James M. Daniels
William W. Dexter
Editors

Basics of Musculoskeletal Ultrasound

Second Edition

Springer

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Preface

It's hard to believe that it's been almost a decade since the first edition of *Basics of Musculoskeletal Ultrasound* was published. Dex thought it was time for an update, and he was right! Point of Care Ultrasound (POCUS) has profoundly changed the way we diagnose and treat musculoskeletal conditions and sports-related injuries. This technology decreases the cost and the time needed to make a diagnosis while increasing our accuracy several fold. POCUS has brought "the joy of practicing medicine" back to both clinicians and patients through its inherent "therapeutic touch." What is even more amazing is the impact it has made on how we train students, residents, and fellows. They no longer memorize two-dimensional anatomy. They experience three-dimensional physiology and pathology.

This edition would not be possible without the hard work of the chapter authors (both new and old): Linda Savage, Tracy Marton, and Debbie Cramsey. This took a bit longer than expected as we hit a few bumps on our journey. While we were working on this project, both Dex's mother and my mother passed. My mother was my first and greatest teacher. . . I am sure Dex feels the same way about his mother.

This book is completed in their memory. They may be gone from us physically, but they will forever live in our hearts.

Quincy, IL, USA
James M. Daniels

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James M. Daniels

Many thanks to my fellows, past and present, who give me direction and purpose and joy in what I do. I hope that this second edition will help bring this game-changing technology to a new group of clinicians. Aimee K – your help and patience with me as we re-illustrated this edition went above and beyond – thank you. And, as always, to my talented and patient wife, Cindy, for bearing with me through all the editing. And to our children, Ben, Sam, and Hannah, on whom I practiced my ultrasound skills and with whom I will now surely move on to the next adventure.

William W. Dexter

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Introduction

1

James M. Daniels and William W. Dexter

Clinical ultrasonography has been around for decades. In Europe, it also has been used for many years, but the way it is utilized differs from the system developed in North America.

In Europe, ultrasound scanning is introduced to medical students very early in their training. These skills are then supplemented in postgraduate training. In the United States, clinical examination skills are taught to all students, but very few are exposed to clinical ultrasonography. Traditionally, a clinician examines the patient, and if it is determined that an ultrasound study is necessary, a comprehensive scan is performed by a highly trained technician, a sonographer. The images are then interpreted by a highly trained physician, a radiologist, who then generates a detailed report back to the clinician. This paradigm has shifted slightly over the years, with cardiologists and obstetricians using ultrasound as a bedside tool to practice medicine, but this training is limited in scope and is only taught in residency or fellowship. Recently, the United States has adopted a hybrid of these two systems, referred to as "point-of-care" ultrasonography. Students and practicing clinicians are now being trained to use bedside ultrasound as an important tool to diagnose and treat patients (i.e., starting central lines in the ICU, FAST scans in the emergency department, dynamic scanning of shoulder joint). More and more medical schools and residency programs are integrating POCUS into their physical examination and clinical reasoning curriculum.

This model integrates the history and physical exam along with treatment decisions into one process by one clinician. It not only decreases the cost and time of the process, it allows the clinician to evaluate three-dimensional real-time anatomy and physiology, which further adds to the accuracy of the diagnosis. These "point-of-care" musculoskeletal ultrasound exams (POC MSK/US) may not always include the "comprehensive" evaluation that traditional ultrasound examinations do. These scans are to supplement the clinical examination and should not be used as a stand-alone way to diagnose the patient's condition. The use of the ultrasound machine can be compared to the use of a stethoscope in the clinical setting. The stethoscope, as we know it, was first used in France in the early 1800s by Dr. René Laennec, but it wasn't widely used until the mid-1900s, when Rappaport and Sprague were able to mass-produce a lightweight, relatively affordable model. Ultrasound technology is currently following this trend. We predict that POC US will be the stethoscope of the twenty-first century. In fact, the year 2013 was heralded as "The Year of Sonography" by a number of health-care organizations. The use of POCUS has vastly changed the way musculoskeletal medicine is now being practiced. Most textbooks on this subject are written by radiologists with years of experience in the traditional paradigm described above. This book is written by busy clinicians with decades of experience using clinical ultrasound and could be used as a stand-alone curriculum for POC MSK/US.

This book is laid out in a way to become a bedside aid to assist in POC MSK/US scanning. Each chapter emphasizes one particular skill set. Introduction chapters demonstrate knobology, tissue scanning techniques, and the certification/accreditation process for MSK/US. Later chapters concentrate on particular regions of the body and explain detailed anatomy with "clinical scanning pearls." This book was developed to be used at bedside, and the best advice we can give clinicians who want to incorporate these skills is to "PRACTICE! PRACTICE! PRACTICE!" If you wait until you have perfect recall of all the anatomy and flawless scanning technique to start doing POCUS examinations on patients, you will never be able to fully utilize this technology. These skills are integrative, not additive. In addition, POCUS allows us to touch our patients, which has been shown to increase both patient and provider satisfaction when it comes to providing health care.

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Understanding Accreditation and Certification in Musculoskeletal Ultrasound

2

Krystian Bigosinski

What Is the Difference Between Accreditation and Certification for Musculoskeletal Ultrasound?

It is important to understand the essential differences between accreditation and certification.

Accreditation

The term "accreditation" is typically used to refer to practices, not people. Therefore, a person or group of people can choose to have their practice "accredited" by a recognized accrediting body. The accrediting body awards practice accreditation to those practices that adhere to certain standards. The standards themselves may vary among different organizations but would generally include language concerning the qualifications of the people performing in that practice, the equipment used (type and maintenance), and the logistics of the practice (patient scheduling, documentation, use of protocols, emergency plans, etc.). Common examples would be fellowship accreditation by the American College of Graduate Medical Education (ACGME) or hospital accreditation by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO).

Certification

The term "certification" is typically used to refer to people/individuals and not practices. Therefore, a person may become certified in a field or technique by demonstrating that he or she has met specific standards. For the most part, this includes documentation of prerequisites (e.g., continuing medical education [CME] and/or years of experience) and passing some type of test (written and/or practical). Individual certification may be used to document an individual's competency in support of an application for practice accreditation, but practice accreditation will not typically suffice to obtain certification. The obvious example is that many, if not most, American Medical Society for Sports Medicine (AMSSM) members are "certified" in sports medicine once they meet the prerequisites (e.g., completion of fellowship) and pass the test that is managed by an outside institution (Board of Medical Examiners).

What Organizations Have Set Up a System for Accreditation and Certification?

Accreditation

Practice accreditation for musculoskeletal ultrasound (MSK/US) is currently available through the American Institute of Ultrasound in Medicine (AIUM). The AIUM is a nonprofit, multidisciplinary organization dedicated to advancing safe and effective use of ultrasound in medicine through professional and public education, research, development of guidelines, and practice accreditation. Although the AIUM promotes all subfields of ultrasound medicine, the organization has recently focused on the emerging field of MSK/US, supporting guideline development, education, advocacy, and, of course, practice accreditation. The AIUM has a long history of practice accreditation and is recognized as a legitimate accrediting organization by CMS and third-party payers. At this time, AIUM practice accreditation is the only available practice accreditation in MSK/US. You do not have to be a member of the AIUM to have the AIUM accredit your practice. We are currently not aware of any other organizations developing practice accreditation in MSK/US. If you are interested in learning more about the AIUM and practice accreditation, go to http://www.aium.org, the official web site of the AIUM.

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Certification

Individual certification for MSK/US has been developed by the American Registry for Diagnostic Medical Sonography (ARDMS). The ARDMS is a nonprofit organization that promotes quality care and patient safety through the certification and continuing competency of ultrasound professionals. Similar to the AIUM, the ARDMS is a well-established organization recognized by CMS and third-party payers as a legitimate certifying/credentialing certification. In fact, most sonographers you know have received one or more credentials (or certificates) from the ARDMS—for example, Registered Diagnostic Medical Sonographer (RDMS) and Registered Vascular Technologist (RVT). The ARDMS has developed two comprehensive examinations, sonography principles and instrumentation and musculoskeletal sonographer, and these two examinations must be completed within 5 years, in addition to meeting examination requirements. The final prerequisites for the ARDMS test are extensive, are specific to level of education, and can be found here: https://www.ardms.org/wp-content/uploads/pdf/ARDMS-General-Prerequisites.pdf.

In general, applicants must be able to document clinical experience with a minimum of 800 studies in the area for which they are applying.

It should be noted that the AIUM and ARDMS are, in a sense, "sister" organizations that complement, not compete, with each other. This is similar to the ACGME and the Board of Medical Examiners. The American College of Rheumatology has also developed a certification process for rheumatologists who perform MSK/US, which can be found here: https://www.rheumatology.org/Learning-Center/RhMSUS-Certification.

What Are the Standards and Guidelines for the Accreditation of Ultrasound Practices?

The AIUM web site has very detailed information on this process: https://www.aium.org/accreditation/accreditation.aspx. AIUM practice accreditation is based largely upon the published AIUM guidelines for Performance of the Musculoskeletal Examination and Qualifications for Performing the MSK/US Examination, both available for free at the AIUM web site. The accreditation application includes sections in which the practice documents compliance with these guidelines. In addition, practices are required to list the different locations in which scanning is performed, who performs the scanning, which US machines are used, what type of US machine maintenance schedule is in place, what scanning protocols are utilized, how patients are scheduled, and how studies are documented in a timely manner. Practice guidelines for the performance of MSK/US as well as training guidelines are also included on this site for free.

