ULTRASONOGRAPHIC IMAGING OF SKELETAL MUSCLE IN NORMAL DOGS

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SUMMARY

Adult greyhound cadavers which had been euthanased for other reasons within 24 hours were used in this study. The scanning was performed on thigh, brachial and scapular regions. A real time B-mode portable scanner (Capasee, TOSHIBA) connected with 7.5 MHz transducer was used in the study. All scanned images were recorded on super VHS tape using a Panasonic video recorder connected to the scanner. The recorded images were later reviewed using an Interspec (Apogee-cx) ultrasound machine. The thermal copies of the best images were produced during review and labelled accordingly. Normal muscle appeared to have consistant ultrasonographic characteristics. Good detail of muscle could be visualized with an high frequency transducer and the detail of the muscle structure could be highlighted including the connective tissue fascia surrounding the muscle fibres, the endomysium. Each muscle group could be well defined, separated by a thin fascia which appeared hyperechoic. Ultrasound would appear to be an excellent modality in imaging of normal muscle structure in small animals.

Keywords: ultrasonography, skeletal muscle, greyhound.

INTRODUCTION

Improvement in ultrasound technology and the development of high resolution transducers in recent times have made imaging of the musculoskeletal system in small animals possible. Until now, ultrasonographic imaging of the musculoskeletal system in humans has been well documented (Heckmatt *et al.*, 1988b; Wilson, 1988; Harcke *et al.*, 1988; Fornage, 1989; Kaplan *et al.*, 1990; van Holsbeeck and Introcaso, 1992). In small animal veterinary practice a few articles have been found in the literature (Berry *et al.*, 1992; Kramer *et al.*, 1997). The homologous hypoechoic background was found to represent the muscle fibres or muscle bundles, and the multiple, fine parallel echoes represent the fibroadipose septa (perimysium) surrounding the muscle bundles (fasciculi) (Kaplan *et al.*, 1990). In transverse images the muscle shows a moderately circular appearance, with spotted areas of increased echogenicity representing the perimysium scattered throughout a homogenous hypoechoic background (Fornage *et al.*, 1983; Gooding *et al.*, 1987). Furthermore, the connective tissue fascia enveloping the muscle appears hyperechoic, separating the muscle groups (Kaplan *et al.*, 1990). Muscle generally appears less echogenic relative to subcutaneous tissue or tendons, and the echogenicity of contracted muscle is often less than that of relaxed muscle (Kaplan *et al.*, 1990).

By using the advance B-mode real time ultrasound scanner (Capasee TOSHIBA) equipped with an high resolution 7.5 MHz linear array transducer the present study was carried out with the aim of observing and defining the normal ultrasonographic characteristic of skeletal muscle of the thigh, ventral abdominal, brachial and scapular regions of normal greyhound cadavers.

MATERIALS AND METHODS

Animals and preparation technique

Four adult greyhound cadavers which had been euthanased for other reasons within 24 hours were used in this study. Upon arrival, the cadavers were examined physically prior to ultrasound scanning. Skin preparation was performed on the thigh, brachial, scapular and ventral abdominal regions. The thigh region was prepared from the level of the hip joint to the level of the stifle joint. The brachial region was prepared from the level of the shoulder joint to the level of the elbow joint. The scapular region was prepared from the dorsal border of the scapula to the level of shoulder joint, and the ventral abdominal region was prepared from the level of the xyphoid cartilage to the pubic brim. The hair of these regions was removed using clippers.

For the thigh muscle scanning, the right and left thighs were marked transversely and longitudinally respectively with a permanent marker pen on both lateral and medial aspects of the thigh at two centimetre intervals. The marked lines were then identified by numbers. For the brachial and scapula regions, the areas for scanning were marked transversely perpendicular to the body of the humerus and the spine of the scapula respectively at two centimetre intervals and identified by numbers. Similarly, the ventral abdominal region was marked transversely across the mid-line at two centimeter intervals from the pubic brim to the level of the xyphoid cartilage and identified by numbers.

