How to Improve Accuracy of Ultrasound-Guided Procedures

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1. Introduction

Ultrasound guidance has traditionally been used to obtain biopsies of masses or abdominal organs, but more recently, it has gained increased recognition for musculoskeletal use, including injection of cervical articular facets, navicular bursa, coxofemoral joints, and sacroiliac joints. All of these structures are otherwise challenging to access using blind techniques. Although these reports illustrate the benefits of ultrasound guidance and describe the approach to these structures, the basic principles of ultrasound-guided procedures are frequently challenging. The expanding use of intralesional therapeutics for tendon and ligament injuries has also created a greater need for practitioners skilled in its use. Ultrasound guidance ensures that these products are deposited directly into the injured portion of the tendon or ligament. The relative expense of intralesional therapeutics to horse owners should encourage practitioners to use ultrasound guidance to maximize any potential beneficial effect. Other benefits of ultrasound guidance include accurate needle placement and increased diagnostic yield when faced with a focal lesion in a large structure such as the spleen or liver (Fig. 1). Ultrasound guidance also prevents inadvertent entry into vital structures such as adjacent bowel or blood vessels that can occur with blind procedures. Lastly, ultrasound guidance can be used for multiple purposes during intra-operative procedures including localization of fracture fragments, masses, or foreign bodies.

The purpose of this paper is to provide the equine practitioner with an easy to follow, step-by-step approach to performing successful ultrasound-guided procedures using a free-hand technique. These techniques can be applied regardless of the structure being injected, aspirated, or biopsied.

2. Materials and Methods

In our opinion, the most important factor when performing ultrasound-guided procedures is for the ultrasonographer to handle both the transducer and the needle/sampling instrument. This is similar to the principles of arthroscopy where coordination is maximized by one surgeon controlling both the arthroscope and instruments. This individual should
have a strong knowledge of ultrasound principles and excellent transducer manipulation skills. We typically employ a second person to handle syringe placement during aspiration or injection procedures. During biopsy procedures, this person controls the biopsy instrument after the needle is positioned by the ultrasonographer (Fig. 2). After the needle is properly placed, the ultrasonographer’s sole responsibility is to ensure that the needle remains stable and is not inadvertently advanced during the injection or sampling procedure. This can only be accomplished by simultaneous real-time visualization throughout the ultrasound-guided procedure.

Site Selection

The site for injection, aspiration, or biopsy should be chosen after thorough ultrasonographic examination to determine the most superficial access to the structure of interest while avoiding overlying vital structures or vasculature. Clipping the hair provides the best image quality for most procedures. After the site has been chosen, Wite Out (quick dry correction fluid) is ideal to mark its location on the skin surface. Two to three marks should be placed at 90° angles at an appropriate distance from the injection site so that they will not be removed during aseptic preparation (Fig. 3). Extension of these lines should intersect at the intended site of sampling. These markings define the region to be prepped and allow rapid revisualization of the intended target. Scanning depth should be set so that the structure being aspirated, injected, or biopsied is centered within the ultrasound image. The distance from the skin surface to the targeted area

Fig. 1. Ultrasound-guided aspirate of a focal mass (arrowheads) within the right liver lobe (RLL) of a 28-yr-old Quarter Horse with hepatic adenocarcinoma. Ultrasound guidance insured accurate placement of the needle tip (arrow) within this 3- to 4-cm mass and prevented inadvertent sampling of the underlying large colon (LC). This image was obtained with a 3.5-MHz curvilinear transducer at a depth of 13 cm.

Fig. 2. Technique to perform an ultrasound-guided procedure. The ultrasonographer is in control of both the transducer and the needle throughout the procedure. An assistant supports the automated biopsy instrument as the needle is positioned into the appropriate location by the ultrasonographer. Note that the needle placement is dorsal to the transducer to improve maneuverability and avoid contamination by the transducer cord compared with ventral needle placement.

