly. Isopropyl alcohol should not be used if electrical defibrillation is anticipated because it poses a burn/fire hazard. The clinician should be aware that isopropyl alcohol may cause probe head damage (see Figure 4.13).

> **Pearl:** By not shaving (or limiting shaving to small acoustic windows), the cosmetic appearance of the patient is preserved (happier clients), the exam time is lessened, and imaging quality is sufficient with most newer ultrasound machines (median AFAST time <3–3.5 minutes) (Lisciandro et al. 2009; Lisciandro 2011, 2012; Boysen and Lisciandro 2013).

> **Pearl:** Maximize image quality by parting the hair and getting the probe head and its acoustic coupling medium in direct contact with the patient's skin to minimize air trapping, which is your imaging enemy because ultrasound does not transmit through air. Placing the probe head on a wetted mat of hair full of trapped air will produce a poor image (see Figures 5.1 and 5.2).

> **Pearl:** Hold the probe in a way that is most comfortable while being able to fan toward and away from the table top while maintaining a longitudinal (sagittal) plane in patients placed in lateral recumbency. Holding the probe like a pencil for many who have learned to scan patients in dorsal recumbency usually becomes problematic at the DH view for the caudal vena cava. Holding the probe on top and keeping the thumb on the probe marker and a finger out to prevent drifting works best.

Patient Positioning

Lateral Recumbency

Right lateral (RL) recumbency is generally preferred over left lateral (LL) recumbency for AFAST because RL recumbency is standard positioning for electrocardiographic and echocardiographic evaluation (Figures 6.2 and 6.3; see also Figure 6.1). Moreover, the left kidney (a window into the retroperitoneal space) at the AFAST SR view and the gallbladder at the DH view (by directing the probe in the gravity-dependent region or toward the tabletop) are readily imaged. RL recumbency over LL is preferred positioning for abdominocentesis because anatomically the spleen lies more on the left side of dogs and cats. LL recumbency may be used in cases in which injury prohibits RL positioning, or the right retroperitoneal space warrants imaging. In a more recent study evaluating RL versus LL recumbency, abdominal FAST time was shorter in LL recumbency and both kidneys were more reliably imaged (McMurray et al. 2016). However, this is probably due to training

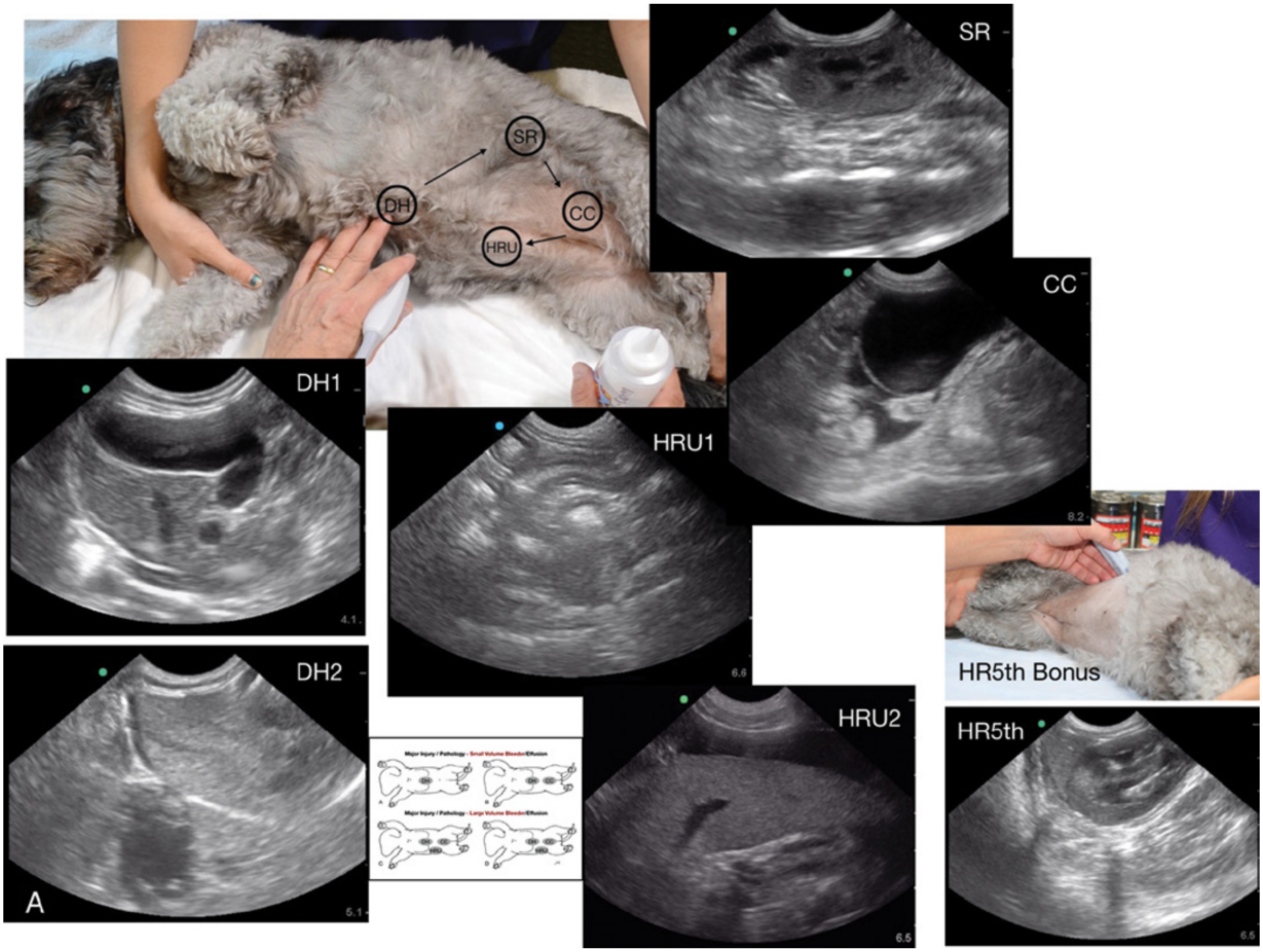

Figure 6.2. AFAST and its five views performed in right lateral recumbency in a dog. (A) AFAST unlabeled and (B) AFAST labeled. The order is always the same as follows: DH to SR to CC to HRU to HR5th bonus view. The final HR5th bonus view is *not* part of the abdominal fluid score. The AFAST images and their proportionality should look nearly the same regardless of positioning. DH, diaphragmatico-hepatic view; DH1, DH 1 of 2 views; DH2, DH 2 of 2 views; SR, spleno-renal view; CC, cysto-colic view; HRU, hepato-renal umbilical view; HR5th, hepato-renal 5th bonus view; HRU1, 1 of 2 views; HRU2, 2 of 2 views. DIA, diaphragm; FF, free fluid; GB, gallbladder; LIV, liver; LK, left kidney; RK, right kidney; SI, small intestine. AFAST views are nearly identical no matter the positioning because the respective target organs are imaged with the same methodology. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood. TX. Illustration by Hannah M. Cole, Adkins, TX.

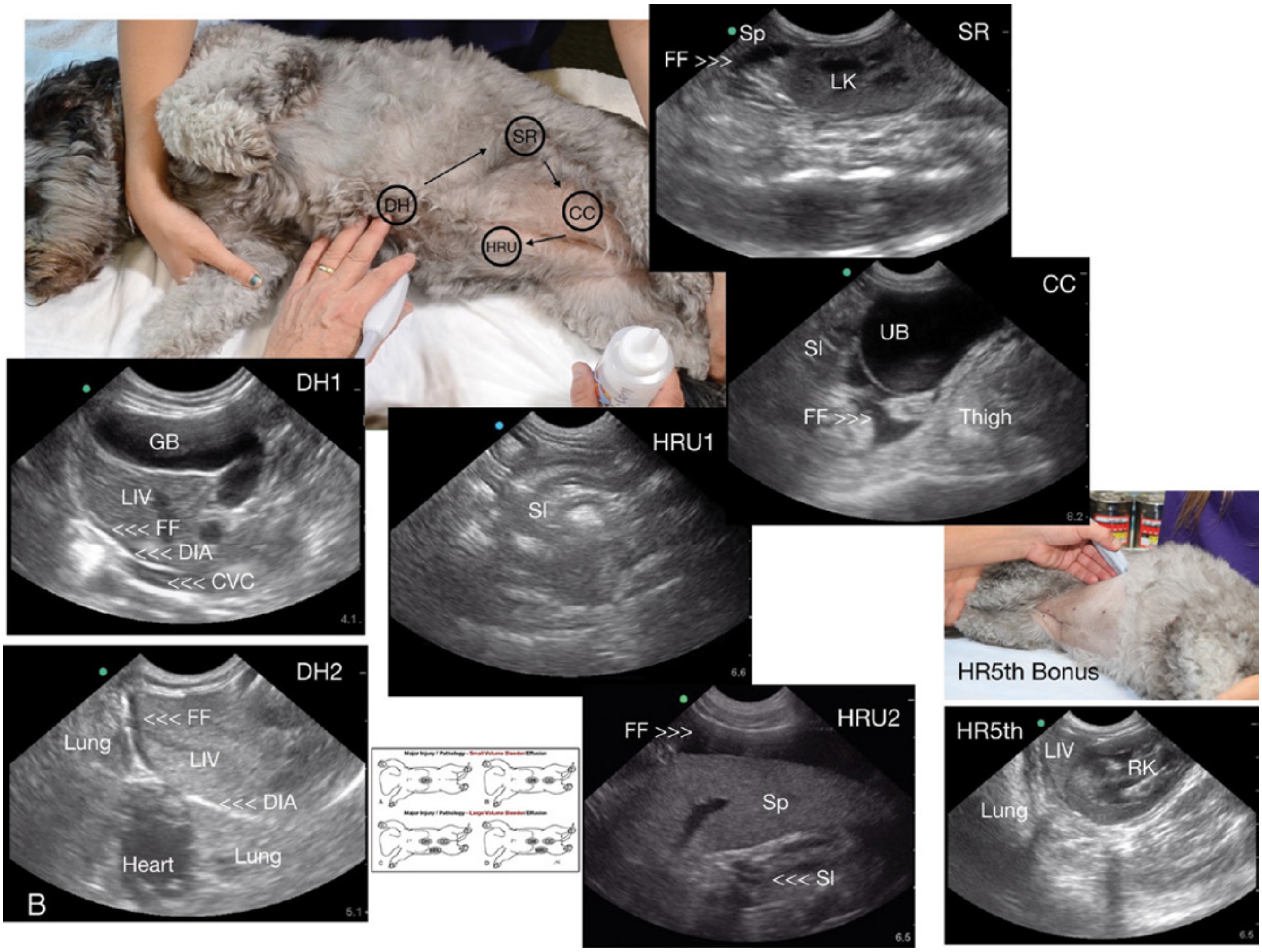

Figure 6.2. (*Continued*)

bias, as we could argue the same in RL recumbency (Lisciandro 2014a,b), and moreover, TFAST echo views are more easily acquired in RL recumbency. When combining AFAST and TFAST, RL recumbency is clearly advantageous. AFAST on a cat is shown in Chapter 39. See Chapters 17, 19, and 20 for echo views.