What Are the AIUM Practice Guidelines for the Performance of the Musculoskeletal Examination?

These are available on the AIUM web site and are free. They can be viewed at this link: http://www.aium.org/resources/guidelines/musculoskeletal.pdf.

What Are the Current AIUM Training Guidelines for Physicians Who Evaluate and Interpret Musculoskeletal Ultrasound Exams?

These are available on the AIUM web site and are free. They can be viewed at this direct link: https://aium.org/resources/viewStatement.aspx?id=51.

Key items that are pertinent are noted below. You should familiarize yourself with the full document on the web site. In summary, a number of pathways can be taken:

1. Completion of a residency and/or fellowship program that includes structured MSK ultrasound training and performance and/or interpretation and reporting of 150 diagnostic MSK ultrasound examinations, under the supervision of a physician qualified to perform MSK ultrasound examinations.

   If completion of residency and/or fellowship occurred more than 36 months ago:
   (a) The supervision and/or performance, interpretation, and reporting of at least 50 diagnostic MSK ultrasound examinations per year and 10 hours of *AMA PRA Category 1 Credits*™, American Osteopathic Association (*AOA*) *Category 1-A Credits*, or Council on Podiatric Medical Education (CPME)-approved credits specific to MSK ultrasound within the previous 36 months must be documented.
   (b) If the supervision and/or performance and interpretation of 50 diagnostic MSK ultrasound examinations per year cannot be documented, 30 hours of *AMA PRA Category 1 Credits*™, *AOA Category 1-A Credits*, or CPME-approved credits specific to MSK ultrasound must be completed, including at least 1 ultrasound course that provided hands-on training in MSK applications.
2. Completion of a residency and/or fellowship program in which the physician did not receive specific training in MSK ultrasound but can document subsequent involvement in the supervision and/or performance,

interpretation, and reporting of 150 diagnostic MSK ultrasound examinations, plus 30 hours of *AMA PRA Category 1 Credits*™, *AOA Category 1-A Credits*, or CPME-approved credits specific to MSK ultrasound within the previous 36 months, including at least 1 ultrasound course that provided hands-on training in MSK applications.
3. Completion of the American College of Rheumatology Musculoskeletal Ultrasound Certification in Rheumatology program. If completion of certification occurred more than 36 months ago, 10 hours of *AMA PRA Category 1 Credits*™ or *AOA Category 1-A Credits* specific to MSK ultrasound must be documented.

Continuing Medical Education

The physician should complete 10 h of AMA PRA Category 1 Credits specific to MSK/US every 3 years.

What Are the Case Study Submission Requirements for AIUM Certification?

Practices will need to submit five cases for review by experts identified by the AIUM staff. These five cases should be representative of your practice. If the practice is a solo practice, then all cases can come from one clinician. However, if more than one person is scanning in the practice, then cases should come from multiple individuals, and you cannot submit two cases from a single physician/clinical provider unless all providers have been represented at least once. Similarly, if the practice evaluates all body regions, then the practice should not submit five shoulder examinations. For each case, the practice will submit all the US pictures and the report. The submitted pictures should comply with AIUM scanning protocols (i.e., Guidelines for Performance of the MSK/US Examination) and be labeled appropriately. The reports should justify the indication for the examination, and the stated results should accurately reflect the submitted US pictures. The AIUM has a well-established protocol for managing the process within HIPAA guidelines. Additional detailed information can be found at https://www.aium.org/accreditation/caseStudyRequirements/mskDiagnostic.pdf.

How Much Will Accreditation and Certification Approximately Cost?

AIUM practice accreditation is based on the number of ultrasound machines and specialties represented and starts at $1250. The fee schedule can be found here: https://www.aium.org/accreditation/fees.pdf. ARDMS MSK examination cost is $250, and further information can be found here: https://www.ardms.org/get-certified/rmsks/.

Do I Need to Get Certified for Payment from Insurance Companies?

Neither practice accreditation nor personal certifications are necessarily tied to reimbursement. As outlined in their mission statements, the primary goals of the ARDMS and AIUM are to ensure best practices and patient safety. An analogy would be board certification in sports medicine. You certainly don't need to be certified in sports medicine to get reimbursed. The primary purpose of the sports medicine board is to ensure best practices in sports medicine; the board was not developed to ensure reimbursement. There is some precedent for CMS and third-party payers to utilize certification and practice accreditation to control patient access and reimbursement. For example, some insurance companies will not pay for imaging done at nonaccredited imaging centers, whereas others may only reimburse interventional spinal procedures performed by specialist's board certified in pain medicine. The reality is that practice accreditation and certification do set a minimum standard that third-party payers may utilize to ensure a minimum standard of care for their patients. Above and beyond the issue of reimbursement, there may be implications for marketing. Practices have certainly utilized specialty certifications and practice accreditations to distinguish themselves from competitors as part of a marketing strategy. Only time will tell how accreditation and certification will impact patient access and reimbursement.

Do Accreditation and Certification Bodies Handle Diagnostic Ultrasound and Ultrasound for Needle Guidance Procedures Differently?

At this current time, the practice accreditation process pertains to diagnostic ultrasound. This means that practices should submit diagnostic ultrasound cases for review as part of their accreditation application. Although not specifically stated, it may be assumed that a practice accredited in MSK/US is accredited for diagnostic and interventional aspects. The AIUM has plans to develop practice guidelines for US-guided interventional procedures. How this will impact the MSK/US accreditation process remains to be determined. Based on our current understanding, the ARDMS certification test is primarily, if not entirely, diagnostic. The emphasis on diagnostic ultrasound for practice accreditation and certification is in line with the general understanding that individuals using US for US-guided procedures should have a basic understanding of diagnostic US. This reflects the European experience in which many clinicians are not taught US-guided procedures until they have met minimum requirements for diagnostic US.

Suggested Reading

American Institute of Ultrasound in Medicine at their website: http://www.aium.org

American Registry for Diagnostic Medical Sonography at their web site: http://ardms.org/

Bianchi S, Martinoli C. Ultrasound of the musculoskeletal system. New York, NY: Springer; 2007.

European Society of Musculoskeletal Radiology at their web site: http://www.essr.org/

Choosing Ultrasound Equipment

3

Krystian Bigosinski

Introduction

Choosing an ultrasound system for musculoskeletal work can be a daunting task. With an increasing number of ultrasound vendors, each potentially offering a wide array of models with varying features, making a choice can be a challenge. A frequently asked question by those new to musculoskeletal ultrasound is “What system should I buy?” That’s akin to someone asking “What car should I buy?” The simple answer is “It depends.”

Console vs. Portable vs. Tablet/Smartphone

The first choice is whether to purchase a cart-based console system or a portable system.

Console systems are generally large-format cart units. Their main advantage lies in their processing power. The bigger platform allows for more powerful processors and cooling fans. This translates into potentially better images and the ability to drive a wider array of transducers. Most also have the capacity to keep multiple transducers plugged in simultaneously, simplifying the process of switching between them.

While mobile (the carts all have casters), the size of console systems limits the ability to move them easily from room to room. Some have limited battery backup, which means that the unit must be fully powered down, unplugged, moved to the new location, and then plugged back in and rebooted. Most offices utilizing console systems, therefore, will dedicate a room to ultrasound, where the system takes up more or less permanent residence.

For those new to musculoskeletal ultrasound, console systems have one major drawback. They cannot be taken home easily, which means that the user is limited to using the machine only while in the office. This may hamper learning for the ambitious student of ultrasonography.

On the other hand, portable machines offer flexibility. The majority have battery backup built in, allowing the unit to be moved freely among exam rooms without having to power down each time. The portability also means the physician can take the unit home to practice, thereby significantly improving one’s skills much more quickly.

Portable machines lack the processing power of the console systems, but for all but the most demanding applications, this is not a serious drawback. Portable units can easily handle the vast majority of musculoskeletal work.

Most portable systems lack the ability to plug in multiple transducers simultaneously. To change transducers, the operator must unplug one transducer and plug in another. On those systems in which the transducer plugs into the bottom of the machine, changing transducers can be more cumbersome or difficult.

If a portable machine is purchased, serious consideration should be given also to purchasing a mobile stand or a *docking cart*. A mobile stand holds the machine securely during use. Most also have various shelves for peripherals such as thermal image printers, CD burners, and holders for transducers. A docking cart, on the other hand, is a powered mobile stand into which the machine slides or docks, similar to a laptop docking station. It allows peripherals and several transducers to remain plugged into the cart; all you do is snap in/out the ultrasound machine.

Stands and carts make it easier to move the machine around the office but also make it much less likely that the machine will fall off an exam table or counter. The cost of a stand is a small insurance premium. In addition, some stands, and most docking carts, have the ability to keep more than one transducer plugged in at the same time, and the choice of which transducer is active is made via the keyboard. (Keep in mind, however, that depending on the system you choose, not all attached transducers may be accessible while the system is operating in battery mode.)

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Finally, there is a new generation of handheld machines that use a platform such as a tablet or smartphone, combined with a probe and software. Some of these systems can be leased and provide an affordable point of entry for those new to ultrasonography. The systems are also the most mobile of all the choices. However, they are limited both by the processors on the device being used and by the technology of the probes, all of which result in decreased image quality overall.