Fig. 3. Preparation for ultrasound-guided procedure with Wite Out markings delineating the area to be aseptically prepped. The biopsy site can be quickly relocated at the intersection of imaginary lines extending from the marks.
Deeper structures such as the coxofemoral joint, sacroiliac joint, or abdominal organs, 6- to 9-in needles are required, depending on the size of the horse. Biopsy needles for use in horses generally range from 14 to 18 gauge. For the majority of biopsy procedures, we have found that 16-gauge biopsy needles yield a quality tissue sample without causing excessive trauma, whereas the smaller 18-gauge needle often does not harvest adequate tissue.

**Patient Preparation**

The patient should be placed in stocks when available and restrained by a skilled handler. Sedation is generally necessary for all ultrasound-guided procedures. The exception is when performing intra-synovial diagnostic analgesia during lameness exams, most commonly of the bicipital bursa. Detomidine HCl (0.004–0.008 mg/kg, IV) or xylazine HCl (0.01–0.02 mg/kg, IV) is used for the majority of procedures. Butorphanol tartrate (0.01–0.02 mg/kg, IV) may also be added, especially when performing biopsies of abdominal organs. A moderate plane of sedation is preferable to deep sedation so that the horse stands without swaying. We typically place a lip twitch unless the horse strongly resents its use. The region should be aseptically prepared in routine fashion using wide margins to accommodate the transducer and needle as well as the steriley gloved hands of the examiner and assistant.

**Transducer Preparation**

Ultrasound-guided procedures require sterile preparation of the ultrasound transducer. Sterile transducer covers are commercially available, but we find that large sterile surgical gloves will easily fit over most transducers and are more economical. The technique to dress a large curvilinear or tendon linear transducer is shown in Figure 5. It is important to remember to place ultrasound gel between the transducer and sterile glove, because any amount of intervening air will interfere with image acquisition. For procedures using a microconvex transducer, the transducer can simply be placed into a finger of the glove because of its small size. For intra-operative procedures, a sterile rectal sleeve can be placed over the steriley gloved transducer to prevent contamination of the surgical field by the transducer cord.

**Technique**

Alcohol is the ideal coupling agent for ultrasound-guided procedures and is best applied with a designated spray bottle. After donning sterile gloves, the ultrasonographer holds the transducer in one hand and the needle in the other hand. The intended target is then relocated using the Wite Out marks as guides. If desired, a SC bleb of local anesthetic can be placed aseptically at the needle site (Fig. 6). We generally use local anesthetics for all biopsies and perineural anesthesia for procedures involving the distal limbs, but we do not find it...
necessary for most other procedures. The advantage of placing the local anesthetic at this time is that the bleb remains visible and does not diffuse into SC tissues during the prep procedure.

When introducing the needle into the skin, care must be taken not to place the needle too close to the gloved transducer, because this increases the possibility of glove penetration and subsequent loss of sterility. For deeper procedures, we typically place the needle 1–2 cm away from the transducer to improve the ability to manipulate the needle. Placement of the needle proximal (or dorsal) to the transducer serves to decrease the likelihood of contamination by the transducer cord compared with distal needle placement. As the needle is advanced, it must remain within the plane of the ultrasound beam to be visualized in its entirety (Fig. 7). This is often the most difficult aspect of the procedure. Correct needle placement relative to the transducer is shown in Figure 8. Common needle placement errors that will not result in needle visibility are shown in Figure 9. Needle angulation relative to the transducer must also be considered based on the depth of the intended target. Superficial structures require a shallow angle of insertion (needle hub farther away from the transducer; Fig. 10A), and deep structures require a steep angle (needle hub closer to transducer; Fig. 10B).

When properly placed, the needle tip should be visible soon after entry through the skin. When sampling deeper structures, the needle may need to be advanced 2–3 cm before becoming visible. If not visible, the needle has not been maintained within the ultrasound beam because of an error in needle placement (Fig. 11). Slow, sweeping motions of the transducer are often successful in relocating the needle (Fig. 12). After the needle is localized and it is still on an accurate path to the intended structure (i.e., needle and target visible on same image), the needle may continue to be advanced. If, however, the structure cannot be accessed with the needle’s current placement (i.e., needle and target not visible on the same image), the needle must be redirected according to its position relative to the intended structure (i.e., cranial or caudal). It is important to