Modified Lateral-Sternal

Modified lateral-sternal recumbency positioning may be used for AFAST in stressed patients by allowing the forelegs to be in sternal and moving the hindlegs together laterally (placed same side as the sonographer) (Figure 6.4). In the modified lateral-sternal positioning the AFS may be estimated because the patient isn't purely in a lateral recumbent position.

Standing/Sternal

In respiratory-compromised patients AFAST is performed in standing or sternal knowing that the fluid scoring system is not validated in this positioning but still provides clinical information regarding the presence or absence of effusion. Whatever the AFAST options for positioning (lateral, modified lateral-sternal, standing/sternal), a negative AFS negates the need for moving the patient to lateral recumbency. Serial exams are always mandated as standard of care for a second opportunity to detect negative AFAST changing to positive, and for rescoring the patient (Lisciandro et al. 2009; Lisciandro 2011, 2014a; Boysen and Lisciandro 2013). See Chapters 36 and 37 for the most efficient ways to perform AFAST in standing-sternal positioning.

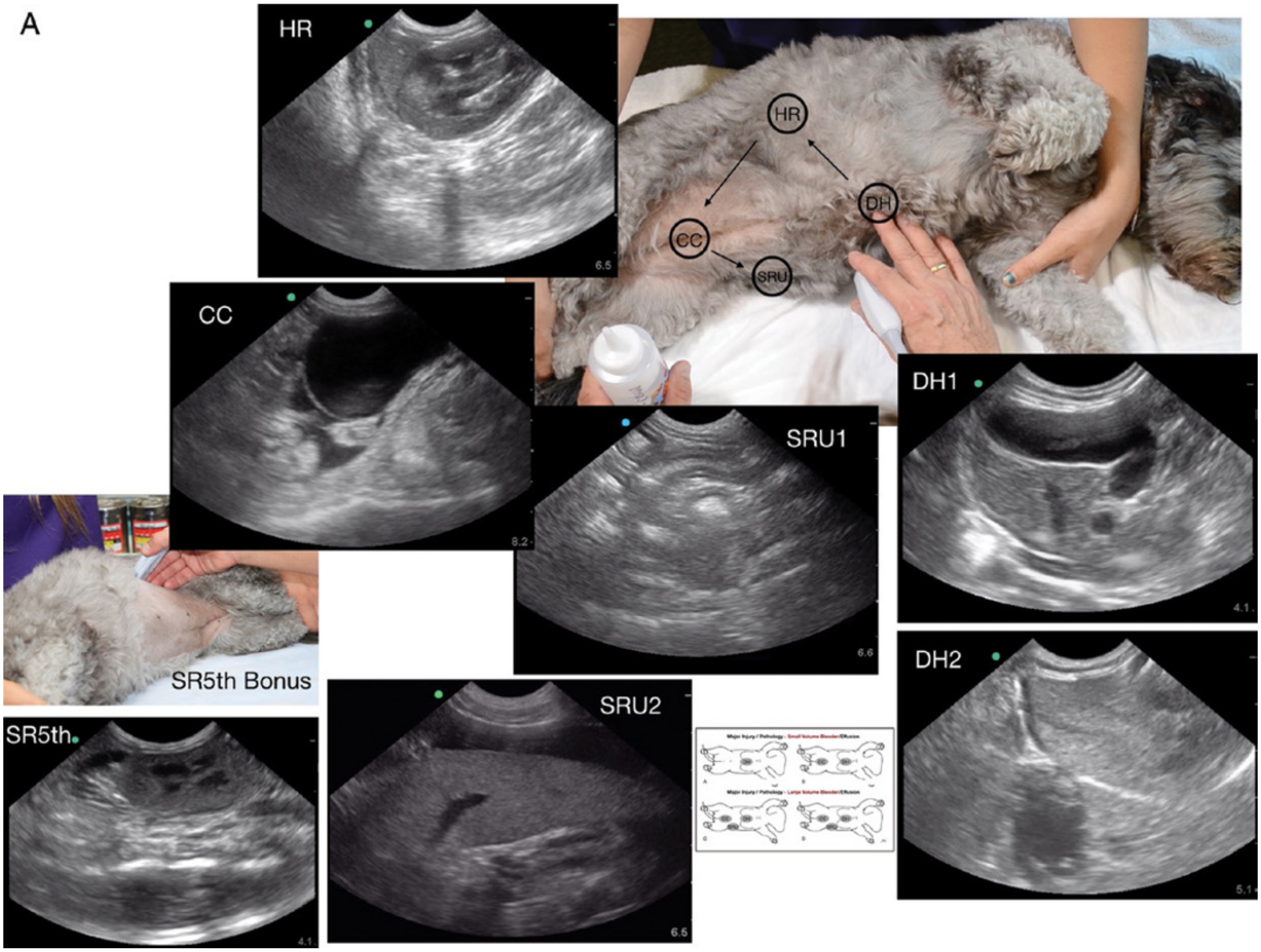

Figure 6.3. AFAST and its five views performed in left lateral recumbency in a dog. Shown is AFAST unlabeled in left lateral recumbency with the same images as Figure 6.2A and B. The order is analogous and always the same as follows: DH to HR to CC to SRU to SR5th bonus view. The final SR5th bonus view is *not* part of the abdominal fluid score. DH, diaphragmatico-hepatic view; DH1, DH 1 of 2 views; DH2, DH 2 of 2 views; SR, spleno-renal view; CC, cysto-colic view; HRU, hepato-renal umbilical view; HR5th, hepato-renal 5th bonus view; HRU1, 1 of 2 views; HRU2, 2 of 2 views. DIA, diaphragm; FF, free fluid; GB, gallbladder; LIV, liver; LK, left kidney; RK, right kidney; SI, small intestine. Note that the images should look identical for each AFAST view regardless of positioning (including standing/sternal, modified sternal). AFAST views are nearly identical no matter the positioning because the respective target organs are imaged with the same methodology. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX. Illustration by Hannah M. Cole, Adkins, TX.

Considerations When Performing AFAST in Standing or Sternal Positioning

If AFAST is negative in standing or sternal positioning, then moving the patient to lateral recumbency is unnecessary. However, if the AFAST examination is positive in standing or sternal, then move the patient to lateral recumbency (if unstable, delay until more stable) and wait for three minutes for fluid to settle before assigning an AFS (Lisciandro et al. 2009; Lisciandro 2011; Boysen and Lisciandro 2013).

When performing AFAST in standing or sternal, the sonographer must keep in mind the following points.

- As long as the AFAST is negative and the target organs are imaged at each respective view, the AFAST is complete.
- When free intraabdominal fluid is present, it will pool in different regions relative to the target organs because gravity-dependent locations differ from lateral recumbency, being at the probe head,