For all system types, also consider how you plan to store images. For example, if you work for a larger medical center that will allow you to use their radiology image servers, being able to upload images from the ultrasound machine directly onto a server and electronic medical record is desirable. Make sure you purchase any software and hardware upgrades needed for this at the time you purchase your machine, as adding them on later can incur unnecessary cost. Otherwise, storing them securely on an encrypted external hard drive may also be an option, and in that case, be sure to contact your information technology or medical informatics department to discuss how to do this securely to protect sensitive patient information. In either case, all machines have finite memory to store images and video, and in a busy ultrasound practice, storage will fill up quickly if data is not regularly uploaded. And regarding the handheld/tablet-based devices, there may be limitations regarding private patient information regarding these devices, so their role in a busy clinical setting may be limited as institutions may not want PPI being stored on tablets or smartphones. Before committing to one of these devices, it is best to think about how it will be used, and discussing how patient data will be stored with your medical informatics department may inform your decision.

Transducer Choices

For musculoskeletal work, the workhorse transducer is the linear probe. The ideal multipurpose transducer should have a frequency range of roughly 8–12 MHz. The vast majority of musculoskeletal ultrasound work is done at 10 MHz, with a smattering at 12 MHz for the more superficial structures (within 2-cm depth) and some at 8 MHz for slightly deeper structures (4–5-cm depth).

Some newer systems offer linear transducers that will scan at frequencies from 8 MHz to as high as 15–18 MHz. However, note that, depending on the particular system, you may not be able to choose the specific scanning frequency. Also, keep in mind that while a higher-frequency transducer may generate a higher-resolution image, it does so at the potentially heavy cost of severely limiting penetration or scanning depth, often to no more than 2 cm. (Remember that frequency and penetration are inversely related.)

Although the majority of work done in musculoskeletal ultrasound is handled by the linear transducer, strong consideration should be given also to purchasing a curved transducer with a frequency range of roughly 3–5 MHz. The curved arrays are essential for work around the hip and buttocks (e.g., hip intra-articular injections) and spine work. However, curved probes can also be extremely helpful in other areas, such as the glenohumeral joint (which is relatively deep and not well visualized by some linear arrays), or in cases of large or obese patients, where the linear transducer lacks penetration. Finally, curved transducers can be helpful to start out getting a wider field of view of an area, for example, to help localize a tear in a muscle belly, and then the linear probe can be used to “zoom in” on the affected area.

A wide assortment of specialized probes is also available, such as small-footprint “hockey stick” probes, small low-frequency curved arrays, and dedicated high-frequency probes. These specialized probes may be useful in practices or specialties that tend to do highly specialized ultrasound. For example, for rheumatologists who use ultrasound extensively to examine and inject the small joints of the hands and feet, a small-footprint high-frequency probe might be well worth the investment. New technology has recently produced probes that can be used for multiple purposes. This allows the clinician to use just one probe to scan virtually all parts of the body.

System Features: “Bells and Whistles”

Features to look for when purchasing a system will largely be dictated by how one intends to use the system and to what extent one desires to develop expertise in musculoskeletal ultrasound.

Some systems are engineered to be more or less “plug and play.” These machines have very limited ability to fine-tune images and settings. They are designed for those practitioners who simply want to turn on their machine and go to work.

For example, there are systems available that lack the ability to adjust scanning frequency independently of scanning depth. The software “assumes” that when the depth is increased, the frequency must be correspondingly decreased to image deeper structures. While this is generally the case, there are times when one may want to decrease the frequency but not the depth. For example, sometimes it is easier to see a needle when performing a guided injection by using a lower frequency, but increasing the depth would compromise the quality of the image. Conversely, it may occasionally be desirable to increase the depth without changing the frequency, such as when scanning the posterior glenohumeral joint.

The ability to adjust scanning depth varies by systems. Some machines “toggle” from one depth to the next, and you cannot go backward; you must continue to toggle forward and back around to the beginning. Likewise, some systems have limited—or no—ability to set and adjust focal points or zones. This is done automatically and determined by built-in software algorithms.

Some systems are touch screen only; they lack a true keyboard. Similar to a tablet, they use a virtual keyboard that appears on the screen.

While some units have separate time-gain compensator sliders (TGCs), others lack this feature or else have it built in to the software settings. TGCs are analogous to a graphic equalizer in a stereo system. They allow the user to adjust a particular band or portion of the image to compensate for variations in tissue density and attenuation.

There are other helpful features to consider. The ability to do side-by-side on-screen comparisons, comparing the pathological side to the "normal" side, can be useful. Beam steer technology, the ability to angle the sound beam to make it more perpendicular to the needle to help in visualization, for example, can be quite useful when performing guided injections. Panoramic view can be helpful when trying to image a structure that extends beyond the visible area of the screen, such as when trying to capture an image of the entire length of the rectus femoris muscle.

Annotation features are an important area to evaluate. How easy is it to label your images on-screen or to change the labels? Does the system offer the ability to create a custom "library" of commonly used terms? Some systems will use different libraries based on the particular scanning settings used, such as one library of annotation labels when scanning the foot and another library when scanning the shoulder.

Post-image processing ability is yet another feature to consider. The ability to label, to relabel, or even to change the appearance of an image or to take a measurement after the image has been taken and saved can be important. Sometimes it can be more efficient to go back and label or fine-tune your images after the visit instead of slowing down while performing the actual exam to change labels. Some systems do not allow any post-image processing at all; once the image is saved, it cannot be labeled or altered.

Finally, the ability to adjust the various parameters of power Doppler, such as pulse repetition frequency (PRF), wall filter, flash suppression, and gain, varies widely from one system to another. For those practitioners who utilize power Doppler to assess for neovascularity or synovitis or who find Doppler helpful to locate nerves via their attendant vascular structures, the ability to fine-tune Doppler settings can be an important consideration.

Oftentimes ultrasound novices are intimidated by systems that have a high degree of adjustability. For many, a less complicated "set it and forget it" system will meet their needs perfectly. As one becomes more skilled in ultrasound, however, the desire to move beyond the basics can be hampered by the limitations of certain systems. In those cases, the choice becomes one of buying a more robust system from the outset and "growing into it" or choosing a system that is more user-friendly to start and then upgrading over time.

Warranties and Extended Service Contracts

Ultrasound systems and probes are all expensive items. True to the saying, if something can break or go wrong, it will—at least, eventually. Most new systems come with a 1-year factory warranty. Beyond that, purchasing an extended warranty is worth considering. Transducers alone can cost up to $5000–10,000 to replace. In addition, most extended service contracts guarantee service within a specified period of time, often in 1–2 days. This minimizes system downtime and revenue loss. Without a service contract, you are often placed in a queue to wait for service, and repairs can be expensive.

Not all extended service contracts need to be purchased from the manufacturer, nor do they need to be purchased with a new system. There are companies that specialize in selling used and demo ultrasound equipment, and many offer extended service contracts; in some cases, they offer better pricing and service than the manufacturer.

By far the most important factor when choosing a system is to pick one that will meet anticipated needs while also fitting within any budget constraints. You should demo each system you are considering by having the company sales representative bring a machine to your office for a day or 2 to try on a variety of patients and scanning conditions. Most companies will gladly oblige such requests.

Finally, there are many financing options for ultrasound machines, including outright purchase with or without a payment program, or leasing. Again, your individual practice budgetary resources or the approach of your purchasing and financial departments, if you are at a larger medical center, will inform these decisions. See Table 3.1 for a comparison of ultrasound machines.

Transducer Care and Cleaning

Proper care and cleaning of ultrasound transducers is important, not only to maintain proper probe functioning but also to prevent infections and transmission of communicable diseases.

The official position statement of the American Institute of Ultrasound in Medicine states, "Practices must meet or exceed the quality assurance guidelines specified in Routine Quality Assurance for Diagnostic Ultrasound Equipment" [1]:

- Instrumentation used for diagnostic testing must be maintained in good operating condition and undergo routine calibration at least once a year.

Table 3.1 Ultrasound machine comparison

Machine type	Cost	Image quality	Image storage	Portability	Probes	Screen size
Tablet/handheld based	Lowest	Typically limited in depth, frequency, and optimization options compared to others	Limited; privacy may be a concern; not always DICOM compatible	Highly portable	Usually limited range of probes	Small, tablet- or smartphone-sized screen
Cart based	Typically in the middle	Typically good ability to optimize images for most MSK applications	Some, usually DICOM compatible	Can be moved easily in cart or taken out of clinic	Broad range of probes, sometimes need to unplug/plug in to change probes	Laptop-sized screen, usually clamshell with limited mobility
Console based	Highest	Typically best image quality with the most imaging options, so of which may not be used in MSK scanning	Usually greater than cart, often DICOM compatible	Usually designated to a room, not easy to take to another clinic or training room	Broad range, often push-button probe changes	Sometimes large, cinematic-sized screen on swing-arm for positioning

- All ultrasound equipment must be serviced at least annually, according to the manufacturers' specifications or more frequently if problems arise.
- There must be routine inspection and testing for electrical safety of all existing equipment.

Most ultrasound manufacturers offer guidelines for cleaning and maintaining the transducer. Practitioners are advised to follow the specific manufacturer's guidelines to prevent voiding any warranties. However, many guidelines are more general.

