Edinburgh Critical Care Research Group
AHP & Nursing Study Day
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Ultrasound for the Assessment of Peripheral Skeletal Muscle Architecture in Critical Illness

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Background

- Peripheral skeletal muscle wasting and dysfunction a major complication of critical illness

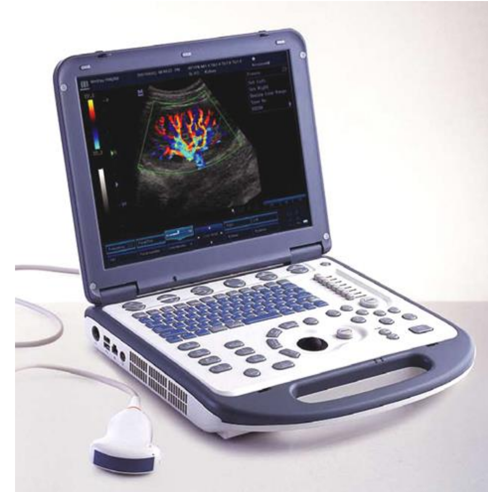
- Risk stratification to optimise patient management

- Assessment of muscle strength
  - Volitional methods
  - Non-volitional methods

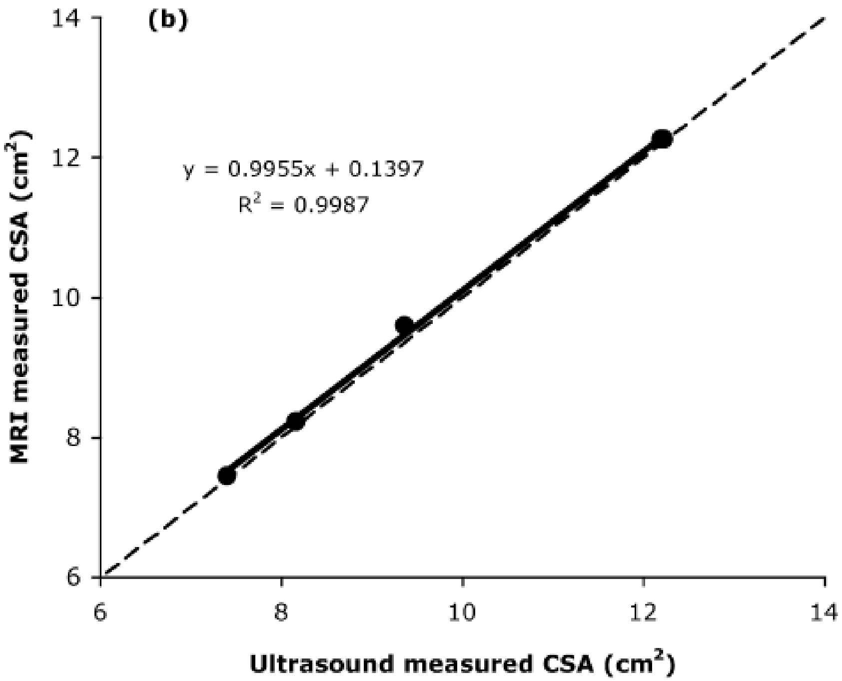
- Emerging interest in alternative tools for monitoring trajectory of muscle dysfunction

Ultrasound

- Pragmatic and clinical advantages
  - Effort-independent
  - Non-ionising
  - Widely available on most ICUs
  - Quick
  - Simple
  - Cost-effective
  - Bedspace utility
  - Portable
  - Usable by non-specialist clinicians