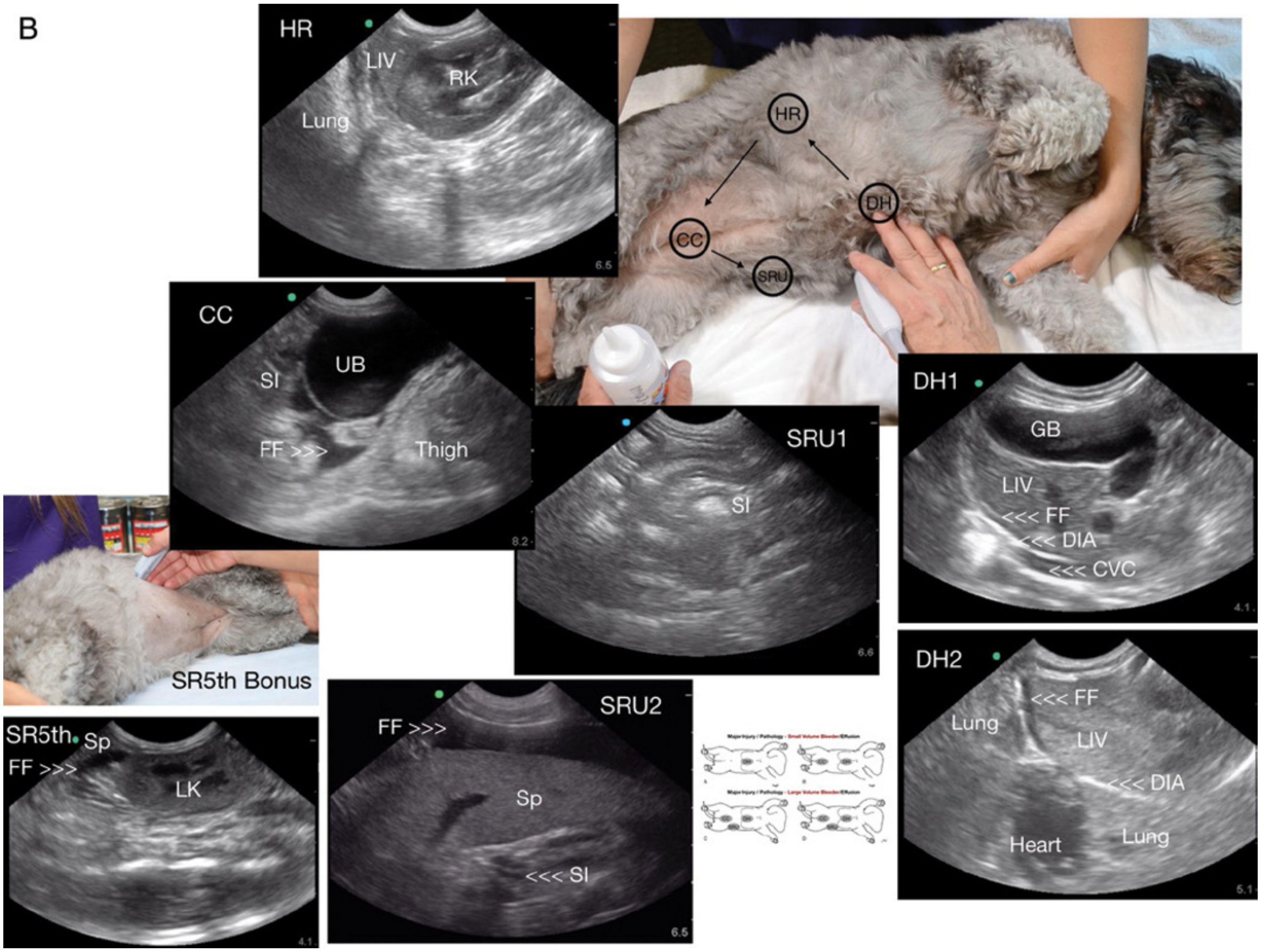

Figure 6.3. (*Continued*)

in the near-field, for the DH, CC, and SR/HR umbilical views.

- The gravity-dependent regions within the lumen of the gallbladder and urinary bladder also differ from lateral recumbency and the sonographer must consider the direction of the beam (its scanning plane) to best detect and interpret findings.
- The AFAST views, when performed properly, should look nearly the same *independent of positioning*.

Dorsal recumbency should never be used for AFAST (TFAST and Vet BLUE) for several reasons but most importantly because of increasing patient risk (Figure 6.5). A hemodynamically fragile patient placed in dorsal recumbency undergoes significant negative changes in ventilation and circulation, specifically venous return. Add to these respiratory and cardiovascular stresses and the increased oxygen demand in a struggling, anxious patient, and the patient risks acute and potentially catastrophic decompensation. Considering trauma, most dogs and cats have concurrent lung contusions and other thoracic-related injuries (Powell et al. 1999; Sigrist et al. 2011; Lisciandro et al. 2008) and intraabdominal bleeding (Boysen et al. 2004; Lisciandro et al. 2009). Considering nontrauma, many hypotensive triaged patients have pleural and/or pericardial effusion, and intracavitary bleeds often accompanied by anemia (McMurray et al. 2016; Lisciandro 2016a,b). Moreover, the AFS system is not validated in dorsal recumbency and only subjective terms of mild, moderate, and severe can be used (Stander et al. 2010; Sutherland-Smith et al. 2006). For clinicians who prefer performing complete detailed abdominal ultrasound in dorsal recumbency,

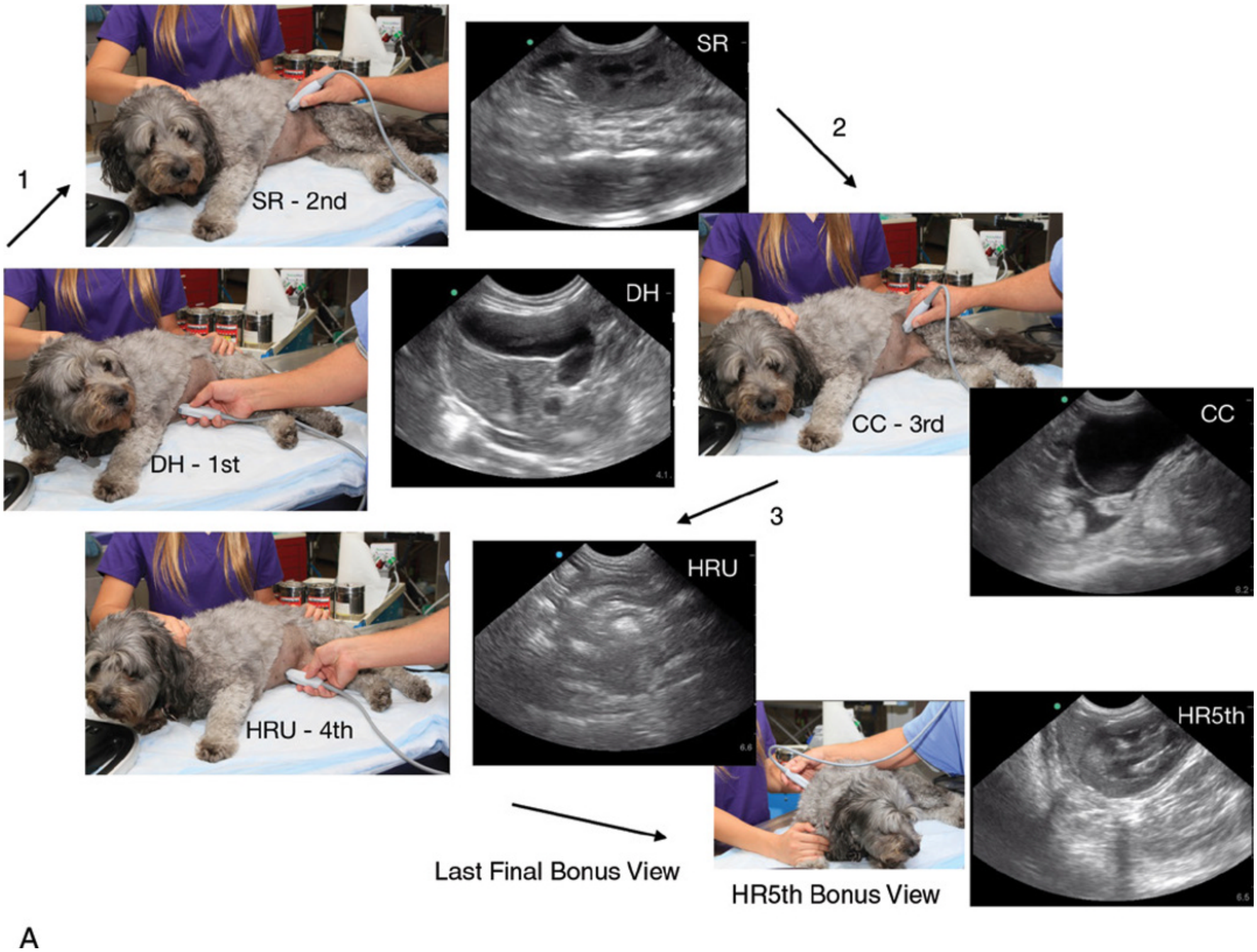

Figure 6.4. Modified lateral-sternal recumbency. The AFAST views are performed in the same order every time as follows: DH to SR to CC to HRU to HR5th bonus view. The final HR5th bonus view is *not* part of the abdominal fluid score.DH, diaphragmatico-hepatic view; SR, spleno-renal view; CC, cysto-colic view; HRU, hepato-renal umbilical view; HR5th, hepato-renal 5th bonus view. Note that the images should look identical for each AFAST view regardless of positioning (including standing/sternal, modified sternal). AFAST views are nearly identical no matter the positioning because the respective target organs are imaged with the same methodology. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

perform a Global FAST *first* before moving the patient to the restraint of dorsal recumbency to best ensure patient safety.

Naming and Order of the AFAST Views

The AFAST sites in the preferred positioning of right lateral recumbency (over left) are named according to target organs at each acoustic window and performed in clockwise order as follows: (1) DH view, (2) SR view, (3) CC view, and (4) HR umbilical (HRU) view that completes the AFAST examination and is a favorable site for abdominocentesis, being most gravity dependent (Lisciandro et al. 2009; Lisciandro 2011; Boysen and Lisciandro 2013; McMurray et al. 2016). AFAST views are shown translated onto an abdominal radiograph and CT study in Figure 6.6. The final view is the HR5th bonus view to image the right kidney and nearby liver that is not part of the AFS; the HR5th bonus view is generally performed as the final view after AFAST, TFAST, and Vet BLUE have been completed.