A generic cleaning protocol may include these points:

- Clean the transducer after each use (follow the manufacturer's guidelines).
- For the most part, the transducer is going to be used on the skin and is not going to be exposed to blood or any other bodily fluids. Wiping the transducer off with a soft cloth using a mild soap and water is acceptable after each use.
- An alternative to this is to clean the transducer with antimicrobial/germicidal wipes, with low alcohol content, a soft disposable cloth dampened with a bactericidal agent, or something similar.
- Before proceeding with any sterile procedure (injection or placing transducer near an open wound or lesion on the dermis), the transducer should be cleaned using an antimicrobial wipe. Many practitioners use sterile sheaths, so the transducer is never directly exposed to bodily fluids. If this is not the case, care should be taken to not expose the transducer directly to bodily fluids. If this happens, follow manufacturer's guidelines to properly sanitize the transducer.

The following should also be considered to properly maintain the transducer:

- It is always a good idea to reference the owner's manual or directly contact the company before using any non-referenced cleaner or sterilization techniques, so the transducer is not damaged.
- Avoid direct contact of the transducer head and cable with sharp objects, such as needles or scalpels.
- Do not clean the transducer with a brush or sponge without consulting the manufacturer, because these objects may damage the transducer head.
- When cleaning or disinfecting the transducer cable, always elevate the head above the cable. This ensures that the liquid on the cable does not drip onto the transducer head.
- Train all office staff with a written protocol/checklist for cleaning and maintenance of the ultrasound equipment.

Summary

Choosing an ultrasound system involves consideration of a number of important variables, only one of which should be price. Intended use, the degree of desire of the provider to master ultrasound, and physical space limitations are also important factors. Almost all of the current ultrasound systems marketed toward the musculoskeletal market will do an adequate job for the majority of musculoskeletal work. However, it behooves the purchaser to at least consider some of those details outlined in this chapter. Price should actually be among the least of the factors considered. In the vast majority of cases, over time, your ultrasound system will more than pay for itself. And over the course of 3–5 years (the length of time most practices keep a system before upgrading), a few thousand dollars become much less significant than the benefits of having not only a system that meets your needs but also one that is a joy to use.

Reference

1. https://www.aium.org/accreditation/qualityAssurance.pdf

4

Knobology

Adriana Isacke

The Machine

The principles of image capturing and quality improvement of images should be similar regardless of the brand of machine being used, though the specific terms for such functions may be different. Refer to the machine's user manual for the specifications.

Mode

There are various types (modes) of ultrasound images that are commonly obtained.

In **B-mode** (brightness mode) ultrasound, a linear array of transducers about the width of a credit card simultaneously scan a plane through the body that can be viewed as a two-dimensional image on screen. This is sometimes described as 2D mode, and it provides the single still images that are frequently used for documentation purposes to define structures.

M-Mode (motion mode) is used to capture multiple images in sequence. In simple terms, it collects a video of a particular scan.

Doppler Mode

The Doppler effect, where the sound frequency of an object changes as the object travels toward or away from the transducer, is used to help define the presence, direction, and velocity of blood flow on ultrasound. It is useful to help provide adequate information about the blood flow around a particular anatomical area. There are several different types of Doppler modes that can be used with most ultrasound machines. They are discussed below.

Color Doppler

This mode is used to define blood flow by superimposing color on a gray-scale ultrasound image. The use of color Doppler helps determine whether blood flow exists (i.e., identifies location of blood vessels) and is conventionally set up to show blue color when the blood flows away from the transducer and red color when it flows toward it. Flow velocity cannot be measured within this feature.

Clinical Application When performing a joint injection – of the hip joint, for example – the use of color Doppler can identify the location of blood vessels so the angle of approach can be set to avoid the path of the vessel.

Pulsed Wave or Duplex Doppler

This provides an image of a moving object along with its waveform. It shows both the presence of flow and defines the velocity of blood flow within a vessel.

Clinical Application During echocardiograms, this setting can define the presence and velocity of flow across a valve.

Power Doppler

This is color Doppler mode with a high sensitivity to blood flow to help visualize small vessels or vessels with slow flow. This mode assigns color regardless of the direction in which the blood flow is traveling. Color will appear when there is increased perfusion of an area secondary to inflammation or neovascularization. The weakness in using this technique is that its high sensitivity can create artifact in certain situations, such as transducer motion, thus making it seem as though vessels are present when they are not. This typically appears as a dense area of "color" on the screen. Additionally, it does not tell directionality or velocity of the flow seen.

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Clinical Application Power Doppler can be used to evaluate neovascularization of the patellar tendon in the setting of chronic tendinosis.

Frequency

A transducer has an inherent ability to send a range of sound wave frequencies toward tissue, which are described by the unit's megahertz (MHz). The higher the frequency of waves being sent, the higher the resolution of the image. However, higher frequency waves are unable to penetrate deeply in tissue and will be unable to clearly visualize deep structures. Low-frequency probes are able to penetrate tissue to find deeper structures and will provide a lower-resolution image.

Image Balance

Gain

Changing the gain is analogous to amplifying or suppressing the volume of signal in an image. By adjusting the gain up or down, visualization of certain structures becomes easier. Each ultrasound machine is equipped with an *autogain* feature, which is the machine's interpretation of the optimal level of gain for the body part or structure being scanned. When first starting out with scanning, autogain is likely going to be a useful tool. We recommend adjusting the gain manually to affect the image quality, then comparing it to autogain for image improvement.

Time Gain Compensation

The sound waves emitted by your transducer at the surface of the skin will attenuate as they travel through tissue on their way to the target. The time gain compensation (TGC) set of controls helps to fine-tune the gain in the areas of interest on the screen for improved visualization of the structures.

Depth

The depth to which a sound wave can penetrate tissue is linked to the frequency capability within your transducer. As noted previously, a high-frequency probe will provide high-quality images at a low depth, whereas a low-frequency probe will excel at visualizing deeper structure, though there may be a compromise in image clarity. When first starting an ultrasound examination, adjusting the depth of the picture is key to ensure that the structures of interest can be seen within the field of view. Each machine will have units of measure on the screen delineating (often in centimeters) the depth of the structure.

Clinical Application Depth can be helpful during an ultrasound-guided injection. The depth will assist in determining the proper position and length of the needle needed to reach a particular structure.

Focal Zones

Focal zones are used to visualize fine anatomy (i.e., follow a nerve course) or to focus the ultrasound beam on a particularly narrow anatomical region. Placing the object of interest into a focal zone ensures a higher-quality image of that object. It is best to minimize the number of focal zones used at a time, as the higher the number of focal zones, the image improvement will not be as robust.

Clinical Application When injecting a calcific tendinopathy, it may be wise to place the focal zone at the depth of the calcific density to optimize the image.

Documenting the Examination

During scanning or while performing a procedure, it is best practice to systematically save pictures or videos that best represent the structures of interest.

Text

Labeling an ultrasound image with text is an important step in documenting the examination for the medical record. The particular buttons that need to be used to label an image are specific to each machine. You can often initiate the text function while scanning if desired (i.e., placing "Right AC joint" on the screen to label multiple images of the same structure and allow for scanning of the structure to continue). You can also freeze the frame first and then add text. Several components should be included in your labeling – laterality, joint, structures of interest, whether the image was taken in short or long axis, and distal and proximal poles of the image. If the image is of an injection, it is important to delineate the needle position, gauge, and medication used.

Measurements

There will be many times when a measurement of a particular object seen on a screen is important. It is important to first freeze the frame of the picture of the object you are trying to measure. Again, the specific keystrokes needed to measure an object are unique to each ultrasound machine.

Clinical Application Measurements of the median nerve in the carpal tunnel distally and at the level of the pronator muscle can help in diagnosing carpal tunnel syndrome. Measurements of cystic structures before drainage and after drainage are important documentation to demonstrate success in the intended purpose (in this case, draining a cyst) of the ultrasound exam.

Initial Steps

Setting up your machine prior to scanning to get the highest-quality pictures possible is important. This includes choosing any presets that may be available on your machine (i.e., choose the body part you are intending to view; ensure you are in musculoskeletal imaging preset). Adding the patient's name and identifying information (i.e., date of birth) is important step for documenting the examination. Ensure the transducer you wish to use is connected to the machine. You can predict somewhat which transducer you will need by considering the depth of the object you are intending to study (i.e., the carpal tunnel is very shallow; the hip joint is very deep) and the size of the object you wish to study (i.e., it will be easier to use a small probe for fingers, larger probe for the shoulder).

As you begin your scanning of a particular body part, you will first adjust the depth until the image can be seen in the field of view. It is important to start with the depth set at maximum so structures are not missed. The depth can then be adjusted to provide the best screen image.

Next, adjust your focal zone. On some ultrasound machines, the focal zone can be adjusted to a specific location within the field. On other machines, you will adjust either the superficial or deeper zone depending on where the object you are visualizing lies. When first using this machine, you may omit this step.

Next, adjust the gain on the screen as needed. By adjusting the gain, you will see that certain structures come into better view.

Remember that you may need to readjust the settings on the screen as you scan for different views of anatomical structures.

Clinical Exercise

1. Become familiar with the controls on the machine by doing the following:
   (a) Demonstrate that you can easily change the transducers.
   (b) Label the scan with the patient's name, date of birth, date of scan, and body part.
   (c) Adjust the depth of the field so the image takes up the whole screen.
   (d) If your machine has presets for different tissues or body parts, select the appropriate one.
   (e) If your machine has focal zones, adjust those to the area that you want to scan (optional).
   (f) Adjust the gain on the machine in two extremes – one bright and one dark.
2. Record a scanned image – one bright and one dark – with the above settings and patient identification. Practice to the point that this is "second nature" by holding the probe in one hand and adjusting the settings in the other. Save the two images for documentation/homework.
3. Repeat the above process, but this time, record an image with:
   (a) Caliper measurements of a structure on the scan. Measure length, width, and circumference of the structure.
   (b) Perform a dynamic scan, such as the impingement exam of the shoulder or valgus stressing of the ulnar collateral ligament of the thumb or elbow.
   (c) Turn on the color Doppler and identify an artery and vein.
   (d) If your machine has the capability, perform a panoramic exam of the structure such as the Achilles or patellar tendon.