Ultrasonographic imaging

Ultrasonographic imaging was conducted in a semi-dark room. The cadaver was laid on the table in lateral recumbency for scanning of the thigh, brachial and scapular regions, and in dorsal recumbency for scanning the ventral abdominal region. The gel was applied prior to scanning. The transducer was then applied directly in contact with the skin surface. The scanning was done on both lateral and medial aspects of the thigh and brachial regions, on the lateral aspect of the scapular region, and on the ventral abdominal region according to the marked lines.

To scan the thigh muscles, the transducer was moved slowly but firmly from the caudal to cranial aspect in transverse scans, and from proximal towards distal in longitudinal scans according to the marked lines on both lateral and medial aspects. The sagittal scans were performed from proximal to distal on the caudal aspect. The hind limb was slightly extended during scanning by traction of the pes.

For the brachial and scapular regions, the scanning was performed transversely perpendicular to the humerus and spine of scapula respectively according to the marked lines, and longitudinally along the muscle fibres on the lateral aspect of the brachium. Longitudinal scans were also done on the scapula region parallel to the spine of scapula. The humerus was used as a reference point in sagittal and parasagittal scans of the brachium. The scanned images were identified by numbers according to the numbers of the marked lines.

A real time B-mode portable scanner (Capasee, TOSHIBA) connected with 7.5 MHz transducer was used in the study. All scanned images were recorded on super VHS tape using a Panasonic video recorder connected to the scanner. The recorded images were later reviewed using an Interspec (Apogee-cx) ultrasound machine. The thermal copies of the best images were produced during review and labelled accordingly.

Gross section preparation

For the thigh muscle, after scanning was done, the cadaver was frozen in a standing position at -20∞C for three days. The hind limbs were then sectioned from the body at the fourth lumbar vertebra. The two hind limbs (left and right) were then separated and serially sectioned transversely and longitudinally respectively according to the marked lines. The sections were place in sequence on the tray and identified by numbers according to the numbers of the marked lines. The sections were cleaned to remove the excess fat and dirt by passing under running tap water for a few second and gentle rubbing of the surface with wet paper tissue. The sections were partially thawed prior to examination to correlate with the scanned images produced earlier.

For the brachial and scapular regions, after the scan was done the left and right forelimbs were removed from the body prior to freezing. The limbs were serially sectioned according to the marked lines, cleaned, partially thawed and examined as above before being photographed.

RESULTS

Skeletal muscle of the greyhound cadavers imaged ultrasonograpically in general showed the same characteristics. Serial ultrasonographic images of the thigh and brachial muscle scanned transversely correlated well with the gross anatomy sections (Fig. 1). The scapular muscles scanned transversely across the spine of scapula and longitudinally parallel to the spine of scapula also correlated well with the gross anatomy sections. A sagittal scan of brachial muscles is shown in Fig. 2.

Normal skeletal muscle imaged ultrasonographically appeared as an homogenously hypoechoic structure with fine echoes scattered throughout the muscle parenchyma. Each muscle group could be identified, separated by a thin hyperechoic structure which was actually the connective tissue fascia. The normal skeletal muscle imaged transversely perpendicular to the muscle fibres appeared homogenously hypoechoic with poorly organised fine echoes corresponding to the fibroadipose septa scattered throughout the muscle parenchyma. In longitudinal images along the muscle fibres, skeletal muscle appeared as homogenous fine parallel echoes scattered throughout the hypoechoic muscle parenchyma. As in the transverse scan, the muscle groups were separated by the thin hyperechoic layers of connective tissue fascia. The bone appeared as a strong hyperechoic image with complete acoustic shadowing distally when the transducer was correctly inclined.

