Muscle Ultrasound

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Goals of this lecture

• Review the use of ultrasound in imaging muscle disorders
  • Discuss techniques.
  • Review key pathologic findings.

• Brief overview of ultrasound in nerve disorders
Muscle Imaging

CT scan

• Pros
  • Quick
  • Good but not best evaluation of soft tissue
  • Allows for evaluation of deeper muscle groups

• Cons
  • Relatively high radiation dose
  • Limited soft tissue contrast.
  • Kids may not be still for it.
Muscle Imaging

MRI

• Pros
  • High soft tissue contrast allowing for excellent assessment of striated muscles.
  • Has a higher sensitivity in detection of dystrophic / myopathic changes as compared to CT.
  • No radiation.
  • Can be performed and rated in a standardized manner suggesting a good inter-rater and intra-rater agreement.

• Cons
  • Duration of study may requires sedation.
  • Motion artifact.
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<td>Normal appearance</td>
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<td>1</td>
<td>Normal appearance</td>
<td>Discrete moth-eaten appearance with sporadic T1 hyperintense areas</td>
<td>Mild: traces of increased signal intensity on the T1-weighted MR sequences</td>
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<td>Fine involvement: Early moth-eaten appearance with scattered small areas of increased</td>
<td>a. Moderate moth-eaten appearance with numerous scattered T1 hyperintense areas</td>
<td>Moderate: increased T1-weighted signal intensity with beginning confluence in less than</td>
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<td>signal or with numerous discrete areas of increased signal with beginning confluence,</td>
<td>b. Late moth-eaten appearance with numerous confluent T1 hyper-intense areas</td>
<td>50% of the muscle</td>
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<td>comprising less than 30% of the volume of the individual muscle</td>
<td>Complete fatty degeneration, replacement of muscle by connective tissue and fat</td>
<td>Severe: increased T1-weighted signal intensity with beginning confluence in more than 50%</td>
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<td>Moderate involvement: Late moth-eaten appearance with numerous discrete areas of</td>
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<td>End-stage appearance, entire muscle replaced by increased density of connective tissue</td>
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<td>increased signal with beginning confluence, comprising 30-60% of the volume of the</td>
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<td>and fat</td>
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<td>individual muscle</td>
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<td>Severe involvement: Washed-out appearance, fuzzy appearance due to confluent areas of</td>
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<td>increased signal or an end-stage appearance, with muscle replaced by increased density</td>
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<td>connective tissue and fat, and only a rim of fascia and neurovascular structures</td>
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Muscle Imaging

• Muscle ultrasound
  • Pros
    • Rapid
    • No issues with claustrophobia
    • Good to measure muscle thickness and muscle echo intensity.
    • Sensitive to scattered atrophic fibers which may not be noted on MRI.
    • Dynamic imaging!
    • Non-invasive and does not require sedation
    • Lack of ionizing radiation
    • Low cost
  • Cons
    • Image resolution may be less than MRI
    • Technician/physician technique variation in image acquisition quality
    • Application tends to be limited to superficial muscle groups because sound wave reflection and absorption lead to difficulties in displaying the deeper structures.
    • Inter- and intra- observer agreement may be difficult.
Basics of Ultrasound

- As sound is transmitted through tissue, attenuation of the beam occurs because of reflection, dispersion, and absorption of sound → thereby often making it more difficult to visualize deeper structures
  - Attenuation is highest in bone.
  - Absorption increases with the use of higher frequency probes.
Muscle Echogenicity

- skin
- (subQ fat)
- muscle
- fascia
- bone
“Normal” / Unaffected Muscle

• Relatively black (low echo intensity) and may have baseline degrees of variability of echogenicity because of different proportions of fibrous tissue and the orientation of muscle fibers.

• Discernible appearance from surrounding subcutaneous fat, bones, nerve and blood vessels.