In LL recumbency the order is as follows: (1) DH view, (2) HR view, (3) CC view, and (4) the SR umbilical

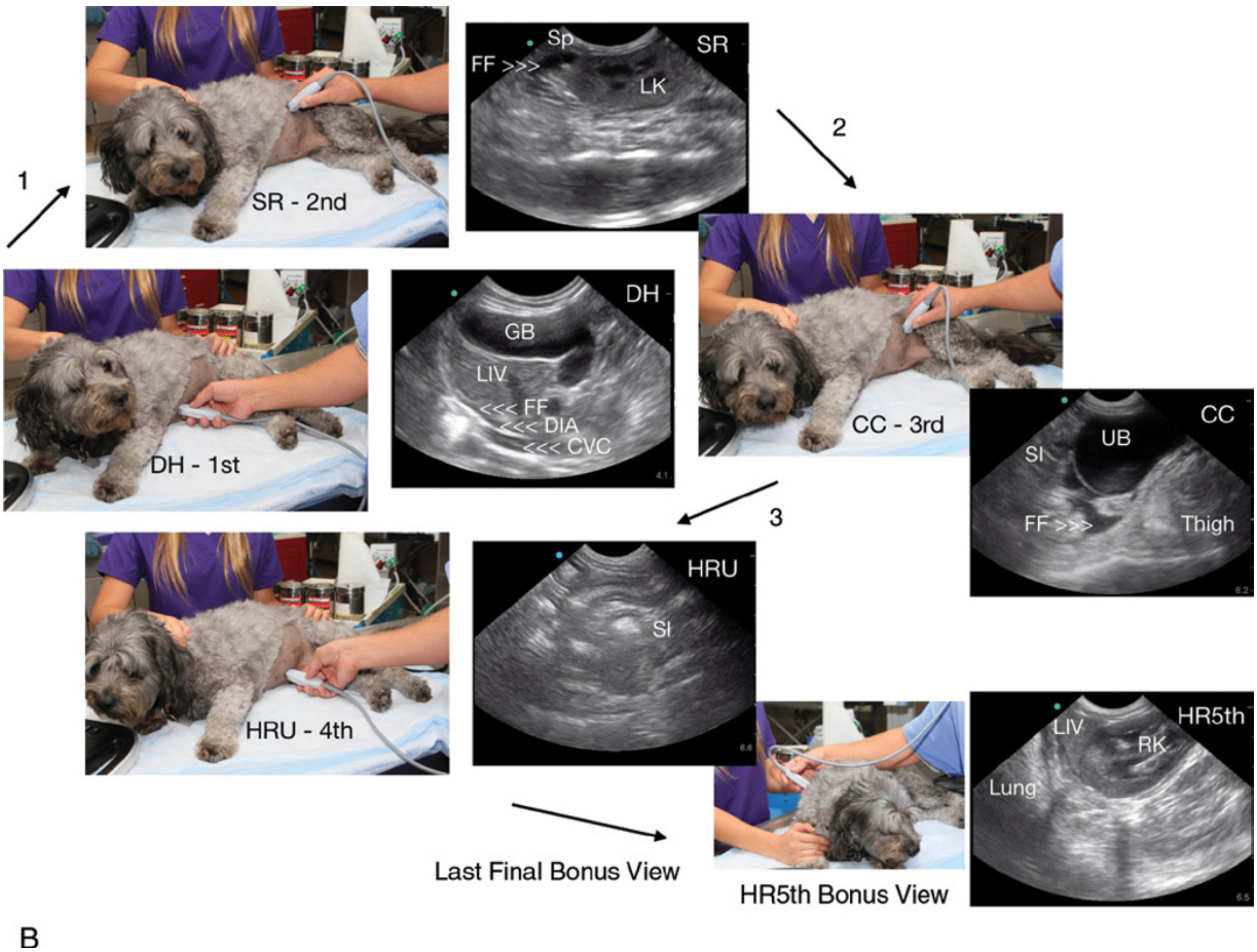

Figure 6.4. (*Continued*)

(SRU) view that completes the AFAST examination and is a favorable site for abdominocentesis, being most gravity dependent (see Figure 6.3). Positioning of the cat is shown in Chapter 39. The final view is the SR5th bonus view to image the left kidney and spleen and is not part of the AFS; the SR5th bonus view is generally performed as the final view after AFAST, TFAST, and Vet BLUE have been completed (Lisciandro et al. 2009; Lisciandro 2011; Boysen and Lisciandro 2013; McMurray et al. 2016).

In summary, the four primary AFAST views are part of the AFS system. The AFAST 5th bonus view (HR5th and SR5th views depending on which lateral recumbency is being used) is not part of the AFAST AFS system, but important for acquiring information for that respective retroperitoneal space and any obvious soft tissue or parenchymal abnormalities of the kidney and its adjacent liver and spleen dependent on positioning. In cats and smaller dogs when using enough depth, both kidneys are often seen through the SR (or HR) view (Lisciandro et al. 2009; Lisciandro 2011, 2012, 2014a; McMurray et al. 2016) (see Figure 6.21).

Pearl: By imaging using the AFAST target organ approach, sonographic anatomy is better recognized, and the sonographer is building POCUS skills on every AFAST exam, with the only pressure being the recognition of free fluid.

Probe Maneuvering is Standardized

All AFAST acoustic views are imaged in longitudinal (sagittal) orientation with the marker of the probe always directed toward the head of the patient; with

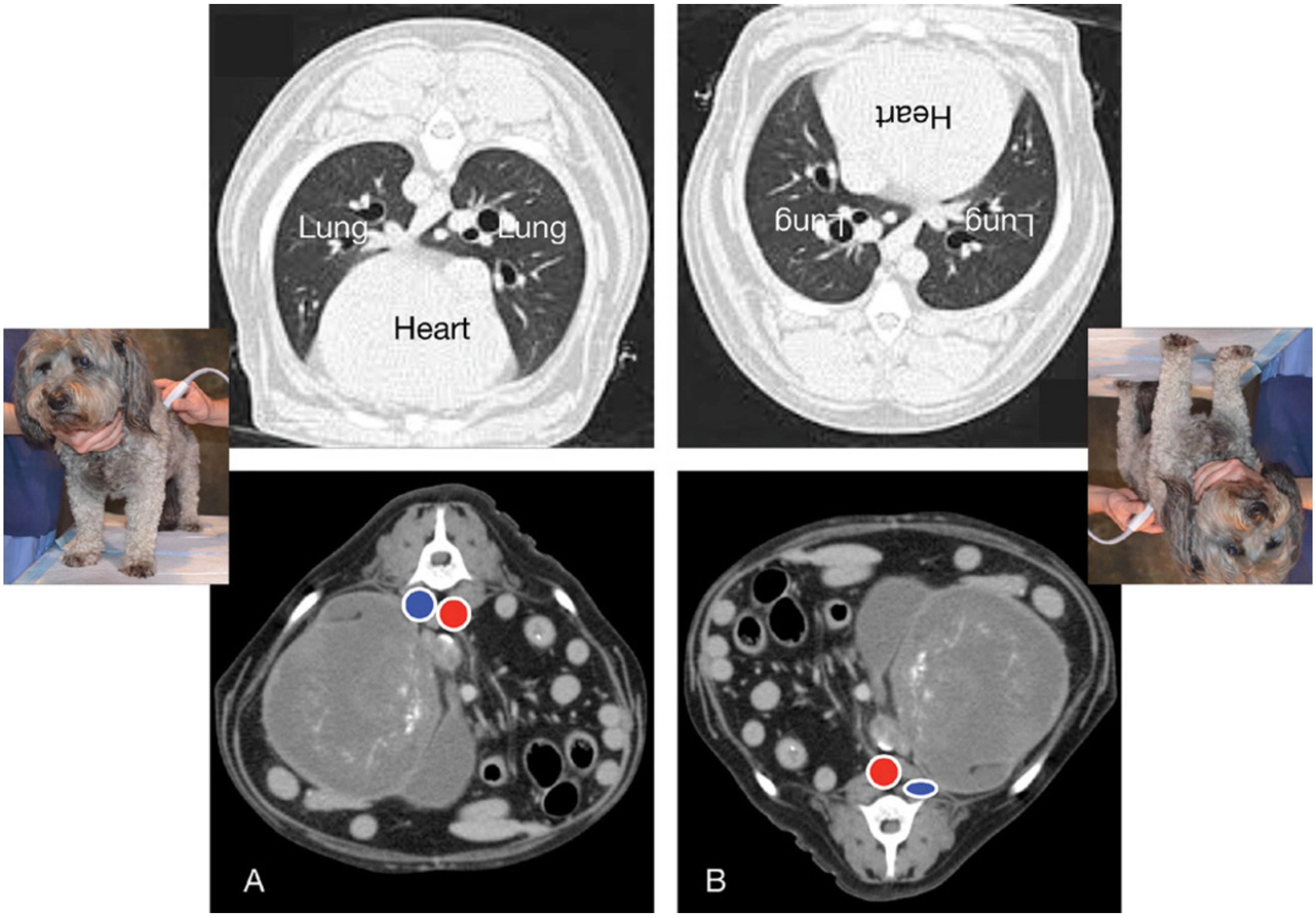

Figure 6.5. Never use dorsal recumbency without doing a Global FAST to assess stability. The use of dorsal recumbency on a hemodynamically fragile or unstable patient is potentially catastrophic. In (A) the computed tomography (CT) of a cross-section of the thorax and abdomen is is compared to (B) in dorsal recumbency. Ventilation is changed from (A) to (B) by moving the most aerated, least perfused, least gravity-dependent lung fields to a ventral and gravity-dependent location. Moreover, the weight of the abdominal organs against the diaphragm further adversely affects ventilation. Venous return to the heart is also markedly changed from (A) to (B) in which the CVC (*blue circle*) next to the aorta (*red circle*) becomes compressed in dorsal recumbency from the weight of the abdominal organs. In hemodynamically fragile patients, there is real risk for decompensation. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

muscle memory, most sonographers quickly learn this repetitive probe motion. In longitudinal (sagittal) orientation target organs are more recognizable than in transverse orientation, especially for the nonradiologist sonographer (Figure 6.7). The single longitudinal (sagittal) orientation is supported by the original veterinary FAST study in which when longitudinal (sagittal) and transverse orientation were compared, they matched in 397 out of 400 views (Boysen et al. 2004). In time, rotating the probe to transverse orientation may be considered as part of each AFAST view as an add-on skill but is unnecessary.

Every AFAST view is a “fan, rock cranially, and return to your starting position” of the probe by fanning through the target organ, rocking cranially, and then returning to your starting point (see Figures 6.2, 6.3, and 6.4).