Suggested Reading

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Tissue Scanning

5

J. Herbert Stevenson

Ultrasound Equipment

Ultrasound equipment at its most basic level includes a transducer (probe) connected to an ultrasound computer that includes a CPU, monitor, keyboard, transducer controls, hard drive, and sometimes a printer (Fig. 5.1). The transducer contains quartz crystals that utilize the piezoelectric electric effect, which transforms electrical current into sound waves and vice versa. The piezoelectric effect allows the probe to generate sound waves that propagate through soft tissue.

Probes come in different shapes and sizes (Fig. 5.2); their use depends upon the clinical indication. A linear probe is most often utilized in musculoskeletal medicine as it allows for more accurate evaluation of structures close to the skin surface. A curvilinear probe by comparison allows great resolution of deeper structures. Linear probes transmit at a higher frequency, generally in the range of 8–18 MHz. The higher frequency allows them to obtain greater resolution of near-field structures at the sacrifice of depth and penetration. When greater depth of visualization is required, a curvilinear probe is preferred. Common clinical indications in musculoskeletal ultrasound for utilization of a curvilinear probe include ultrasound of the hip, spine, and glenohumeral joint. Ultrasound of small structures, including the hands and feet, may be best visualized with a small-footprint probe such a "hockey stick" probe. The sound waves are able to be reflected back or echo at varying rates depending upon the type of tissue they encounter. The probe is then able to receive the mechanical sound waves and transform them into an electric current that can be analyzed by the CPU. The data are subsequently displayed as two-dimensional real-time images on the screen. There is now new technology available to perform this task using a computer chip. This innovation allows the use of just one probe to do all tissue scanning.

Anatomic Terminology

A thorough understanding of body sections and anatomical planes is required in order to properly perform and interpret musculoskeletal ultrasound images. Body sections can be

Fig. 5.1 Image of ultrasound equipment

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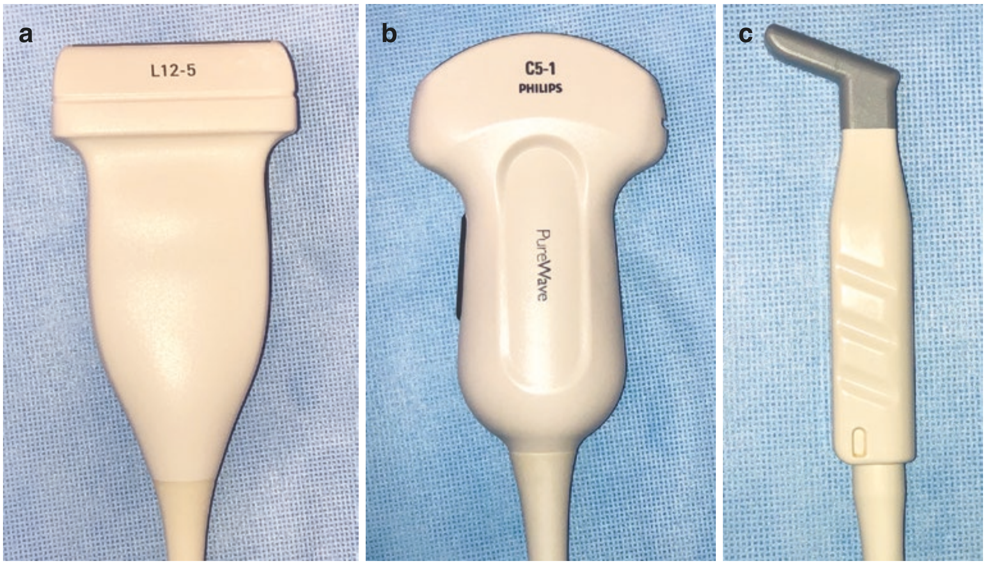

Fig. 5.2 (**a**, **b**, **c**) Linear, curvilinear, and "hockey stick" probe

divided into sagittal, transverse, and coronal planes (Fig. 5.3). A sagittal plane is a vertical plane passing from front to back through the body separating it into a left and right partition. A transverse plane is one that passes along a horizontal plane dividing the body into an upper and lower partition. A coronal plane is a vertical plane passing from side to side that divides the body into ventral and dorsal partitions.

Anatomic definitions illustrated in Fig. 5.3 include anterior, posterior, proximal, distal, lateral, medial, cranial, and caudal.

Ultrasound Terminology

Ultrasound terminology differs from descriptive terminology utilized in other modalities such as MRI because it describes the echogenicity of the structures being imaged. Echogenicity refers to the extent to which different substances and structures within the body reflect sound waves. The greater the percentage of sound waves that are reflected from a particular structure, the higher the echogenicity of the structure detected by the probe. Different tissue types will produce unique echogenic images that tend to be consistent across tissue types (i.e., muscle, tendon, bone). The higher a structure's echogenicity, the brighter it will be displayed on the monitor. Conversely, the lower a structure's echogenicity, the darker it will appear (Fig. 5.4a, b). The following is a list of descriptive ultrasound terminology:

- Hyperechoic (HYPER): high reflectivity displayed as a bright or light signal. Bone (radial head (RH)) and tendon are examples of hyperechoic objects.

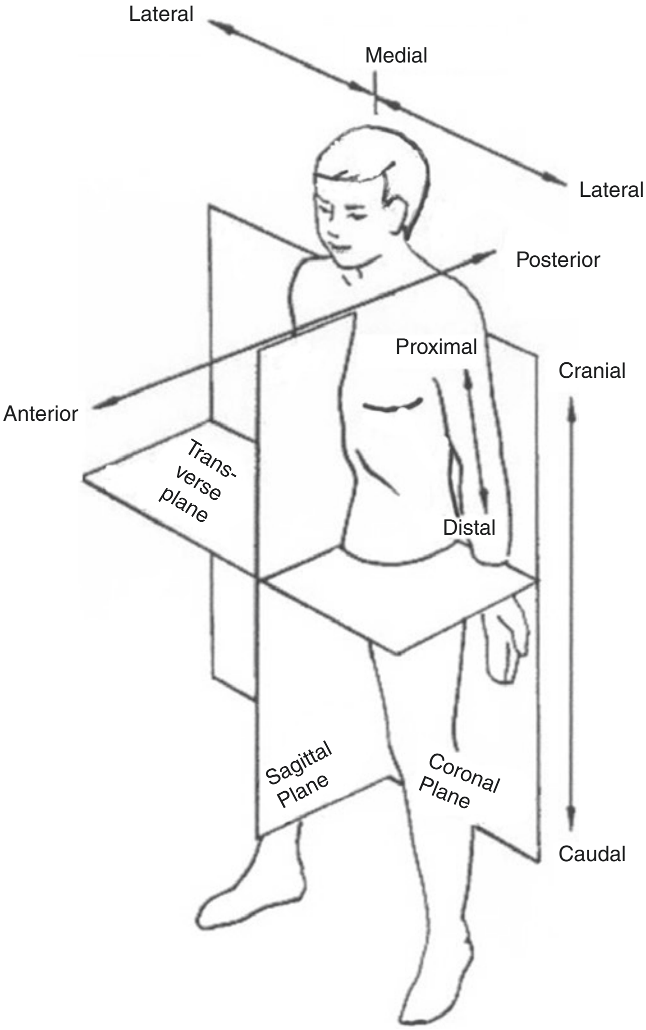

Fig. 5.3 Sagittal, transverse, and coronal planes. Anterior, posterior, proximal, distal, lateral, medial, cranial, and caudal. (Adapted from http://msis.jsc.nasa.gov/images/Section03/Image64.gif)

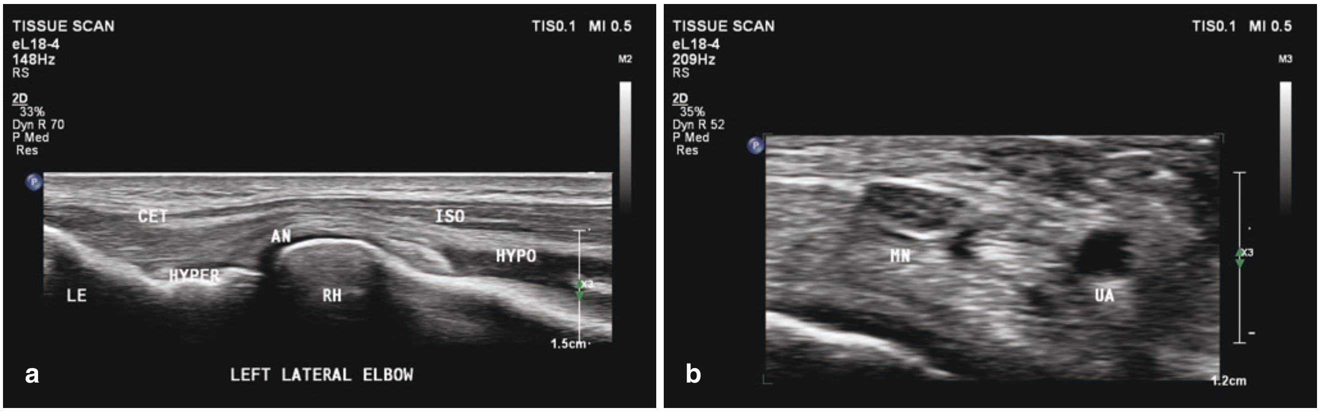

Fig. 5.4 (**a**) Lateral elbow: examples of hyperechoic (HYPER), isoechoic (ISO), hypoechoic (HYPO), anechoic (AN). (**b**) Short-axis view of hyperechoic median nerve (MN) and anechoic ulnar artery (UA)