• Divided by echogenic sheets of perimysial connective tissue → speckled appearance in the transverse plane + hyperechoic lines forming a linear or pennate structure in the longitudinal plane.
Figure 6.39 Morphological 'types' of muscle based on their general form and fascicular architecture. It is possible to classify muscles based on their general shape and the predominant orientation of their fibres relative to the direction of pull (Fig. 6.39). Muscles with fibres that are largely parallel to the line of pull vary in form from flat, short and quadrilateral (e.g. thyrohyoid) to long and strap-like (e.g. sternohyoid, sartorius). In such muscles, individual fibres may run for the entire length of the muscle, or over shorter segments when there are transverse, tendinous intersections at intervals (e.g. rectus abdominis). In a fusiform muscle, the fibres may be close to parallel in the 'belly', but converge to a tendon at one or both ends. Where fibres are oblique to the line of pull, muscles may be triangular (e.g. temporalis, adductor longus) or pennate (feather-like) in construction. The latter vary in complexity (see Fig. 6.39) from unipennate (e.g. flexor pollicis longus) and bipennate (e.g. rectus femoris, dorsal interossei) to multipennate (e.g. deltoid). In some muscles the fibres pass obliquely between deep and superficial aponeuroses, in a type of 'unipennate' form (e.g. soleus). In other sites muscle fibres start from the walls of osteofascial compartments, and converge obliquely on a central tendon in circumpennate fashion (e.g. tibialis anterior). Some muscles have a spiral or twisted arrangement (e.g. sternocostal fibres of pectoralis major and latissimus dorsi, which undergo a 180° twist between their median and lateral attachments). Others spiral around a bone (e.g. supinator, which winds obliquely around the proximal radial shaft), or contain two or more planes of fibres arranged in differing directions, a type of spiral sometimes referred to as cruciate: sternocleidomastoid, masseter and adductor magnus are all partially spiral and cruciate. Many muscles display more than one of these major types of arrangement, and show regional variations which correspond to contrasting, and in some cases independent, actions.
What can be assessed? Muscle echogenicity

- The amount of returning echoes per square area determines the gray value of the image – also known as the echo intensity.

- Muscle echo intensity normally increases with age (may be due to age-related muscle replacement by fat and fibrous tissue / sarcopenia).

- In neonates and young infants, the muscle tissue may have increased echogenicity due to the smaller size of muscle fibers and increased amount of endomysial and perimysial tissue per region of interest.
Muscle Echogenicity: Heckmatt Score

- In 1982, Heckmatt et al developed a visual grading for muscle echogenicity. *J. Pediatr* (101) 5: 656-660

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<th>Description</th>
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<td>I</td>
<td>Normal</td>
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<tr>
<td>II</td>
<td>Increased muscle echo intensity with distinct bone echo</td>
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<tr>
<td>III</td>
<td>Marked increased muscle echo with reduced bone echo</td>
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<tr>
<td>IV</td>
<td>Very strong muscle echo and complete loss of bone echo</td>
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FIGURE 6. Transverse ultrasound image of a normal left quadriceps muscle (A) and of a patient with Duchenne muscular dystrophy (DMD) (B). Both are 3.5 years of age. The rectus femoris muscle is encircled. The mean echo intensity is measured for this region, as shown in the histograms below (scale: black = 0; white = 255). The rectus femoris of the DMD patient has increased muscle echo intensity, with the corresponding histogram being displaced to the right. Note the fine granular pattern of echo intensity, homogeneously spread among the muscle with attenuation of the ultrasound beam; that is, the echo intensity in deeper areas of the muscle is decreased compared to the superficial areas. Fascia within the muscle, such as the central fascia in the anterior part of the rectus femoris (single arrow), are more difficult to recognize in the DMD patient. VM, vastus medialis; VL, vastus lateralis; VI, vastus intermedius; F, femur; double arrow, subcutaneous tissue. The quadriceps muscle was measured halfway along the line from the anterosuperior iliac spine to the patella.

European Journal Translational Myology 2010; 1 (4): 145-155
Muscle Echogenicity: Automated Analysis Pipeline of the Ultrasound Muscle Images

1. Image normalization
2. Intensity histogram equalization
3. Adaptive threshold
4. Connect component analysis
5. Image morphology processing
6. Post-processing
7. Image labeling to differentiate fats and muscle fibers.