- *DH view*: Fan through the gallbladder in both directions until the gallbladder disappears in both directions, and then rock cranially to image the “cardiac bump” before returning to your starting point for one final look within the abdominal cavity.
- *SR view*: Fan through the left kidney in both directions until the left kidney disappears in both

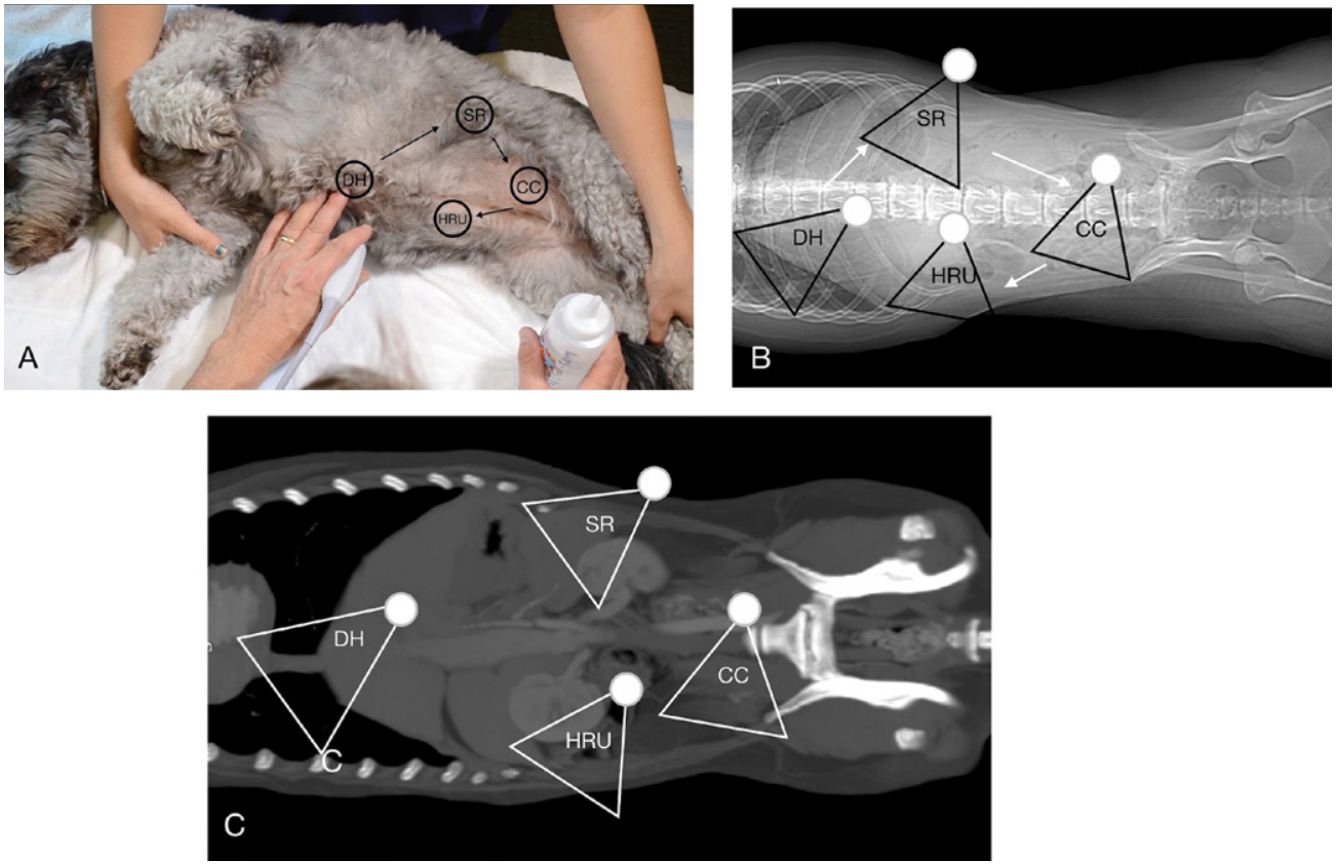

Figure 6.6. Correlation of AFAST acoustic windows with a dog in right lateral recumbency to an abdominal radiograph and CT. Sites are named by their target organs. In (A) the AFAST acoustic windows are labeled and correlate in (B) to a radiograph and (C) to computed tomography. The AFAST order is always the same: DH to SR to CC to HRU view. Note that the head is always to the left and tail to the right in both ultrasound and radiography. Computed tomography and radiograph courtesy of Dr Daniel Rodriguez, VETTEM, and Dr Jesús Paredes, CVM, Mexico City, Mexico. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

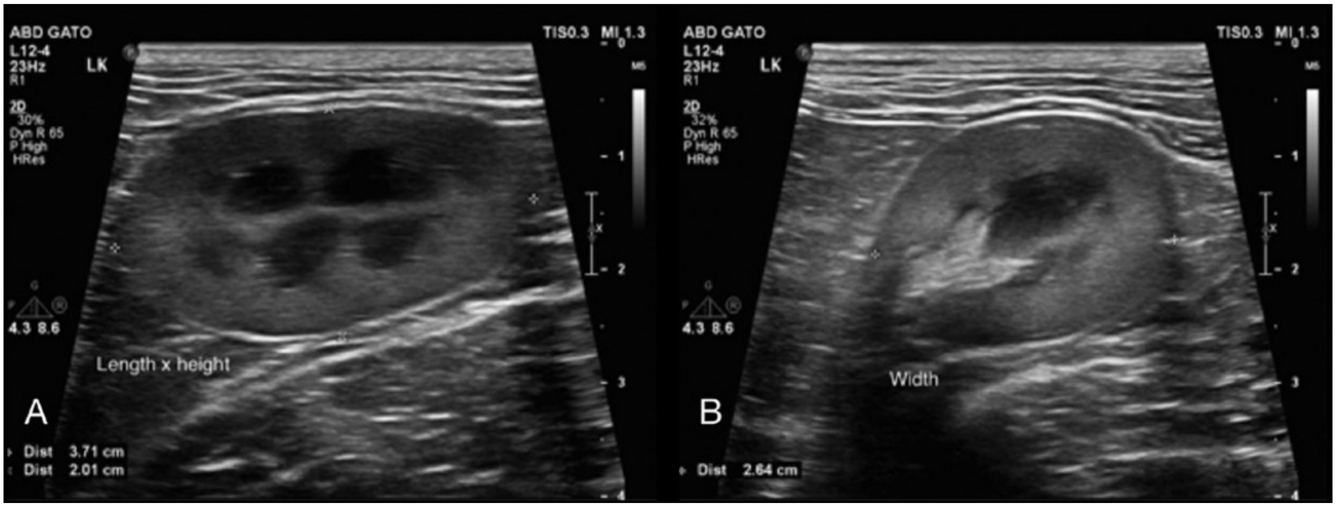

Figure 6.7. Longitudinal orientation for AFAST. (A) Kidney in longitudinal orientation, standard for all the AFAST views, because organs are more readily apparent in longitudinal over transverse scanning planes for most nonradiologist sonographers. (B) The same kidney as in (A) but in transverse orientation. The author keeps it simple – "fan (longitudinal planes), rock (direct the scanning plane cranial) and return to your starting point" is the AFAST mantra. Transverse orientation should be considered as an add-on AFAST skill but is unnecessary for the detection of free intraabdominal fluid (Boysen et al. 2004). Computed tomography courtesy of Dr Daniel Rodriguez, VETTEM, Mexico City, Mexico. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

directions, and then rock cranially to image the head of the spleen (fan on it too) before returning to your starting point of the left kidney for one final look. The kidney is *retroperitoneal* and the spleen *peritoneal*. The head of the spleen is reliably imaged in both dogs and cats.

- *CC view*: Fan through the urinary bladder in both directions until the bladder disappears in both directions, and then rock cranially to image the "CC pouch", its most gravity-dependent region, and back to your starting point for one final look.
- *HRU view* (right lateral recumbency): Fan through the small bowel and spleen in both directions and then rock cranially to image the cranial abdominal region before returning to the "HRU pouch", its most gravity-dependent region, for one final look. The left kidney may be viewed with increased depth through a single HR view, especially in cats and smaller dogs (Lisciandro 2014a; McMurray et al. 2016).
- *SRU view* (left lateral recumbency): Fan through the small bowel and spleen in both directions and then rock cranially to image the cranial abdominal region before returning to the "SRU pouch", its most gravity-dependent region, for one final look. The right kidney may be viewed with increased depth through a single SR view, especially in cats and smaller dogs (Lisciandro 2014a).
- *HR5th bonus view* (right lateral recumbency): Fan through the right kidney in both directions until the right kidney disappears in both directions and then rock cranially to image the right liver lobes before returning to your starting point of the right kidney for one final look. This view is generally unnecessary if the right kidney is imaged through the SR view.
- *SR5th bonus view* (left lateral recumbency): Fan through the left kidney in both directions until the left kidney disappears in both directions and then rock cranially to image the spleen before returning to your starting point of the left kidney for one final look. This view is generally unnecessary if the left kidney is imaged through the HR view.

Pearl: For both those learning AFAST and experienced AFAST sonographers, only longitudinal (sagittal) orientation is necessary for the detection of free fluid at each view, with this standardization accelerating the learning process by building consistent sonographic expectations of the AFAST target organs. In time, transverse orientation may become an add-on skill but it is unnecessary.