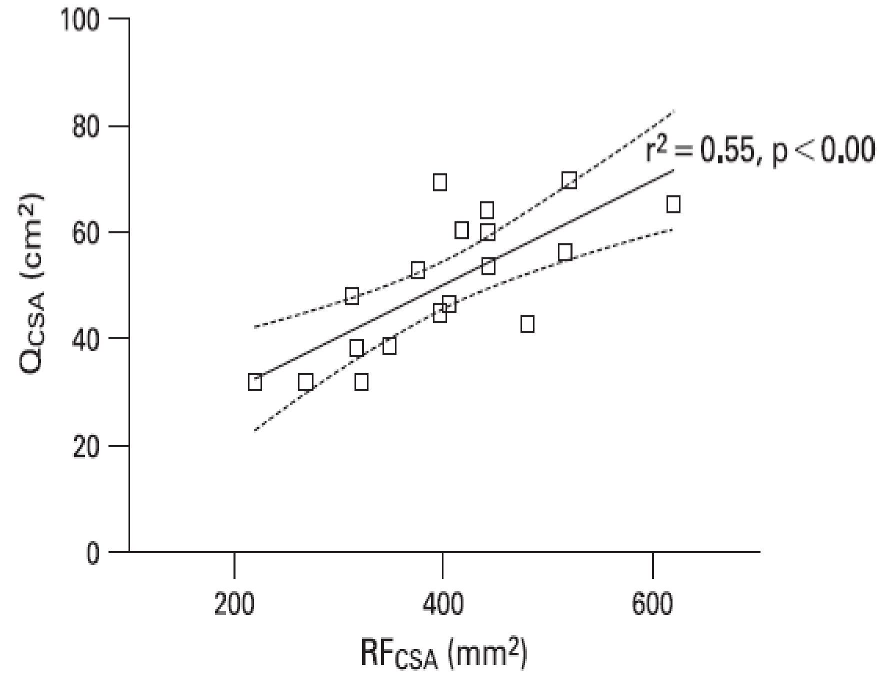
Compared to the gold standard



ICC, US against MRI

Reliability = 0.998; Validity = 0.999

Reeves *et a*l, Eur J Appl Physiol, 2004, 91, 116-118

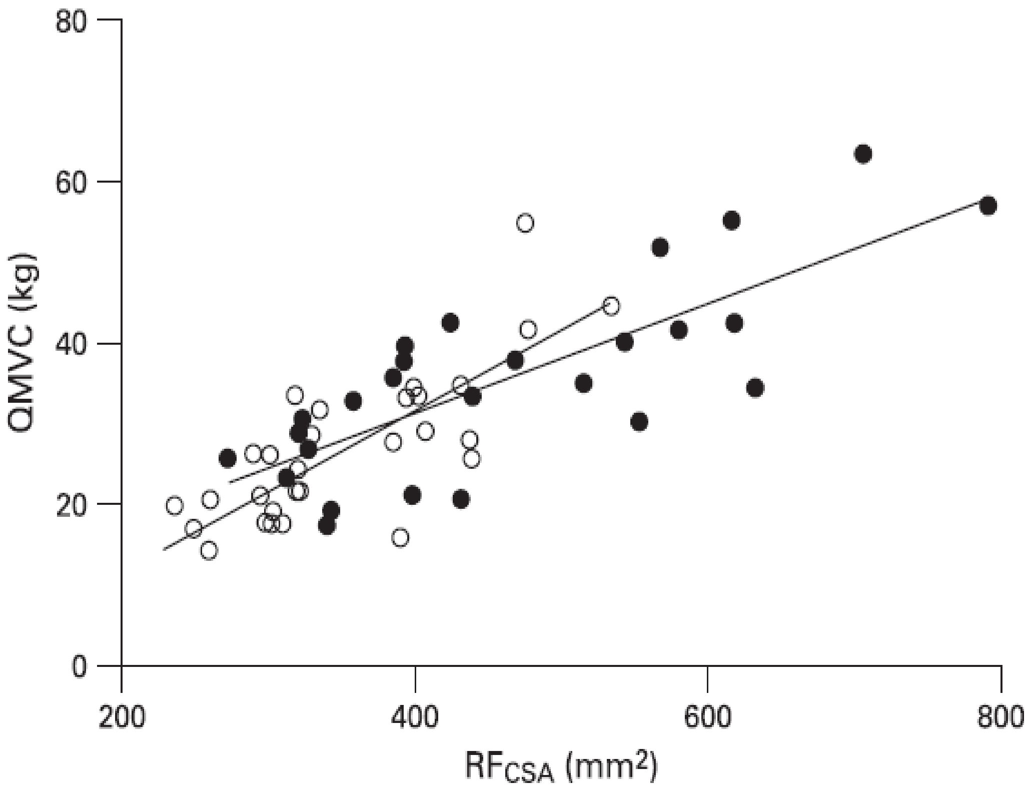


ICC, US against CT,

RF_{CSA}, r=0.88

Seymour e*t a*l, Thorax, 2009, 64, 418-423

Surrogate for strength?



Healthy subjects

RF_{CSA}

QMVC, r=0.8, p<0.001

TwQ, r=0.72, p<0.001

COPD patients

RF_{CSA}

QMVC, r=0.78, p<0.001

TwQ, r=0.69, p<0.001

How does ultrasound work?