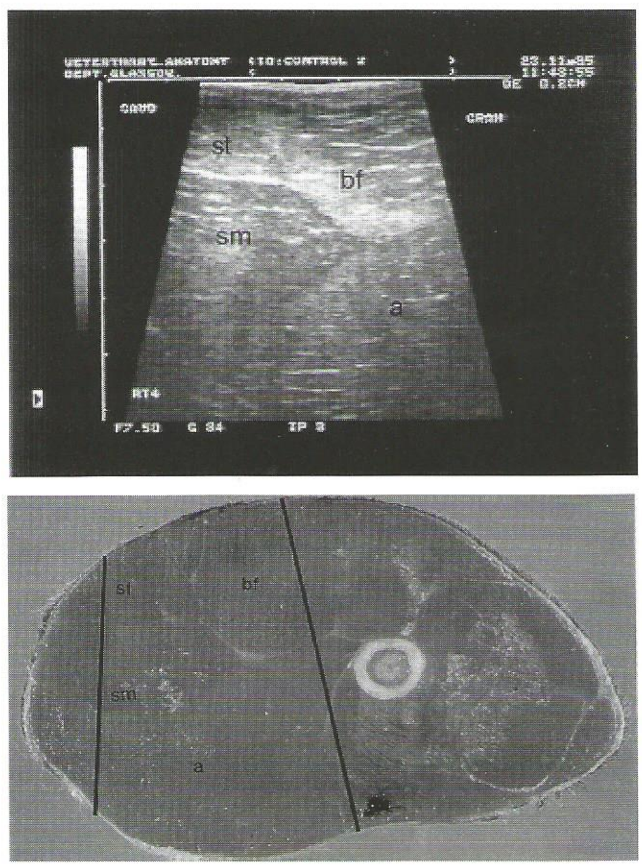


Fig. 1. Transverse image of the thigh muscles on caudo-lateral aspect and its correlation with the gross anatomy section. The muscles appear hypoechoic with poorly organized fine echoes. The muscle groups are separated by thin connective tissue fascia (epimysium). sm, semimembranosus muscle; st. semitendinosus muscle; bf, biceps femoris muscle; a, adductor muscle.

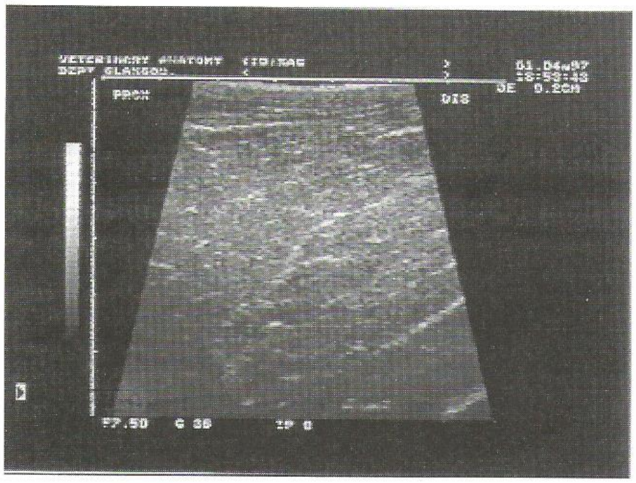


Fig. 2. Sagittal scan of brachial muscles of the left fore limb from caudal aspect. Note that muscle tissue appears hypoechoic with disorganized fine echoes scattered throughout the muscle parenchyma.