AFAST Diaphragmatico-Hepatic View

Questions Asked at the DH View

Is there any free fluid in the abdominal (peritoneal) cavity?	Yes or no
How much free fluid is at the DH view using the AFAST AFS system?	0, 1/2, 1
Is there any pericardial effusion?	Yes or no
Subjective amount?	Small (<1 cm), moderate (1–2 cm), large (>2 cm) (Candotti and Arntfield 2015)[a] Must be placed into clinical context
Is there any pleural effusion?	Yes or no
Subjective amount?	Trivial, mild, moderate, severe
What does the pulmonary-diaphragmatic surface look like?	Unremarkable (dry lung) or abnormal
Are there any lung lesions along the diaphragm?	B-lines and Vet BLUE B-line scoring, shred sign, tissue sign, nodule sign, wedge sign
What does the gallbladder look like?	Unremarkable, halo sign (sonographic striation), abnormalities in its lumen or wall
What does the liver look like?	Unremarkable or abnormal
What do the caudal vena cava and its associated hepatic veins look like?	Unremarkable (bounce) or abnormal (FAT, flat): see Tables 7.6 and 36.3 and Figures 36.8 and 36.9
Could I be mistaking an artifact or pitfall for pathology?	Know pitfalls and artifacts

[a]The AFAST target organ approach for parenchymal abnormalities is binary using "unremarkable" or "abnormal" to capture the case for additional imaging and confirmatory testing. Over time, more interpretative skills may be gained through experience and accompanied by additional POCUS study and training.

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The classic AFAST DH view is in fact part of AFAST, TFAST, and Vet BLUE because it provides a huge amount of clinical information, including structures within both the peritoneal and pleural cavities.

The DH view begins with longitudinal placement of the probe with the probe marker towards the patient's head immediately caudal to the xiphoid process.

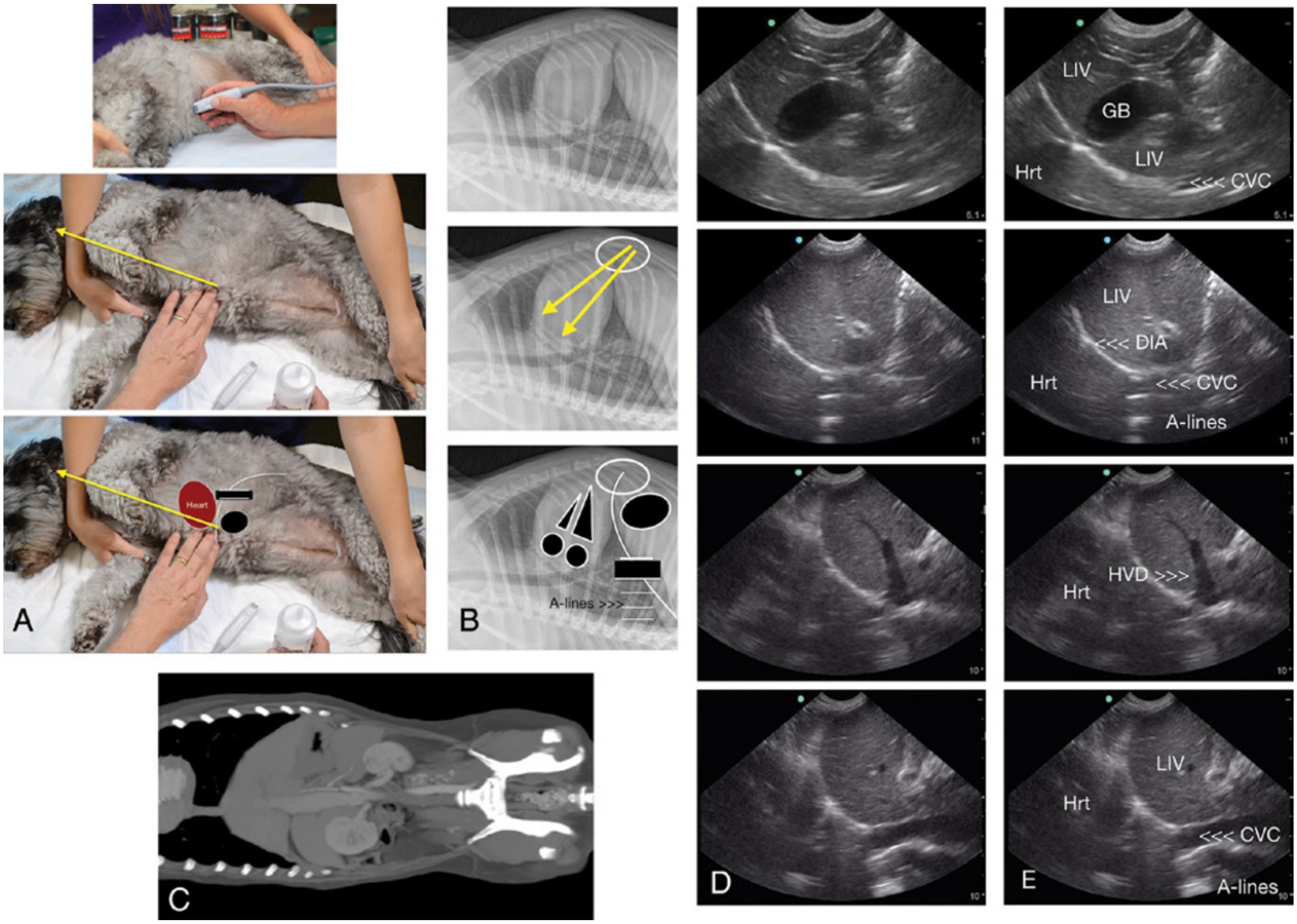

Figure 6.8. The DH view in a dog. In (A) is shown where the probe is placed immediately caudal to the xiphoid (*top image*) and directed cranial (*arrow*) in middle and bottom images with overlay of heart, diaphragm (*curved white line*), gallbladder (*black oval*), CVC (*black rectangle with white line as near wall and longer white line as far wall*). In (B) inverted correlating lateral thoracic radiographs in the top image, unlabeled, the middle image having arrows for direction of the ultrasound beam (scanning plane), white circle for probe placement, and bottom image with overlay of structures including the gallbladder, diaphragm, CVC, including A-lines beyond its far wall through the far-field from aerated (dry) lung, and the heart with ventricles as triangles and atria as circles. In (C) is CT for another correlation of the anatomy of the DH View. (D) and (E) are unlabeled and labeled ultrasound images of the DH view's anatomical features. Note the *consistency* of where the diaphragm is located in each of the ultrasound images. CVC, caudal vena cava; DIA, diaphragm; GB, gallbladder; Hrt, heart; HVD, hepatic venous distension; LIV, liver. Computed tomography courtesy of Dr Daniel Rodriguez, VETTEM, and Dr Jesús Paredes, CVM, Mexico City, Mexico. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

The probe is then directed far more cranially than most sonographers expect (Figure 6.8). Depth should be adjusted so that the diaphragm courses through the distal two-thirds of the image on the screen so that the near-field is two-thirds abdomen and the far-field one-third thorax. This allows for adequate screening of both the abdomen and thorax.

The gallbladder, if not in view, is found by fanning toward the table top (when in right lateral recumbency) because of its location right of the midline in dogs and cats (further right in cats). In normalcy, the canine gallbladder is easy to find because it is generally much closer to midline than the more laterally located feline gallbladder (see Chapter 39).

The mantra for the DH view is to have a general overview of three structures – the gallbladder, "cardiac bump", and caudal vena cava – before starting the fanning, rocking, and returning. Start with a depth of 7–8 cm for cats and small dogs to 10–15 cm for medium to large dogs and then decrease depth as indicated.

Once the gallbladder is in view, then in a sequential way specifically interrogate the following.

- The abdominal cavity for free fluid by fanning through the gallbladder and adjacent liver in both directions, followed by…
- Rocking the probe toward the sternum to best image the "cardiac bump" where the muscular apex of the heart is very near or immediately against the diaphragm for pericardial effusion, and then…
- Imaging along the diaphragm for pleural effusion, and lung pathology along the pulmonary–diaphragmatic interface.

In this same plane or close by, and making sure that the probe is immediately against the xiphoid, look for the CVC as it traverses the diaphragm present in both canines and felines. The CVC is recognized by the two bright white (hyperechoic) bars that make up the near wall (short bar) and far wall (long bar) with reverberation artifact (A-lines) extending through the far-field dependent on depth and the presence of dry lung in that patient.

The steps taken during the AFAST DH view are as follows.

- The gallbladder wall and its shape should be noted and the gain adjusted based on the echogenicity of its luminal contents. In normalcy, the homogeneous anechoic (black) echogenicity of bile should approximate what would be expected for most types of free fluid.
- In dogs, the gallbladder reliably lies immediately against the diaphragm when positioned in right lateral recumbency; however, the gallbladder–diaphragm proximity is much less reliable in cats.
- When the canine gallbladder does not lie immediately against the diaphragm, liver enlargement should be suspected, and when the gallbladder is not located, the rule-out list placed into clinical context should include its rupture, its displacement (diaphragmatic herniation), or the presence of gallbladder stones, mineralization, sludge, mucoceles, and emphysematous cholecystitis.
- Once the gallbladder is recognized, fanning takes place by directing the probe away from the tabletop to the patient's left, and then by fanning toward the tabletop toward the patient's right, interrogating the adjacent liver. The feline gallbladder and biliary tract differ from dogs (see Figures 8.4 and 39.4, and Chapters 8 and 39).
- By doing so, the liver and abdominal cavity are interrogated for obvious free fluid between liver lobes and between the liver and diaphragm, and the gallbladder and liver are screened for any obvious abnormalities or sonographic deviations from normal (Figures 6.9 and 6.10).

Pearl: To perform the DH view consistently and effectively, while fanning through the gallbladder and liver, maintain the diaphragm in the distal two-thirds of the field of view.

Pearl: In low-scoring benign and pathological small-volume effusions, our research has shown the DH view as most commonly positive. These small-volume effusions are detected between the liver and diaphragm as an anechoic stripe, and between liver lobes and within the "CC pouch" as anechoic triangulations (Lisciandro et al. 2009, 2015, 2019; Hnatusko et al. 2019).