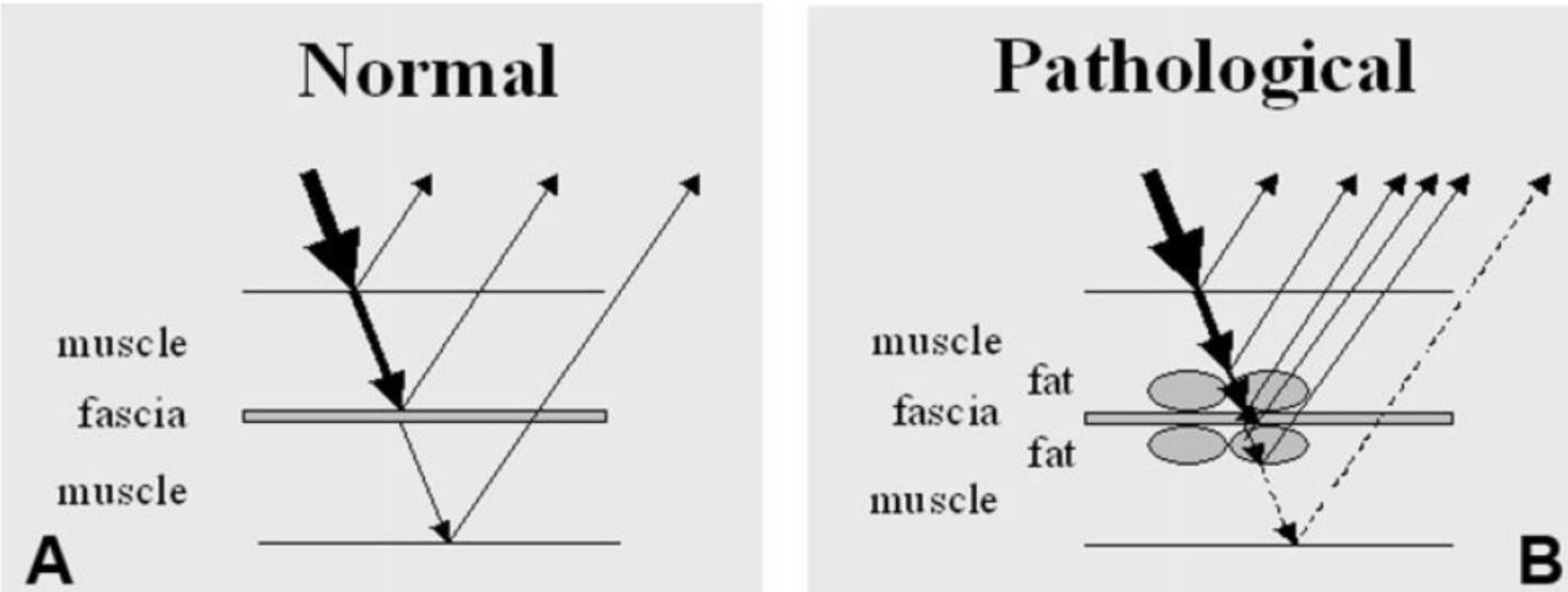
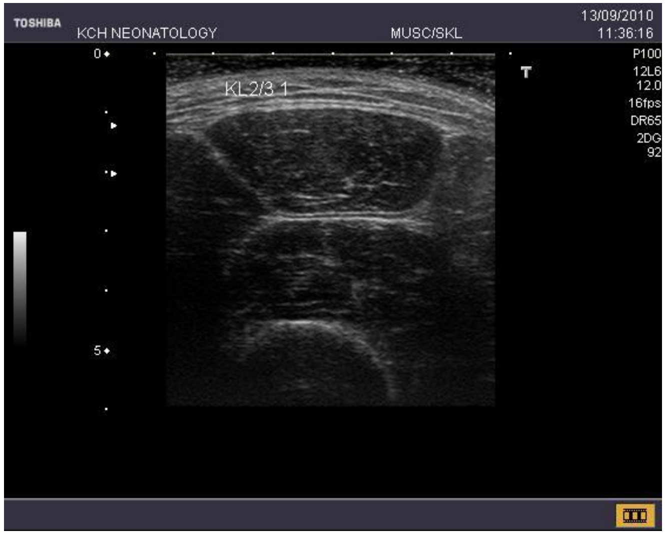