Fig. 5. Technique for sterile preparation of a large curvilinear transducer. The same procedure can be used for a tendon linear format transducer. (A) Place ultrasound coupling gel on transducer head. (B,C) Stretch large sterile glove over transducer head. (D) Leave edge of cuff at mid transducer level. (E) Reflect wrist of glove back to transducer-cord junction. (F) Gather and hold cuff firmly around cord. Allow fingers of glove to drape downward. (G) Grab fingertips and pull back to transducer-cord junction. (H) Gather and hold cuff and fingertips firmly around transducer-cord junction. (I) Secure with white tape. (J) After donning sterile gloves, hold the transducer as shown. The back one-half of the gloved transducer and the portion of the ultrasonographer’s hand closest to the white tape should not be considered sterile.

Fig. 6. Correct placement of a SC bleb of local anesthesia using aseptic technique in preparation for a right liver lobe biopsy. The bleb should be placed 2–3 cm from the top of the transducer at the chosen needle site.
remember that previous needle tracts often remain visible and can be confused with the needle itself. It is sometimes helpful to choose a slightly different approach to avoid confusing the needle with previous needle tracts. The needle should be continuously monitored on the ultrasound screen as it is advanced toward the target. If needle movement is not detected as the needle is being advanced, the ultrasound beam is slightly oblique relative to the needle. Usually, only slight transducer movements are required to correct this problem.

Although commercially available needle guides are available for ultrasound-guided procedures, they do not guarantee needle visibility and carry a number of disadvantages. Each guide is designed to fit only a specific transducer and is not interchangeable between different size transducers. They are relatively expensive and must be sterilized after each use. Because they attach directly to the ultrasound transducer, glove breakage and subsequent loss of sterility is common. Finally, some needle guides are situated at a predetermined angle that restricts needle positioning or repositioning. For these reasons, we feel that the free-hand technique is much preferable. Even slight movements of the horse can change the desired direction and angle of the needle. The free-hand technique allows for rapid and unrestricted corrections throughout the procedure and can be mastered with practice.
Biopsy Phantoms

For practicing ultrasound-guided procedures, a biopsy phantom can be constructed with double-strength unflavored Knox gelatin made according to the package directions. After adding items such as olives, small peppers, and/or small balloons or fingers from exam gloves filled with water, the mixture is poured into an enema bag, sealed, and refrigerated until firm. The phantom can be used repeatedly for several weeks if kept refrigerated.

Practice Tips for Intraleisional Tendon and Ligament Injection

For injections in the distal limb (metacarpal, metatarsal, and pastern), placement of regional perineural anesthesia maximizes patient tolerance and personnel safety. After the needle is properly placed, it is important that the ultrasonographer stabilize the needle at all times so that it is not inadvertently advanced when the syringe is attached by the assistant. Syringe attachment after needle placement reduces the risk of injectant loss if the horse reacts to needle placement. Division of the injectant into 2–3 syringes also reduces loss from blowouts and other complications. The degree of resistance should be noted during injection. If significant resistance is met, the needle may not be located within the lesion and should be withdrawn or advanced slightly until the solution can be injected. The ultrasound image should be monitored in real time to insure proper intraleisional deposition throughout the procedure (Fig. 13). In our experience, multiple injection sites are not necessary for all injuries. Because the injectant distributes along the path of least resistance (region of fiber tearing), it often extends along the length of the lesion with one needle placement (Fig. 14). Large areas of injury (>10–12 cm in length) typically require more than one needle placement. Ultrasonographic monitoring during injection is helpful to determine the distribution of injectant and the need for additional sites of injection.

Although the majority of procedures are performed in the weight-bearing limb for injections into the proximal suspensory ligament of the hindlimb, we have found it useful for an assistant to hold the limb in flexion after placement of local anesthesia. This results in improved limb control, and the resultant tendon and ligament laxity facilitates needle placement. The use of a lateral approach from the

Fig. 10. Needle angle and positioning considerations based on the depth of the target from the skin surface. (A) When sampling superficial structures, the needle is entered at a shallow angle relative to the skin surface with the needle hub oriented away from the transducer. (B) When sampling deeper structures, the needle is entered at a steep angle relative to the skin surface, and the needle hub is oriented close to the transducer.