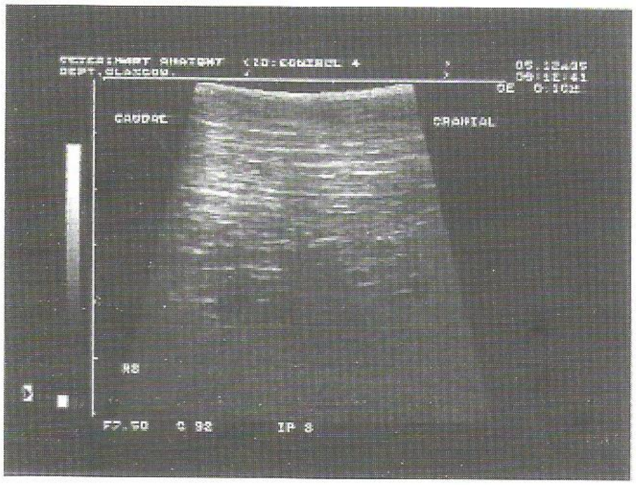
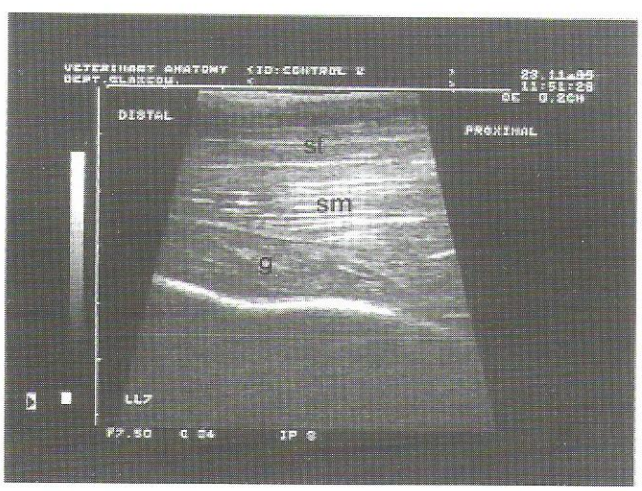


Fig. 3. Sagittal scan of the thigh muscles from the caudal aspect. Note that the muscle appears hypoechoic with fine parallel echoes corresponding to the fibroadipose septa surrounding the muscle fibres.



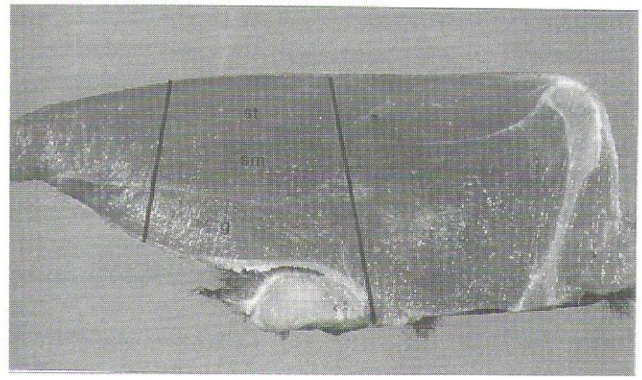


Fig. 4. a. Longitudinal scan of the thigh muscles from the caudo-lateral aspect demonstrates the semimembranosus muscle (sm) and semitendinosus muscle (st) with fine parallel echoes within the hypoechoic background, and the gracilis muscle (g) with homogenous fine echoes. Note that the image is well correlated with the gross section in b.

Sagittal scanning of the thigh muscles caudally demonstrated a typical ultrasonographic appearance of the skeletal muscle imaged along the muscle fibres (Fig. 3).

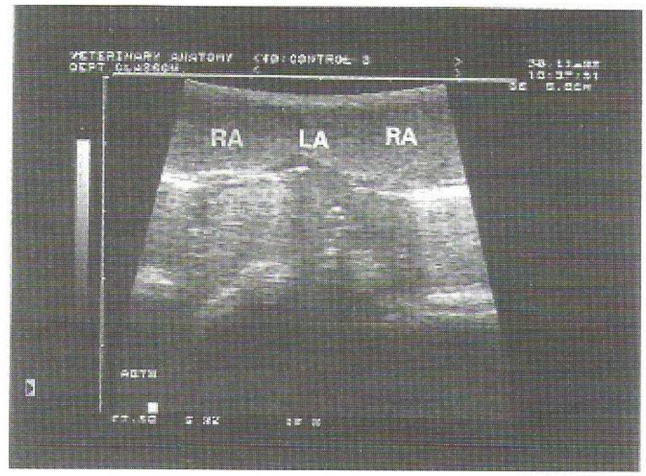


Fig. 5. Transverse scan of the ventral abdominal mid-line caudal to the umbilicus. Note that the ventral abdominal mid-line (linea alba) appears isoechoic relative to the muscle echotexture. LA, linea alba; RA, rectus abdominis muscle.