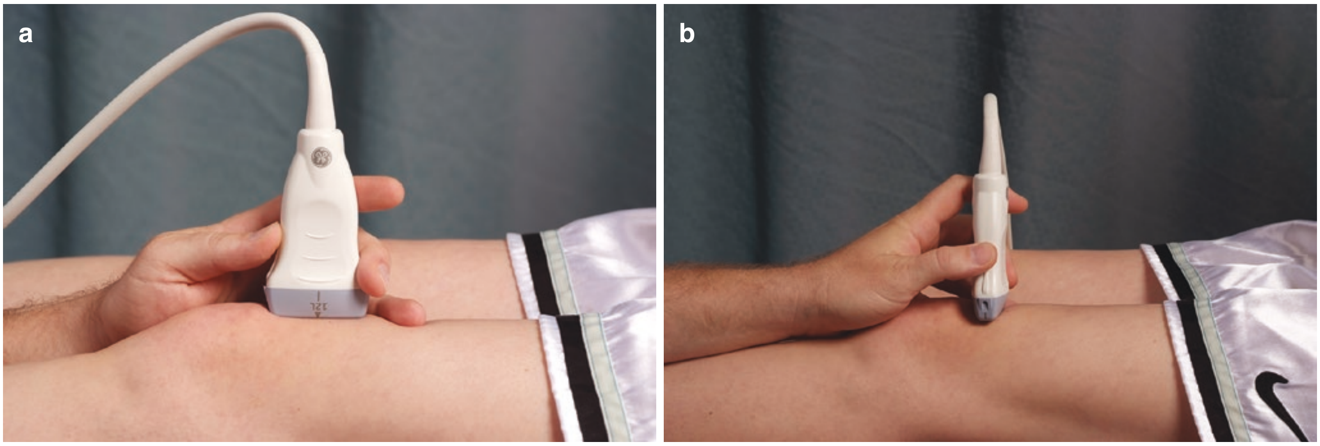

Fig. 5.5 (**a**, **b**) Proper handling of an ultrasound probe

- Isoechoic (ISO): when two adjacent objects are of equal echogenicity (common extensor tendon (CET) and fascia).
- Hypoechoic (HYPO): low reflectivity displayed as a darker area. Muscle fiber bundles are an example of hypoechoic structures (muscle fibers).
- Anechoic (AN): absence of ultrasound reflectivity/signal displayed as a black area. Fluid and articular cartilage are commonly displayed as anechoic.

Technical Aspects of Ultrasound Image Acquisition

The ability to acquire a clear and accurate image with musculoskeletal ultrasound requires a systematic approach along with a sound understanding of three-dimensional anatomy. Additionally, the ability to manipulate the probe in its three planes of movement is crucial, as even slight alterations in probe position will significantly affect the quality of the image. Ultrasound competency requires routine practice and repetition to become proficient in its use.

Probe Handling

Probe handling is essential to the proper performance of an accurate and repeatable ultrasound exam. A steady and secure handling of the probe will facilitate a clear image with minimal artifact. The probe should be held in a steady but not rigid grip between the thumb on one side of the probe and the second and third fingers on the other side. The fourth and fifth fingers, along with ulnar/hypothenar aspect of the palm, should rest on the skin of the patient examined. This connection to the patient at all times will facilitate a secure platform from which to manipulate the probe for optimal image resolution (Fig. 5.5a, b).

Probe Coupling Agents

Coupling of the probe to the skin is necessary to provide a link between the transducer and the patient. The sound waves produced and received by the transducer will not pass through air. A coupling agent is required and generally consists of gel or a standoff pad.

Gel

Ultrasound gel is an ideal medium that allows for coupling of the ultrasound signal without providing distortion. Gel should completely cover the probe surface but not be too excessive so as to cause one to lose grip of the probe. Bony surfaces or irregular surfaces may require additional gel to compensate for the peaks and valleys of the surface, allowing for uniform coupling. Finally, sterile gel should be utilized for ultrasound-guided injections/aspirations/needle procedures when the needle may potentially come in contact with the gel.

Standoff Pad

The standoff pad is made of an acoustically transparent medium that provides a compliant surface to image bony or uneven surfaces. Standoff pads also assist in imaging shallow or sensitive areas by increasing the depth of the structures and providing a cushioned surface (Fig. 5.6).

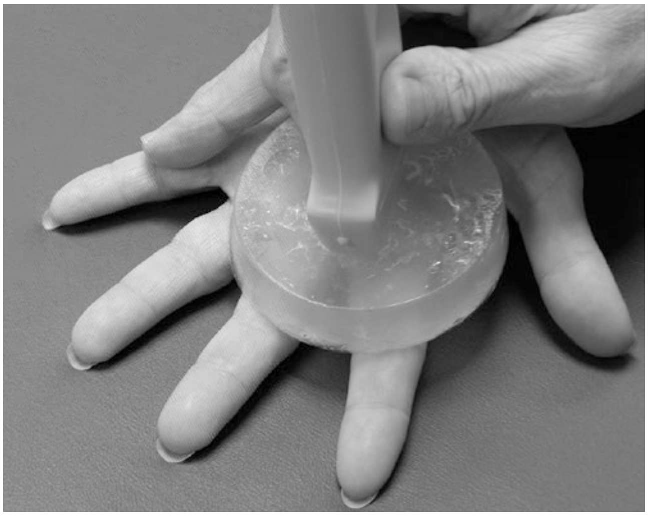

Fig. 5.6 Standoff pad

Probe Orientation to the Patient

In order to maintain consistency, the left side of the probe should correlate with the left side of the screen, while the right side of the probe should correlate with the right side of the screen. Most commercial probes will have a notch or indicator light on one side of the probe that aligns with the same side of the display, allowing for rapid detection of orientation. An important point is to ensure that both the examiner and the patient are comfortable during the procedure. The patient may be positioned on a table, recliner, or stool. The examiner should be sitting with the US monitor close and at the proper height (eye level) to comfortably perform the exam.

By convention, the probe should be oriented cephalad when in a sagittal or coronal plane. When the transducer is in the axial plane, the left side of the probe should align with the right side of the patient's body; conversely, the right side of the probe should align with the left side of the patient's body. Some clinicians may reverse this depending on their hand dominance during certain procedures. A simple way to check for probe orientation related to the patient and the screen is to gently tap one side of the probe (with gel applied) with a finger and look at the screen to determine probe orientation. Any orientation is acceptable as long as it is consistent, marked, and documented.

Probe Axis to the Imaged Structure

Once the probe is placed on the skin, the probe will need to align with the long or short axis to the structure one is visualizing. The long (or longitudinal) axis is along the plane that parallels the greatest length of the structure, while the short (or transverse) axis runs perpendicular to the long axis and parallel to the greatest width of the structure (Fig. 5.7a, b). Figure 5.7a is an ultrasound screenshot corresponding to the long-axis probe placement over the quadriceps tendon demonstrated in Figs. 5.5a and 5.7b is an ultrasound screenshot corresponding to the transverse probe placement over the quadriceps tendon demonstrated in Fig. 5.5b.

Probe Manipulations

Once on the skin, the ultrasound probe can be manipulated along any of its three axes of movement (X, Y, Z axis) to facilitate proper image acquisition. Key to image acquisition is the centering of the object desired and optimizing the ultrasound probe, so the beam is aimed perpendicular to the structure. The manipulation of the probe is particularly important when imaging curved or irregular structures. The five probe planes of manipulation as defined by the American Institute of Ultrasound in Medicine are listed below:

- *Sliding*: translates the probe along the length or width to the structures without rocking or tilting the probe. This allows visualization of the structure in length as well as width (Fig. 5.8a, b).