Fig. 11. Schematic representation of a common error in needle placement. The needle has entered the skin appropriately, but it has been directed slightly outside the ultrasound beam and is no longer on a path to the intended target. The needle’s position relative to the target must be identified, and the needle must be repositioned appropriately as in Figure 12.
plantar aspect of the fourth metatarsal bone also helps to avoid the flexor tendons and medial vasculature.

Practice Tips for Intrasyovial Injection/Aspirate
When placing a needle for intrasynovial procedures, visualization of the needle tip within the joint capsule can occur due to synovial tenting and does not always indicate synovial penetration. If fluid is not obtained on aspiration, needle twisting may produce enough fluid to obtain a diagnostic sample. Another technique is to advance the needle until contact with bone or tendon is made and then to withdraw the needle slightly. Gentle negative pressure should be exerted as overzealous aspiration often causes synovial obstruction of the needle. Similar to intralesional injections, real time monitoring should be used to insure appropriate intrasynovial placement of anesthetic or therapeutic agents. Finally, when using spinal needles for sample collection or injection, the stylette should be replaced prior to removal to maximize therapeutic effect and to prevent contamination of surrounding structures.

Practice Tips for Abdominal Procedures
The majority of transabdominal biopsy or aspirate procedures involve the kidneys, liver, or spleen. The ultrasonographer should confirm the absence of overlying bowel and should choose a site that minimizes the risk of inadvertent penetration of bowel deep to these structures. For biopsy procedures, a stab incision through the skin with a #50 scalpel blade after placement of SC anesthesia will prevent needle drag when advancing the needle through the skin. When at the target, it is important to consider the distance that the biopsy needle will be advanced or “thrown” during the biopsy procedure. The “throw” of most biopsy needles is 1–2 cm regardless of whether or not an automated biopsy instrument is used. Therefore, it is sometimes necessary to place the tip of the needle at the edge of a small lesion to obtain a diagnostic sample. Finally, it is important to avoid inadvertently advancing the nee-
dle deeper into the patient during sample acquisition. It is our preference to obtain 2–3 samples wherever possible to maximize diagnostic yield. Acquisition of an automated biopsy instrument greatly facilitates biopsy procedures. One is used for all of our biopsy procedures because of a reduction in procedure time and improved accuracy of sampling compared with free-hand technique.

3. Results

From January 2005 to December 2008, 235 horses underwent at least one ultrasound-guided procedure by the Large Animal Ultrasound Service at the William R. Pritchard Veterinary Medical Teaching Hospital. A total of 484 procedures were performed and included 356 injections, 77 aspirates, 42 biopsies, 7 intra-operative procedures, and 2 tendon- or ligament-splitting procedures. Of the procedures, 97% (470 of 484) were considered successful (the sample was obtained or the injectant was placed correctly). The most common reason for an unsuccessful procedure was that no fluid was obtained on aspiration. No significant complications were associated with any procedure, including biopsy of abdominal structures.

Musculoskeletal procedures were most common, including 284 intrasynovial aspirations or injections and 16 periarticular injections, primarily of the sacroiliac joint. Intra-articular cervical facet injections were the most common procedure and were performed in 48 horses (Fig. 15). The articular facets of C6–7 (46 horses) were most often injected followed by C5–6 (39 horses) and C4–5 (30 horses). Sites of injection were based primarily on radiographic evidence of osteoarthritic changes of the facet joints. All were injected bilaterally because of the lack of communication between facet joints and the inability to definitively lateralize abnormalities.