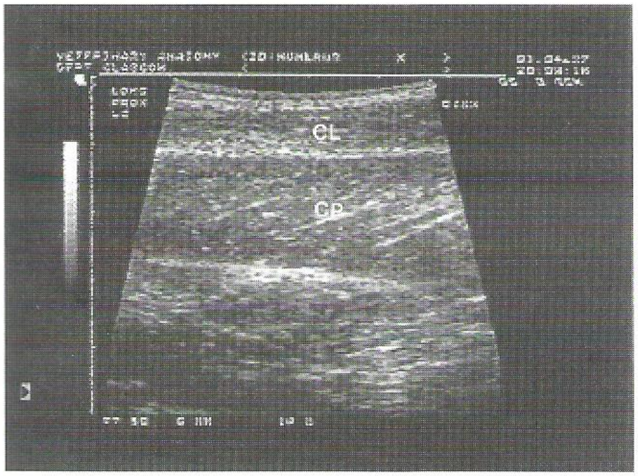


Fig. 6. Longitudinal scan of brachial muscles on latero-caudal aspect of the fore limb. Note that the muscle appears hypoechoic with a characteristic of 'feathery appearance' produced by the *caput longus* of the triceps muscle. The connective tissue fascia, perimysium surrounding the muscle fibres is responsible for this appearance. CL, caput lateralis; CP, caput longus.

In contrast the sagittal scan of brachial muscle caudally appeared more as in a transverse scan (Fig. 2). The connective tissue fascia (perimysium and epimysium) appeared as hyperechoic fine parallel echoes in sagittal scan along the muscle fibre axis. Ultrasonographic imaging of the thigh muscles longitudinally on the latero-caudal aspect demonstrated two different groups of muscle with different muscle fibre orientation. The semitendinosus and semimembranosus muscles appeared hypoechoic with fine parallel echoes while the gracilis muscle appeared as homogenous and hypoechoic with fine parallel echoes (Fig. 4). These groups of muscle were separated by hyperechoic connective tissue fascia.

The ultrasonographic image of the ventral abdominal region scanned transversely is shown in Fig. 5. The linea alba appeared isoechoic relative to the surrounding muscle tissue. The connective tissue fascia enveloping the rectus abdominis muscle appeared hyperechoic.

The caput longus of the triceps muscle gaves a characteristic of "feathery appearance" on a longitudinal scan (Fig. 6). This appearance was produced by sheaths of connective tissue (perimysium) surrounding the muscle bundles.

DISCUSSION

The normal ultrasonograpic appearance of the skeletal muscles has been documented in both human and animals (Harcke *et al.*, 1988; Fornage, 1989; Kaplan *et al.*, 1990; Smith *et al.*, 1996; Kramer *et al.*, 1997). The typical muscle has a bright outer margin caused by the connective tissue fascia, with a medium level central echo pattern representing the muscle fibres or muscle bundles (Harcke *et al.*, 1988). Muscle fibres are surrounded by a thin loose connective tissue, called endomysium. A mass of muscle fibres blocks together and forms a bundle of muscle fibres. This bundle is surrounded by a dense connective tissue membrane or fascia called perimysium. The bundles form a muscle which is surrounded by a thick fascia called epimysium (Craigmyle, 1986). These two fasciae, perimysium and epimysium which are highly echogenic substances can be detected by ultrasound. The perimysium, in particular gives rise to a typical characteristic ultrasonographic imaging of the muscle. Thus, a longitudinal scan parallel to the muscle long axis revealed an image of homogenous fine parallel echoes, the fine echoes originating from fibroadipose septae, perimysium which surround the muscle bundles. The muscle groups can be differentiated from each other by an hyperechoic white line which is actually the fasciae surrounding them (epimysium).