Dr. Lin Yang, www.uky.edu/~lyya227
Results

Each image can be processed in less than 1 second

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Muscle Echogenicity

- Bicep
- Tricep
- Rectus Femoris
- Tibialis Anterior
- Vastus Lateralis
- Medial Gastrocnemius
- Lateral Gastrocnemius

Different muscle groups are compared with varying levels of echogenicity.
Muscle Thickness

• Muscle ultrasound is a reliable method to measure muscle thickness and cross-sectional area, and some studies have used ultrasound to establish muscle thickness in healthy subjects
  
  • But this is dependent upon:
    • Placement of the probe (must use standard measurements)
    • Position of the subject (must keep patients in a standardized position – e.g. supine)
    • Age: particularly in childhood, when muscle thickness increases rapidly
    • Weight of the patient
    • Sex: but only after puberty: males reach their peak between 25-50 years of age

• Studies that have looked at the test-retest reliability of muscle thickness and CSA show that there is a correlation coefficient of 0.98-0.99 and a correlation of 0.99 with MRI measurements of muscle.
Muscle Thickness: 10-15yo boys & girls

- Bicep + Brach
- Tricep
- RF
- RF + VI
- VL
- VL + VI
- TA

Graph showing muscle thickness for various muscle groups in 10-15 year olds, including NML, DMD, COL6, and LAMA2.
Subcutaneous Tissue Thickness: 10-15yo boys and girls
Muscle Ultrasound Technique
Muscle Ultrasound

• Keep the exam standardized with the patient in a supine position and arms supinated.
  - Note the presence of contractures or the patient’s inability to bring joints into full extension.
Muscle Ultrasound

- Fixed proportional distances are recommended for visualizing the greatest muscle bulk, particularly if you are trying to track change over time.
  - Bicep: 2/3 distance acromion → antecubital fossa
  - Finger extensor/flexor → 2/5 distance from antecubital fossa → lateral wrist
  - Rectus femoris: 1/2 distance between ASIS → mid patella.
  - Tibialis anterior: 1/4 distance between lower patella → lateral malleolus
Muscle Ultrasound

• Examiner can assess:
  • Echogenicity of muscle – Grade and distribution (homogeneous vs. inhomogeneous; increased or even decreased)
  • Atrophy of muscle – may cause usual anatomy of musculature to shift.
  • Fascia – note if thickened or bright
  • Abnormal movements in the muscle suggestive of myokymia or fasciculations

• One can also use this time to identify which muscle would be best to biopsy
Deltoid
Tibialis Anterior
Other muscles that can be assessed:

- **Tongue** Muscle Nerve (2012) 46: 31-37
- **Facial Muscles** Muscle Nerve (2013) 48: 375-380
- **Diaphragm** Muscle Nerve (2013) 47: 319-329
Myopathic / Dystrophic disorders

- Usually identified as homogeneous increase of muscle echo intensity
  - Exceptions to this include rimming or presence of the “central cloud”.
- Muscle may be hypertrophic, atrophic or normal
- There may be sparing and/or selective involvement some muscles.
Collagen 6 Disorders

- Central cloud.
- Rim of degenerative changes that may affect a variety of muscles.
RYR1

- Sparing of the adductor longus, gracilis, and rectus femoris is common.
SEPN1

- Selective affliction of the sartorius and have a relative sparing of the quadriceps and gracilis muscle.
- May have sparing of the rectus femoris as well.
LMNA

- Preferential involvement of the vasti and medial gastrocnemius muscle.
LGMD 2L (ANO5)

• Highly variable

• Relative sparing of the rectus femoris

• Preferential involvement of the medial gastrocnemius
DMD

Rectus Femoris

Vastus Lateralis
Ultrasound in Neuromuscular Disease

- Neurogenic disorders
  - Inhomogeneous, patchy and stripy echo densities with interposed hypodense areas.
    - Atrophic = hyperechoic / bright; tend to be more often in lower than upper extremities
  - In young children, there may be increased subcutaneous tissue diameter → prominent in floppy infants with SMA.
  - Fasciculations
Inhomogeneity: SMA3

Deltoid

Tibialis Anterior

Lateral Gastrocnemius
Streak-like changes: SMA3
Dynamic Changes: Fasciculations
Dynamic Changes: Myokymia
Thank you!

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