After interrogating the abdominal cavity, return to the starting point of the DH view. The probe is then rocked toward the patient's sternum, remaining on a strict longitudinal plane searching for the "cardiac bump," the reverberation of the beating heart against the diaphragm (Figure 6.11). The "cardiac bump" is used to diagnose pericardial effusion and rounded effusion, and as a single view, the "racetrack sign" (see Chapters 7, 18 and 21).

Then use the DH view as an acoustic window via the liver and gallbladder into the thorax to interrogate the pleural cavity for the presence or absence of pleural effusion, anechoic triangulated effusion, and lung along the pulmonary–diaphragmatic interface (see Chapters 7, 18, and 21).

Pearl and Pitfall: The "cardiac bump" is reliably imaged in dogs, but less reliable in cats because of more interposing feline lung in between the heart and diaphragm. However, most clinically relevant pericardial effusion is detected in both dogs and cats at the DH view (Lisciandro 2016a) (see Figure 6.11 and Chapter 39). Pneumothorax in either species is another reason for the inability to view the "cardiac bump."

Always look cranially past the diaphragm into your patient's thorax for pericardial effusion, pleural effusion, and deep lung pathology along the

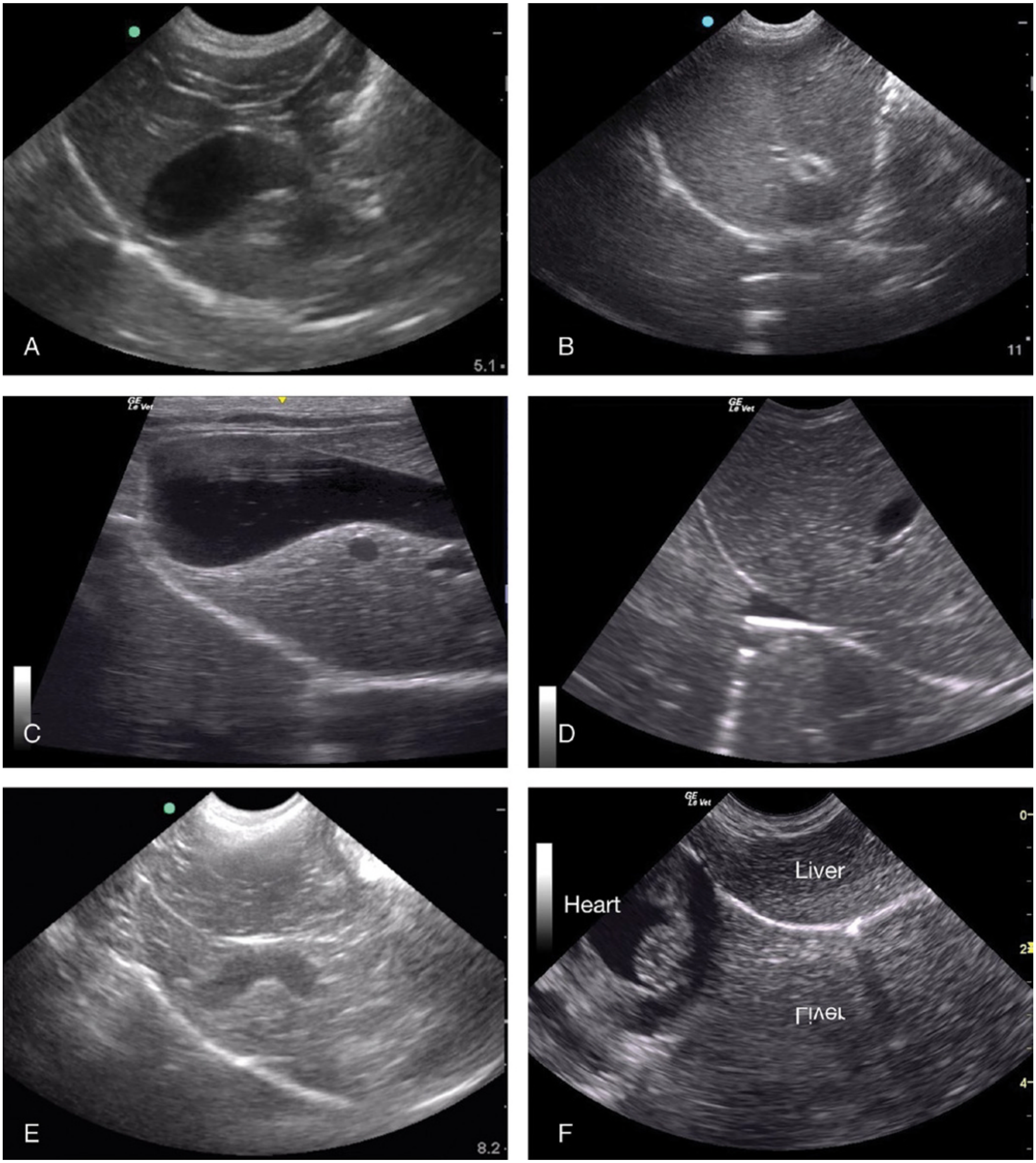

Figure 6.9. Images showing various anatomic features at the DH view. None of these images are positive for free fluid and only (F) is labeled. Compare these images to those labeled in Figure 6.8. In (A) the gallbladder is expected to be in close proximity to the diaphragm. Note the mirror image of the gallbladder into the thorax. In (B) the caudal vena cava is seen in the far-field as two hyperechoic bars, one as its near wall and the other as its far wall (see Figure 6.11 and Chapters 7, 26 and 36 for greater CVC detail). In (C) another image of the canine gallbladder is shown in close proximity to the diaphragm. (D) shows an anechoic triangulation formed by the CVC as it traverses the diaphragm that should not be mistaken for free fluid. A-lines are seen past the CVC's far wall due to the dry lung against the CVC. In (E) the gallbladder appears bilobed in the cat and in the near-field is robust falciform fat (see Chapter 39 for more detail). In (F) with the probe directed near parallel to the sternum, the heart ("Heart") and its left ventricle are clearly in view and may be interrogated. The liver appears homogeneous as expected and is labeled "Liver" with it mirrored on the other side of the diaphragm due to mirror image artifact common at the DH View. Note how consistent the diaphragm is within the images as a landmark for proper DH view image acquisition. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

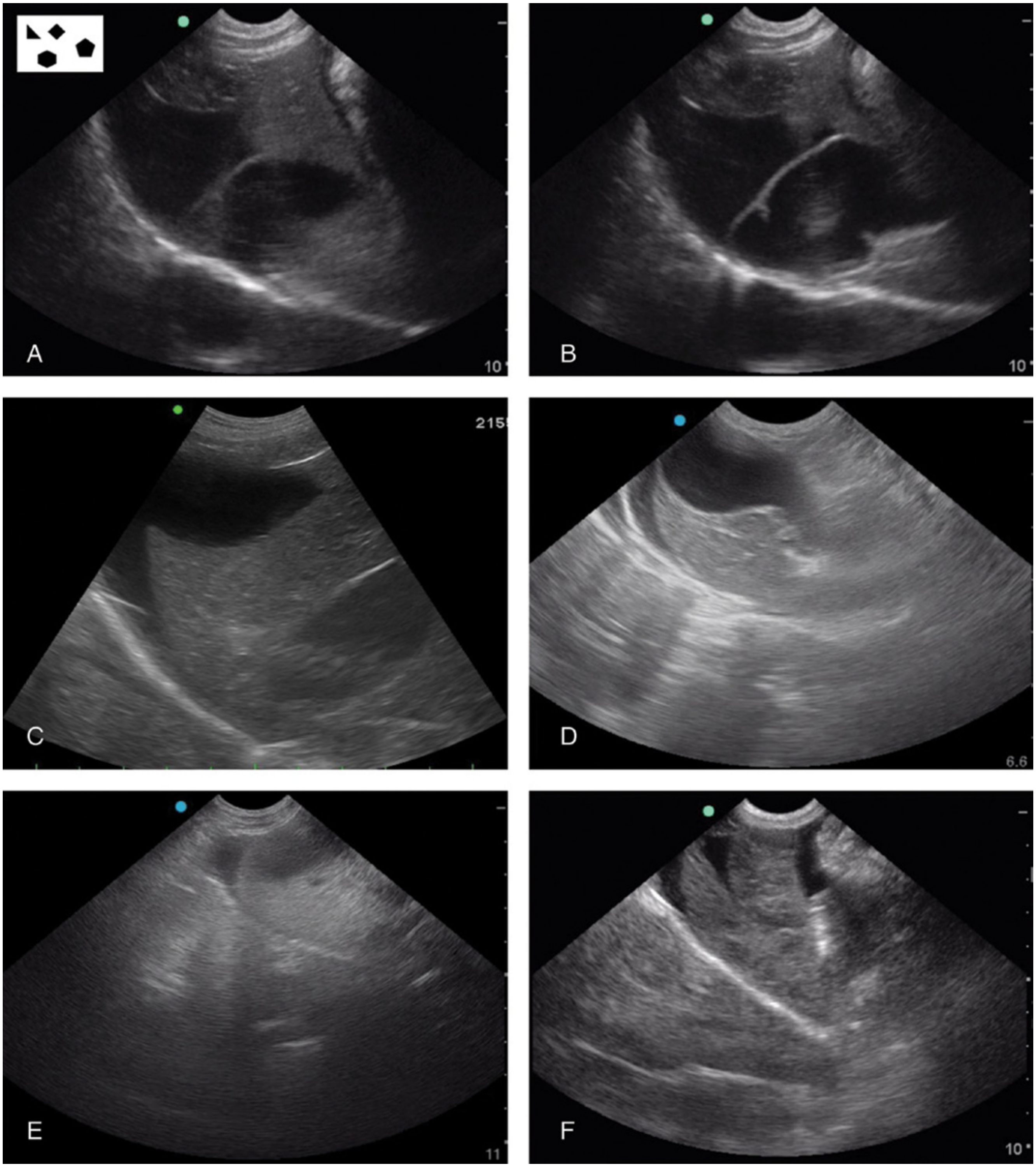

Figure 6.10. Variety of typical positive studies at the DH view. In (A) free fluid is apparent in the near-field to the gallbladder. In (B) similarly free fluid is in the near-field to the gallbladder. In (C) free fluid separates the liver from the diaphragm. In (D) there is a smaller abdominal effusion present separating the liver from the diaphragm. In (E) the same type of positive as in (D) is shown but with an even smaller volume. Note the probe is rocked cranial enough to get the diaphragm at the xiphoid, which is good practice for the DH view. In (F) the liver lobes are separated from one another due to the abdominal effusion. Note how consistent the diaphragm is within the images as a landmark for proper DH view image acquisition. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