Although most muscles are arranged along the long axis of the extremity in a parallel fashion, there are usually slight obliquities in the individual muscles, with each having a slight different orientation (Harcke *et al.*, 1988). This could suggest why the ultrasonographic appearance of the thigh musculature imaged longitudinally from latero-caudal aspect has two different appearances as demonstrated in Fig. 4. The bundles of the semimembranosus and gracilis muscles are actually not running parallel with each other. The semimembranosus muscle bundles are running from the ischiatic tuberosity to the medial side of the distal end of the femur and the proximal end of the tibia while the bundles of gracilis muscle are running from the pelvic symphysis to the cranial border of the tibia (Evans and Christensen, 1993). Similarly, in the sagittal images of the thigh and brachial muscles, the thigh muscle appeared hypoechoic with fine parallel echoes, while the brachial muscle appeared hypoechoic with homogenous fine echoes scattered throughout the muscle parenchyma. Muscle structure with ultrasonography has also been shown to depend on the angle of inclination of the transducer (Cady *et al.*, 1983). If the transducer is roughly perpendicular to the fascicular axis, the parenchyma echoes are dense and ultrasonography in a plane parallel to the fasciculi reveals several linear echoes at right angles to the transducer.

A feathery appearance of the skeletal muscle was demonstrated by a *caput longus* of the triceps muscle when imaged longitudinally from the latero-caudal aspect. Such appearance was not demonstrated by other muscles of the thigh region. A thin layer of fat and connective tissue fascia (perimysium) surrounding the muscle bundles is responsible for the feathery appearance of the individual muscle seen ultrasonographically (Kaplan *et al.*, 1989; van Holsbeeck and Introcaso, 1990). Kaplan *et al.* (1990) showed the feathery appearance of normal skeletal muscle on a longitudinal scan of part of lateral head of gastrocnemius muscle. The result suggested that not all individual muscle groups produce the characteristic of 'feathery appearance' on a longitudinal scan along the muscle fibres. Only certain individual muscle produces this characteristic such as *caput longus* in this study.

The echogenicity of the skeletal muscle structures in this study was found to vary between individual animals. The variability in echogenicity of skeletal muscle has been reported and it could be due to the gain setting and the inclination of the transducer (Cady *et al.*, 1983) or it might be due to muscle hypertrophy (van Holsbeeck and Introcaso, 1990). When the gain setting is set higher for the near and far field, more sound is reflected back to the transducer, and therefore the overall image is bright and echogenic. In contrast, when the gain setting is set lower, less sound is reflected back, and the overall image is less bright and hypoechoic. In hypertophied muscle, the muscle cells and therefore the bundles have become larger while the connective tissue within muscle remain constant. Thus the image will appear hypoechoic compared to the normal muscle. Hypertrophied muscle imaged ultrasonographically in humans has been demonstrated to have an hypoechoic appearance (van Holsbeeck and Introcaso, 1990).

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RINGKASAN

ULTRASONOGRAFI IMEJAN OTOT-OTOT SKELET ANJING NORMAL

Anjing baka Greyhound yang telah mati dalam masa 24 jam disebabkan oleh lain-lain faktor telah digunakan dalam kajian ini. Pemeriksaan ultrasonografi telah dilakukan pada kawasan paha, lengan dan skapula. Mesin ultrabunyi masa-sebenar mod-B' (Capasee, TOSHIBA) yang disambungkan kepada pengaruh berfrekuensi 7.5 MHz telah digunakan. Semua imej ultrasonografi telah direkodkan dalam pita perakam menggunakan perakam video Panasonic yang disambungkan kepada mesin. Imej yang dirakamkan kemudiannya di lihat semula menggunakan mesin ultrabunyi 'Interspec, Apogee-cx'. Imej yang terbaik dicetak dan dilabel. Otot yang normal mempunyai ciri-ciri ultrasonografi yang sama. Dengan menggunakan pengaruh berfrekunsi 7.5 MHz, struktur terperinci otot boleh dilihat termasuklah tisu penyambung fasia yang menyelaputi serat otot, iaitu endomisium. Kumpulan otot yang dipisahkan oleh fasia boleh dilihat melalui ultrasonografi. Ultrabunyi boleh menjadi alat yang terbaik bagi melihat otot skelet yang normal dalam haiwan.