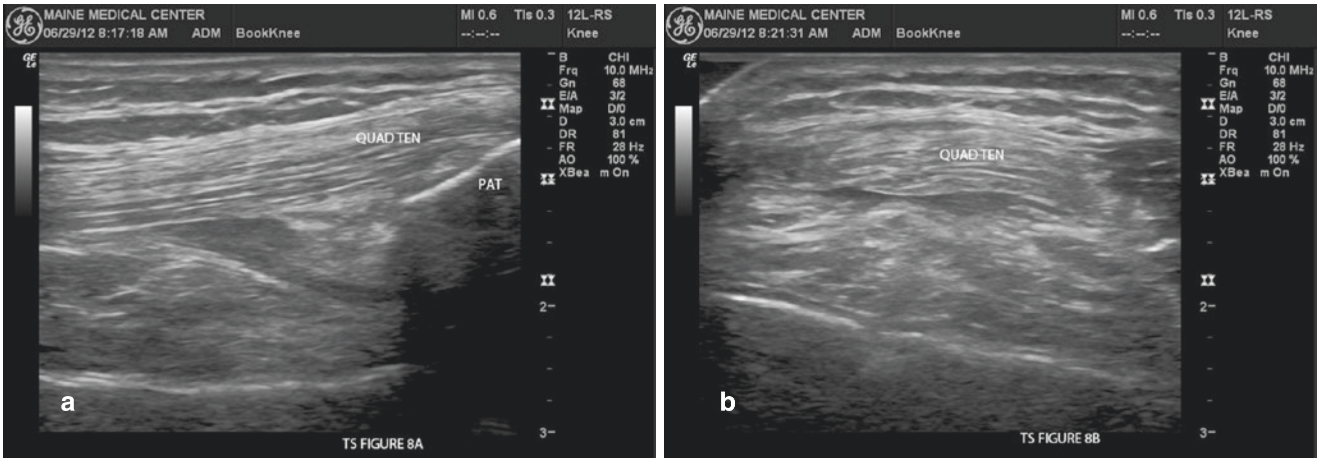

Fig. 5.7 (**a**, **b**) Long- and short-axis views

- *Rocking*: tilting (heel-toe movement) of the probe to one edge or the other (Fig. 5.8c, d). This is helpful when there is a narrow window of imaging, and adjacent structures are to be centered or visualized. Rocking may also facilitate extending the field of view, such as in the cephalic or caudal direction. A common example of rocking is utilized to visualize the proximal biceps tendon that runs in a deep to superficial direction as it passes through the bicipital groove.
- *Tilting*: the side-to-side movement of the probe to bring additional planes of tissue into focus without sliding the probe (Fig. 5.8e, f).
- *Rotating*: movement of the probe in clockwise or counterclockwise movement. Rotating facilitates obtaining the long- and short-axis views of structures (Fig. 5.8g, h).
- *Compression*: pressing down with the probe. Compressible structures such as veins or bursa fluid will decrease or disappear with compression. Compression also allows deeper structures to appear more superficial. Finally, compression may allow proper contact between the probe and patient to allow clear visualization on curved or irregular structures (Fig. 5.8i).

Focusing/Knobology

Focusing may be done prior to placing the probe on the skin if the ultrasound machine has appropriate presets for the structures imaged (i.e., shoulder, knee, wrist). Conversely, focusing may occur manually after the probe has been placed on the skin. A thorough understanding of the controls and their appropriate settings (“knobology”) is another key element in obtaining an accurate and optimal image. Knobology is discussed in detail in Chap. 4.

Ultrasound Imaging Artifact

Numerous ultrasound artifacts can occur and affect the proper imaging and interpretation of anatomic structures. These often occur due to the change of sound propagation through different tissue densities as well as alterations in the path taken by the US beam. An understanding of these artifacts and why they occur will enhance one’s ability to properly interpret ultrasound images.

Anisotropy

Anisotropy is the property of tendons, nerves, and muscle to display a different appearance depending upon the angle the ultrasound signal is directed (insonation). When an ultrasound sound beam is at an angle less than 85°, the majority of the sound waves will not reflect back to the transducer. This results in a normally hyperechoic (bright) structure appearing hypoechoic (dark). Tendons exhibit the greatest amount of anisotropy, and the loss of the normal tendon fibrillar structure may be misinterpreted as a tear or area of tendinosis. The operator can correct the anisotropy by angling the probe sound waves perpendicular to the structure with the maneuvers described above. Figure 5.9a shows anisotropy of the flexor tendons in the carpal tunnel, and Fig. 5.9b shows anisotropy resolved using tilting.

Acoustic Shadowing

Acoustic shadowing is the attenuation of sound waves due to very dense substance that reflects nearly all the sound waves. Figure 5.10 shows acoustic shadowing from the scaphoid in the volar wrist. This results in a lack of visualization deep to

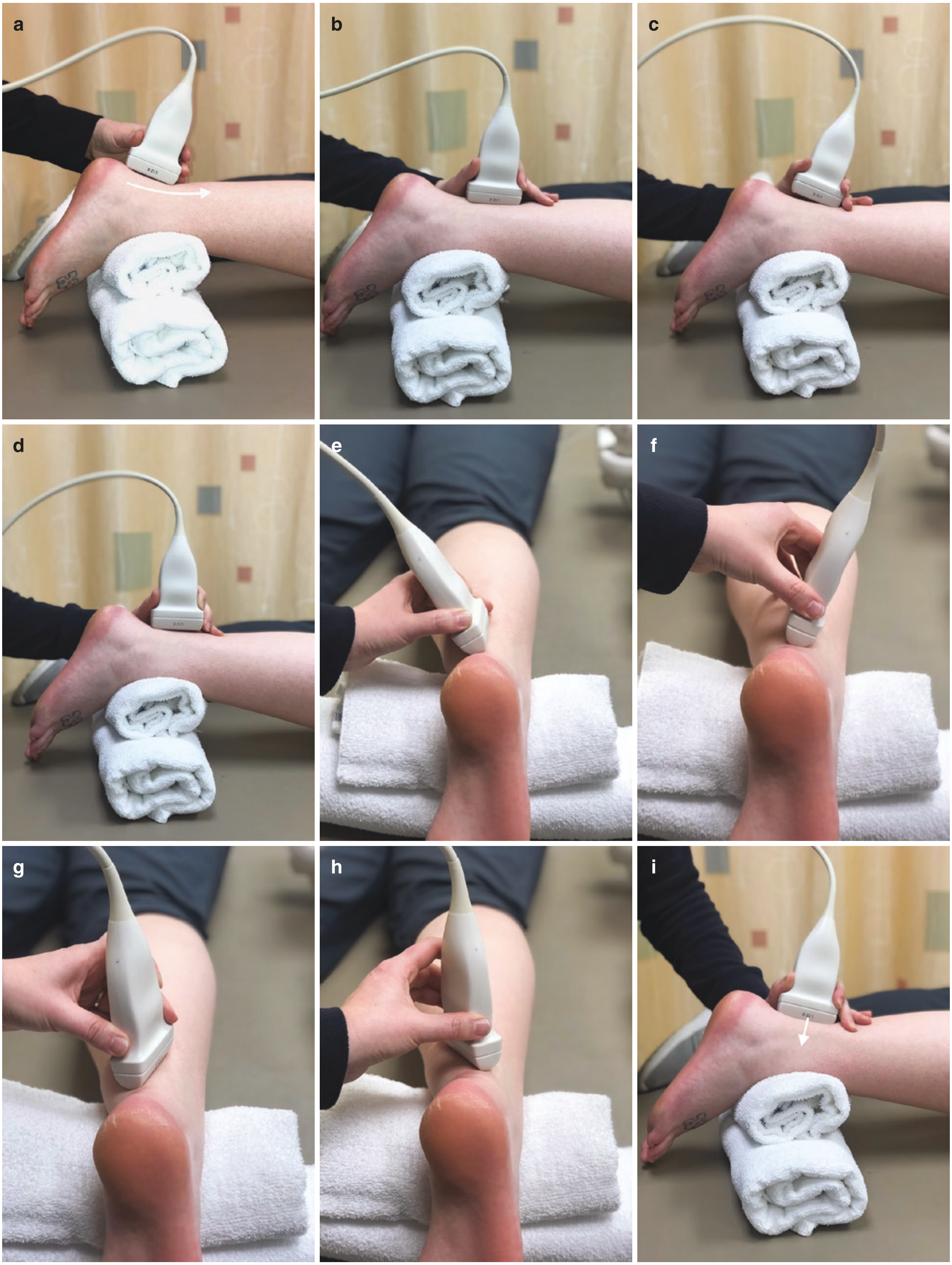

Fig. 5.8 (**a**–**i**) Example of five probe movements: sliding, rocking, tilting, rotating, compression

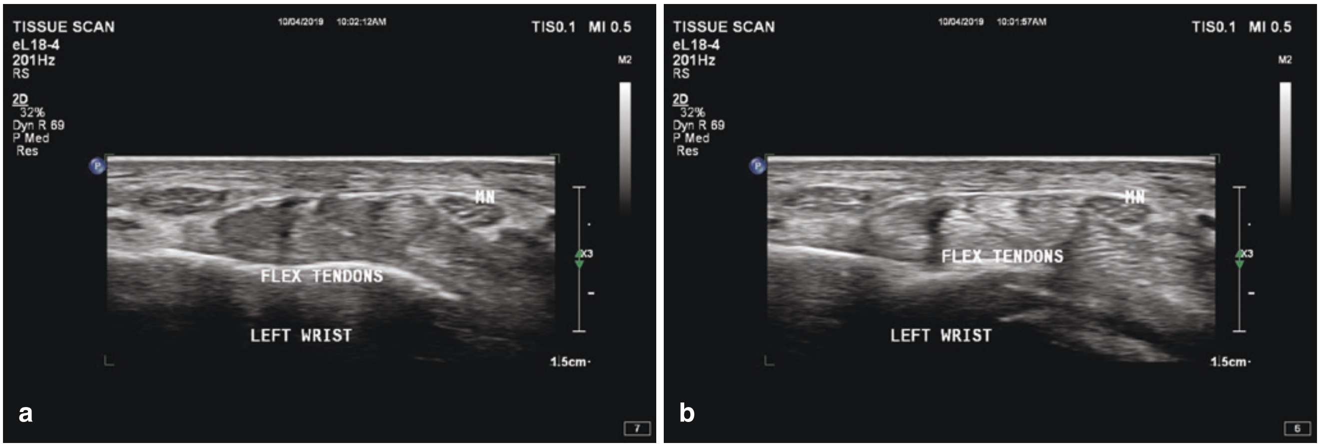

Fig. 5.9 (**a**, **b**) Example of anisotropy (**a**), anisotropy resolved (**b**)

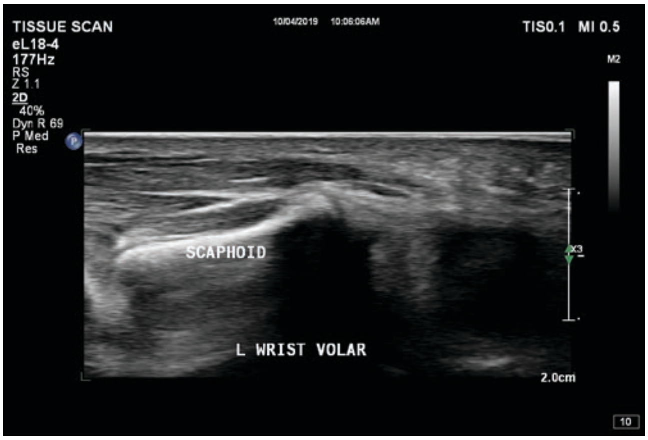

Fig. 5.10 Example of acoustic shadowing

the structure. Commonly, this can occur from bone, foreign bodies, and intratendinous/muscular calcifications.