Depo-Medrol^1 (20–80 mg per site) was used in nearly all horses. The amount injected was primarily based on the number of injection sites. Aspiration or injection of the bicipital bursa was the second most common intrasynovial procedure and was performed in 11 horses. Procedures were performed for intrasynovial anesthesia (7 horses), confirmation of sepsis (2 horses), and intrasynovial treatment of non-septic bursitis (2 horses). Ten coxofemoral joint injections were performed in six horses for diagnostic (3 horses) and treatment purposes (3 horses). Although an alternative ultrasound-guided approach has been described,^7 we prefer to use a dorsal needle approach relative to the transducer to prevent needle-transducer cord contact and to enable better external visualization for

Fig. 14. Longitudinal ultrasound image of a ruptured peroneus tertius tendon (arrows) after ultrasound-guided injection of stem cells at the level of the mid tibia. Note the proximal to distal extent of injectant with hyperechoic gas echoes that resulted from just one needle placement and injection. Because of the length of this injury (24–30 cm), two additional sites were chosen to ensure adequate distribution of injectant.

Fig. 15. Positioning of the spinal needle (18-gauge, 3.5-in needle) and transducer for an ultrasound-guided intra-articular cervical facet injection and corresponding ultrasound image. The horse’s head is to the right of the image. The needle (arrows) remains visible throughout the ultrasound image to the joint space (JT) because of its correct placement within the ultrasound beam. This image was obtained with an 8.5-MHz small curvilinear (microconvex) transducer at a depth of 8 cm.
needle placement (Fig. 16). Additional intrasynovial procedures involved the digital sheath (4 horses), elbow joint (4 horses), lateral femorotibial joint (3 horses), middle carpal joint (2 horses), patellar joint (2 horses), tarsocrural joint (1 horse), tarsal sheath (1 horse), extensor carpi radialis tendon sheath (1 horse), calcaneal bursa (1 horse), femoropatellar joint (1 horse), medial femorotibial joint (1 horse), and infraspinatus bursa (1 horse). The majority of these structures were sampled to evaluate for sepsis and were confirmed through cytology in 12 cases. Two horses with temporomandibular joint swelling were confirmed to be septic by ultrasound-guided aspiration. Additional needles were subsequently placed for through-and-through lavage as a standing procedure in both horses.

Injection of the suspensory ligament (34 horses) was the most common intralesional procedure and was performed at one or more sites in 29 horses. Injections were similarly divided between forelimbs (18 horses) and hindlimbs (16 horses) and involved the suspensory origin (21 horses), mid-to-distal suspensory body (6 horses), and suspensory branches (11 horses). The superficial and deep digital flexor tendons were injected in 16 and 12 horses, respectively. Other intralesional procedures included the short dorsal sacroiliac ligaments (8 horses), collateral ligaments of the distal interphalangeal joint (7 horses), abaxial palmar (plantar) ligaments of the proximal interphalangeal joint (3 horses), and distal sesamoidean ligaments (oblique [three horses]; straight [2 horses]). The supraspinous ligament, peroneus tertius, inferior check ligament, and intersesamoidean ligament were each injected in one horse. Products used included platelet-rich plasma, stem cells (bone-marrow–derived mesenchymal cells or stromal vascular fraction containing fat-derived mesenchymal cells), and bone-marrow aspirate concentrate. The choice of injectant was often based on clinical preference as well as client budget.

Liver biopsy (18 horses), aspiration (3 horses), or both (3 horses) was the most common transabdominal procedure. Twenty samples were obtained from the right liver lobe, and 7 were obtained from the left liver lobe. The majority of biopsies differentiated between various hepatopathies. Most were submitted for culture, and a positive bacterial growth was found in only 2 cases. An additional horse also grew *Corynebacterium pseudotuberculosis* from an aspirate sample. A positive diagnosis of neoplasia was obtained through biopsy samples from 5 horses. Renal procedures included 8 biopsies and 3 aspirates. The right and left kidneys were sampled in 8 and 3 horses, respectively. Aspiration of a left and right renal abscess in 2 different horses yielded mixed growth with large numbers *Streptococcus equi ss zooepidemicus* and pure growth of *C. pseudotuberculosis*, respectively. Biopsy confirmed various nephropathies in 6 of 7 submitted samples. Another horse underwent biopsy of a large mass that extended between both kidneys. Splenic biopsy (5 horses), aspiration (2 horses), or both (1 horse) was performed in 8 horses. Aspiration confirmed splenic abscessation caused by *C. pseudotuberculosis* (1 horse) and *E. coli* (one horse). Splenic biopsy yielded a positive diagnosis of T-cell lymphoma (1 horse), B-cell lymphoma (1 horse), and metastatic melanoma (1 horse). One foal with an extensive caudal abdominal abscess caused by *S. zooepidemicus* underwent ultrasound-guided aspiration, lavage, and drainage through a transgluteal approach.