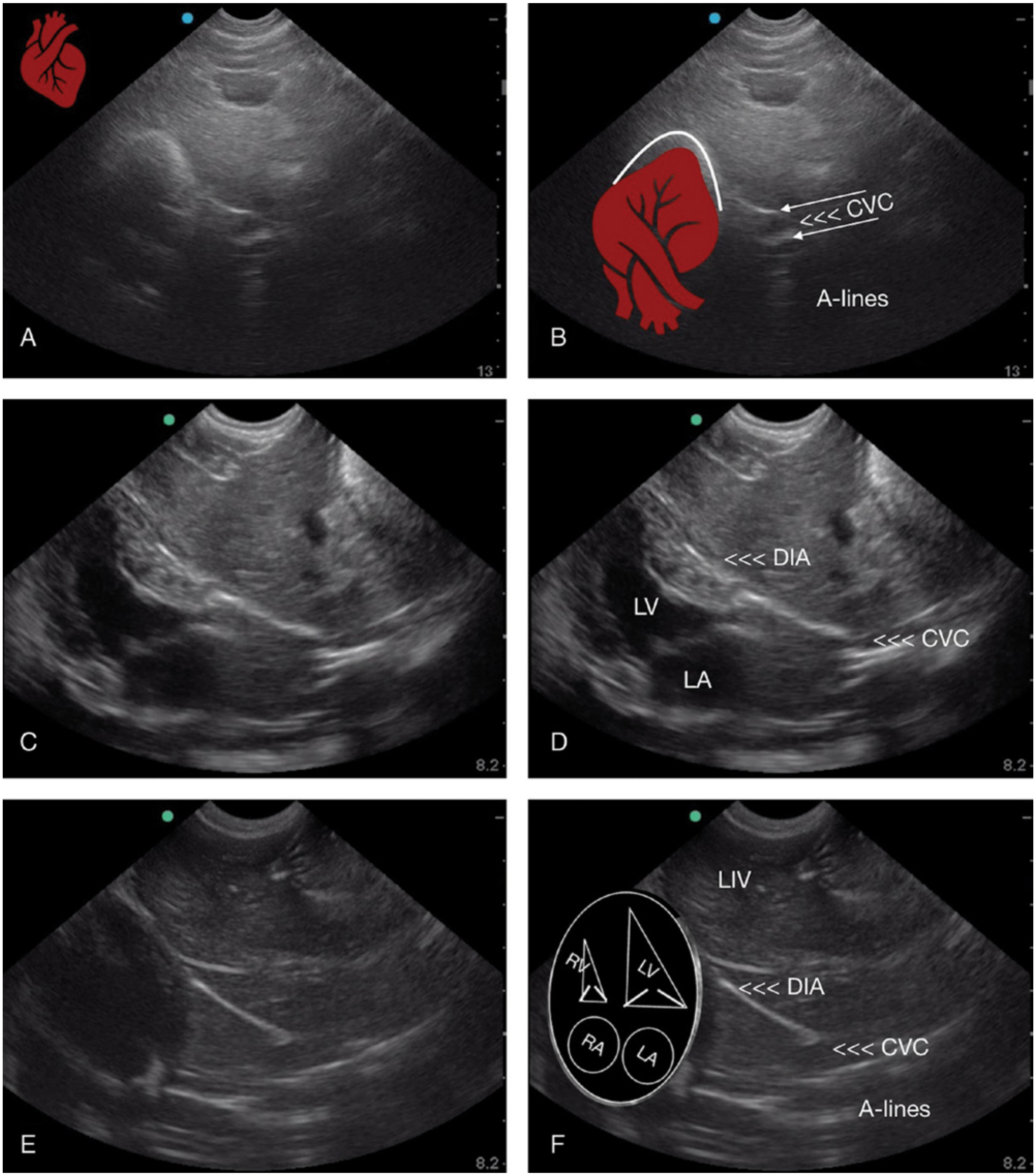

Figure 6.11. The "cardiac bump" at the DH view. In (A) the apex of the heart is indenting the diaphragm and in real time can be seen clearly beating against the diaphragm. In (B) a heart is superimposed to give a better idea of orientation. The arrows point out the near and far wall of the caudal vena cava (CVC). In (C) the heart is unlabeled with the left ventricle and left atrium both in view as well as the mitral valves with the same image labeled in (D) and the heart is positioned similar to the pictorial of the heart in (F). This cardiac orientation is really important to learn because the heart is generally more sonographically accessible than transthoracic TFAST pericardial site views and its echo views in respiratory distressed patients. In (E) is the unlabeled heart against the diaphragm and labeled with the addition of an overlay of the cardiac orientation in (F). Note how consistent the placement of the diaphragm is within the images as a landmark for proper DH view image acquisition. CVC, caudal vena cava; DIA, diaphragm; LA, left atrium; LIV, liver; LV, left ventricle; RA, right atrium; RV, right ventricle. Source: Reproduced with permission of Dr Gregory Lisciandro, Hill Country Veterinary Specialists and FASTVet.com, Spicewood, TX.

diaphragmatic–pulmonary interface (see Chapters 18, 22, and 23) and use TFAST pericardial site views and Vet BLUE to confirm, refute and support findings at the FAST DH view.

Following interrogation of the pleural cavity, pericardial sac, and lung along the diaphragmatic–pulmonary interface, along the same longitudinal plane of the "cardiac bump," look for the CVC, making sure depth is adequate as the CVC is the deepest structure at the DH view (Figure 6.12).

If the CVC is not seen, look for it while you rock slowly back to your starting point, making sure you are on a longitudinal plane on midline and immediately caudal to the xiphoid.

The CVC is reliably imaged with experience and should be characterized where it traverses the diaphragm, searching for the small white line in the near-field and the longer white line in the far-field paralleling one another and representing the near and far walls of the CVC, respectively. The lines that extend beyond the CVC's far wall are in fact A-lines created when aerated (dry) lung (most common) is immediately against the far wall or possibly in the presence of pneumothorax (far less common) (see Figure 6.12).

Pearl: Excessive probe pressure caused by pushing the probe into the patient's abdomen can distort the CVC, resulting in its flattening and false assessment (Darnis et al. 2018).

Typical DH Positives

The classic intraabdominal positives at the DH view are usually seen while fanning away from the tabletop in the following locations: the near-field to the gallbladder, between the divisions of the liver lobes, between the liver and the diaphragm, and between the liver lobes and the falciform ligament and fat. In the near-field, the falciform ligament and fat, which can be robust even in thin cats, are typically hyperechoic (bright) in the near-field, having a coarser, brighter echotexture (hyperechoic) relative to the liver (see Figure 6.10 and Chapter 39).

The most common AFAST positive views in low-scoring AFS 1 and AFS 2 bluntly traumatized dogs and cats, clinically normal adult dogs and cats, and juvenile puppies and kittens are the nongravity-dependent DH and CC views over the most gravity-dependent HRU and SRU views (Lisciandro et al. 2009, 2015, 2019). Moreover, the umbilical HRU and SRU views are rarely the only positive view(s) among different subsets of dogs and cats (Lisciandro et al. 2009, 2015, 2019; Romero et al. 2015). Thus, pay special attention to the presence of anechoic triangles (free fluid) while fanning through liver lobes (see Figure 6.10).

Artifacts and Pitfalls of the DH View

The DH View has many, if not all, the described ultrasound artifacts, including mirror image, acoustic enhancement, edge shadowing, side-lobe and slice-thickness (see Chapters 3 and 5). It is very important to be familiar with these common artifacts at the DH view (Figure 6.13). These same artifacts are possible at the CC view (see Figure 6.26), another AFAST view with a fluid-filled structure (DH view – gallbladder, CC view – urinary bladder).

Pearl: A good learning exercise is to focus on a specific artifact and then look through several DH view video clips from different patients looking for that specific artifact.

Artifacts

Mirror Image Artifact

The DH view is the classic example for mirror image artifact, which requires a strong air–soft tissue interface such as between the lung diaphragm and liver (see Figure 6.13). As a result, the ultrasound machine's software displays the liver and its structures as mirrored into the thoracic cavity (see Chapters 3 and 5).

Common DH view mirror image artifact misinterpretations include the following.

- The liver and gallbladder mirrored into the thorax and mistaken for a diaphragmatic hernia.
- The gallbladder mirrored into the thorax and mistaken for pleural and pericardial effusion, noting that a "partial" mirroring of the gallbladder can occur.
- Ascites mirrored into the thorax can be mistaken for pleural and pericardial effusion, and liver appearing as lung, noting that a "partial" mirroring of ascites can occur.

Acoustic Enhancement Artifact

The gallbladder will make the soft tissues distal to its fluid-filled luminal contents appear much brighter (more echogenic or hyperechoic) than adjacent soft tissues, similar to what occurs with the fluid-filled urinary bladder (see Figure 6.26). Typically, the