Acoustic Enhancement

Acoustic enhancement results from sound waves passing through anechoic (black-appearing) structures (fluid). The structures deep to the fluid then appear more echogenic than the same tissue on either side of the fluid. Figure 5.11 shows acoustic enhancement of the biceps tendon (BT).

Reverberation Artifact

Reverberation artifact results from sound waves reflecting back and forth between the surface of the transducer and a highly echogenic structure. The resulting image is one of evenly spaced lines of the structure at increasing depths. Needle guidance is a common scenario in which reverberation artifact can occur when the needle is near perpendicular to the probe (Fig. 5.12).

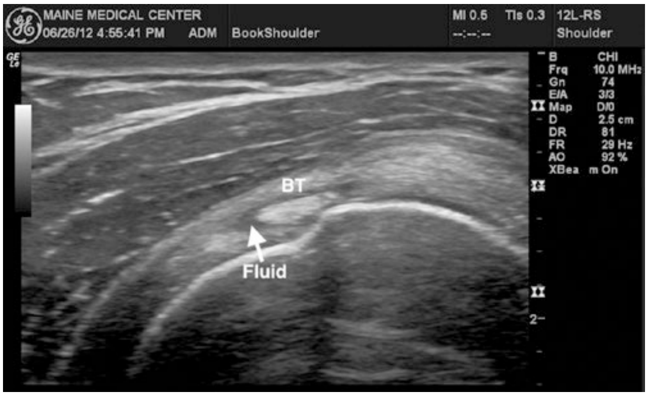

Fig. 5.11 Example of acoustic enhancement

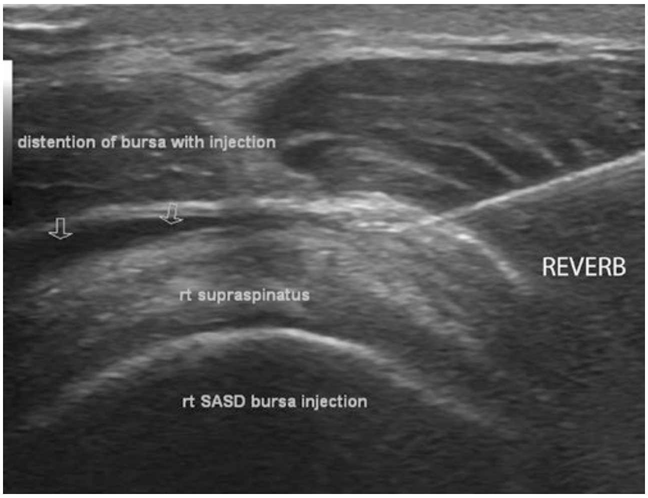

Fig. 5.12 Example of reverberation artifact

Refraction Artifact

Refraction artifact is also known as edge shadowing and occurs distal to the edges of curvilinear structures. Sound waves impacting a curved surface are refracted/bent from their original direction, resulting in falsely hypoechoic edge shadowing distally (Fig. 5.13).

Ultrasound Imaging of Normal Tissue

The understanding and identification of normal tissue architecture is fundamental to performing musculoskeletal ultrasound. The following is a brief overview of the different tissue characteristics that help differentiate one from the other.

Skeletal Muscle

Skeletal muscle is viewed as a heterogeneous structure with hypoechoic muscle fiber bundles interspersed with hyperechoic stromal connective tissue (perimysium). On long-axis view, this will give a pennate appearance similar to barbs converging on a feather (Fig. 5.14a, gastrocnemius and soleus muscles, long axis). The hyperechoic stromal connective tissue will converge toward the end of the muscle into the muscle tendon. Muscle on cross section is displayed as a "starry night" appearance, with wavy, hyperechoic connective tissue interspersed with the hypoechoic muscle fibers (Fig. 5.14b, gastrocnemius and soleus muscles, short axis).

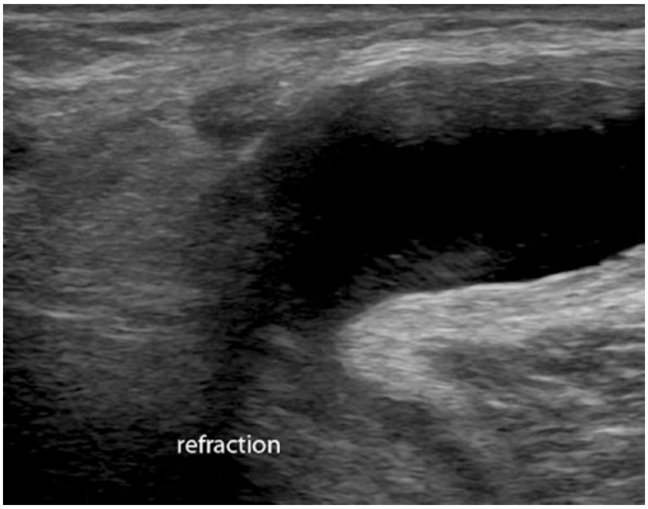

Fig. 5.13 Example of refraction artifact

Tendons

Tendons are displayed as a mixture of bright echogenic tendon fibers interspersed with hypoechoic surrounding connective tissue in a parallel course. On long-axis view, this results in a linear fibrillar appearance. Tendons imaged on short-axis view will demonstrate hyperechoic collagen bundles seen in short-axis view interspersed between hypoechoic connective tissue. Because of the compact fibrillar structure of tendons, they can suffer from anisotropy artifact if visualized at an angle less than perpendicular (Fig. 5.15a, Achilles tendon in long axis; Fig. 5.15b, Achilles tendon in short axis).

Ligaments

Ligaments are visualized as bright hyperechoic linear fibrils with linear areas of hypoechoic connective tissue (Fig. 5.16). Ligaments have a similar appearance to tendons but tend to be more compact, with their individual collagen fibrils more closely aligned. Ligaments may also suffer from anisotropy artifact when imaged.

Fascia

Fascia is displayed as hyperechoic (bright) structure (Fig. 5.17, fascia in hamstring). Fascia thickness can vary depending on the structure and location imaged.

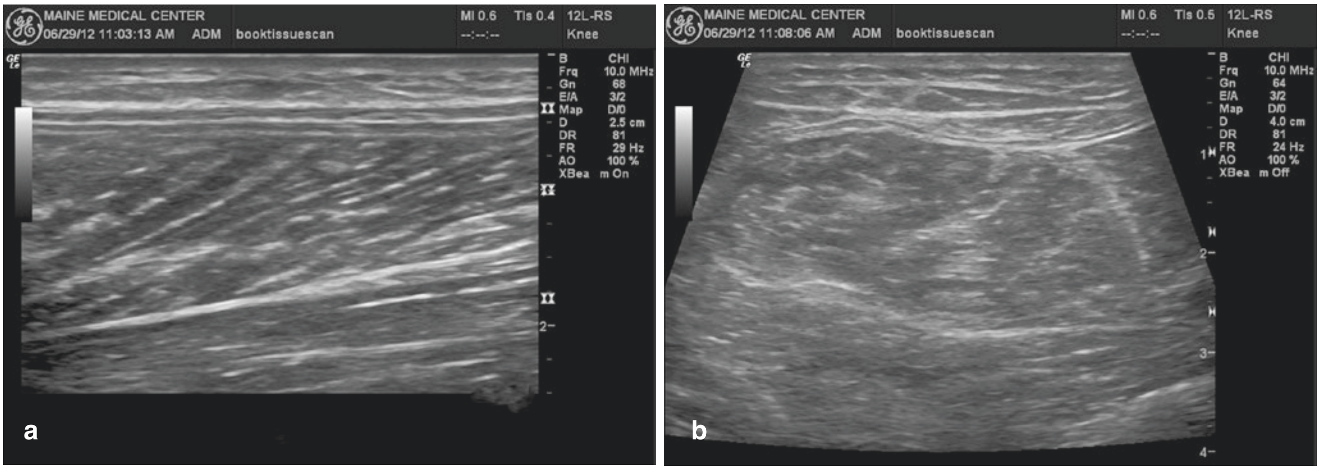

Fig. 5.14 (**a**, **b**) Example of skeletal muscle, long and short axis