Nine peripheral abscesses were aspirated; this included 6 horses with large *C. pseudotuberculosis* abscesses deep within the triceps region, all of which underwent ultrasound-guided incision, drainage, and lavage because of the close proximity of these abscesses to the heart (Fig. 17). Intrathoracic masses were sampled in 2 horses, yielding a diagnosis of melanoma and granular cell tumor, respec-
by application of transducer pressure. Procedures can be ultrasonographically monitored and assisted within an abscess. (D) Drainage of the abscess during lavage.

Fig. 17. (A) The ultrasonographic appearance of a large (19 × 20 × 8 cm) *C. pseudotuberculosis* abscess located deep to the triceps musculature in a horse with right forelimb lameness and triceps swelling. The typical depth and size of these abscesses requires a low-frequency (2–5 MHz) transducer for complete visualization. Note the close proximity of the abscess to the heart (RA, right atrium; RV, right ventricle). (B) Ultrasound-guided placement of an 18-gauge, 8-in spinal needle into the caudal extent of the abscess. The most superficial extent of these abscesses is often located at this site 6–10 cm dorsal to the olecranon. This needle will be used for aspiration and then as a guide for incision and drainage through blunt and sharp dissection. (C) This ultrasound image shows a large-bore chest tube within an abscess. (D) Drainage of the abscess during lavage procedures can be ultrasonographically monitored and assisted by application of transducer pressure.

4. Discussion

The use of ultrasound guidance in our hospital has steadily increased throughout the study period from 60 procedures in 2005 to 142 procedures in 2008. This is partially caused by increasing demand for cervical facet injections and intralesional treatment for tendon and ligament injury. It is also because of its beneficial effects on patient management in many types of cases. As our skill level has improved over the years, the diagnostic yield of sampling procedures has also increased. Our high success rate (97%) is similar to that reported in other studies (72–100%) and has the added benefit of shorter procedure times compared with blind-injection techniques. This has had a direct impact on treatment planning and case management, especially in cases of septic arthritis or septic tenosynovitis. Such horses often have minimal effusion with severe synovial thickening that complicates acquisition of a diagnostic sample. Ultrasound is extremely valuable to localize small pockets of fluid for sampling and also to help identify the best site that minimizes the potential for contamination from overlying lacerations or cellulitis.

Ultrasound has also been valuable for obtaining diagnostic samples from abdominal organs to differentiate between inflammatory, infectious, or neoplastic conditions, all of which can produce a similar ultrasonographic appearance. This has been especially helpful to confirm renal, hepatic, and splenic *C. pseudotuberculosis* infection as well as other abnormalities that may present with focal, relatively small lesions, especially in the early stages of disease. Antimicrobial selection can then be based on culture and sensitivity results to maximize treatment effect. Without ultrasound guidance, the likelihood of obtaining a diagnostic sample from these sites would depend on luck. In addition, the somewhat variable size and position of the liver lobes and kidneys can increase the risk of bowel penetration during blinded biopsy procedures that are based on external landmarks alone.

The number and diversity of cases presenting for ultrasound-guided procedures at our hospital illustrate its widespread acceptance and perception of value by our clinicians and represent a steady increase compared with previous years. The low complication rate reported by multiple studies cited in this report is mirrored by that of our own experience. Our approach to ultrasound-guided procedures represents an accumulation of experience gained while sampling multiple regions in the horse for a variety of purposes. We hope that this report can serve as a foundation for practitioners new to ultrasound-guided procedures and to assist those who may have struggled with the procedure. Our high success rate, coupled with the absence of significant complications, should encourage equine practitioners to incorporate the use of ultrasound-guided procedures into their practice.
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References and Footnotes

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