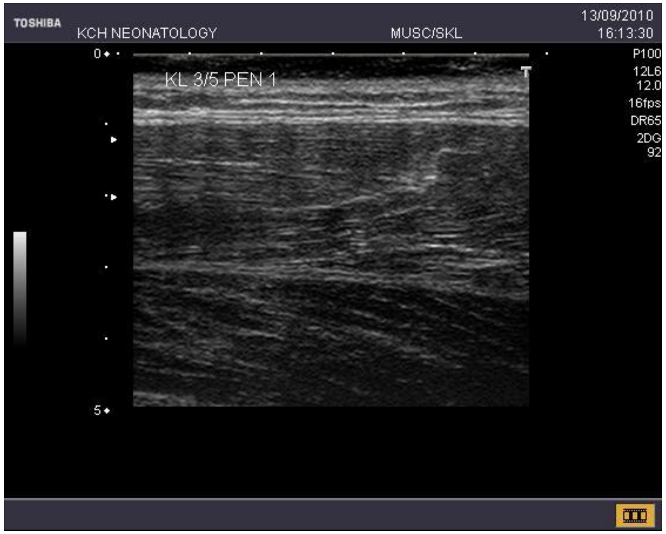
FIGURE 1. Schematic representation of the composition of an ultrasound image. Partial reflections of the ultrasound beam occur when the sound beam encounters a different tissue **(A)**. The ultrasound image is created based on these returning echoes and their temporal and acoustic properties. The amount of returning echoes per area determines the gray value of the image, that is, the echo intensity. In diseased or aged muscles, replacement by fat and fibrous tissue occurs. Both fat and fibrous tissue have a different acoustical impedance, thereby increasing the number of reflecting interfaces in the muscle, which gives the muscle a whiter appearance **(B)**.

- Walker et al, Clinical Neurophysiology, 2004, 115, 495-507
- Pillen et al, Muscle & Nerve, 2008, 37, 6, 679-693
- Pillen et al, Eur J Translational Myology, 2010, 1, 4, 145-155

Assessment of muscle

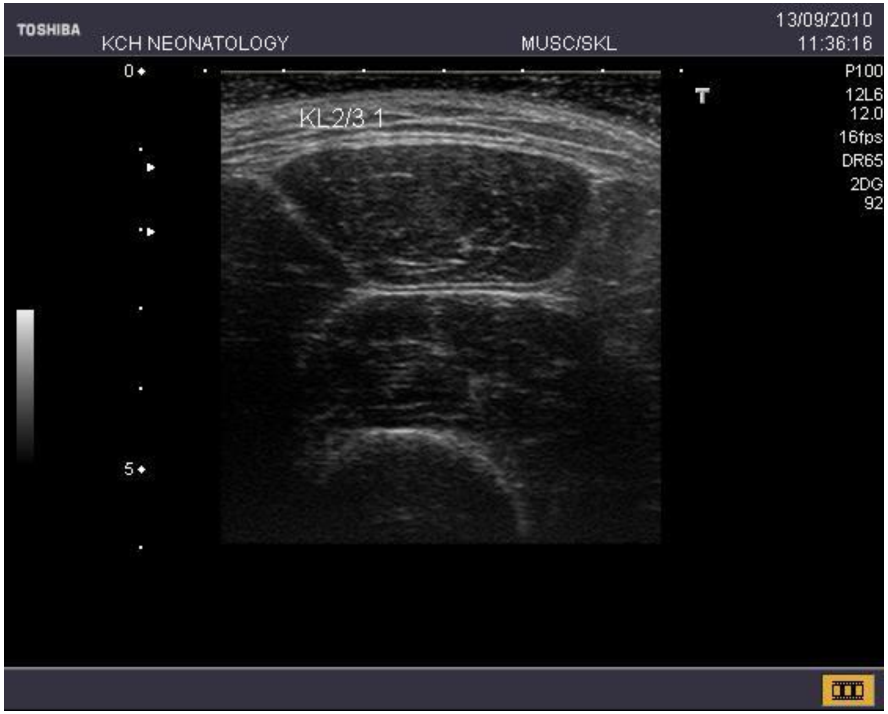
- Distinct sonographic features
  - Low echointensity i.e. relatively black
  - Divided by echogenic layers of perimysial connective tissue
  - Speckled appearance in TS plane
  - Epimysium bordering the muscle is highly echogenic for muscle delineation
  - Longitudinal axis, hyperechoic lines of muscle fibres are visible indicating pennate structure

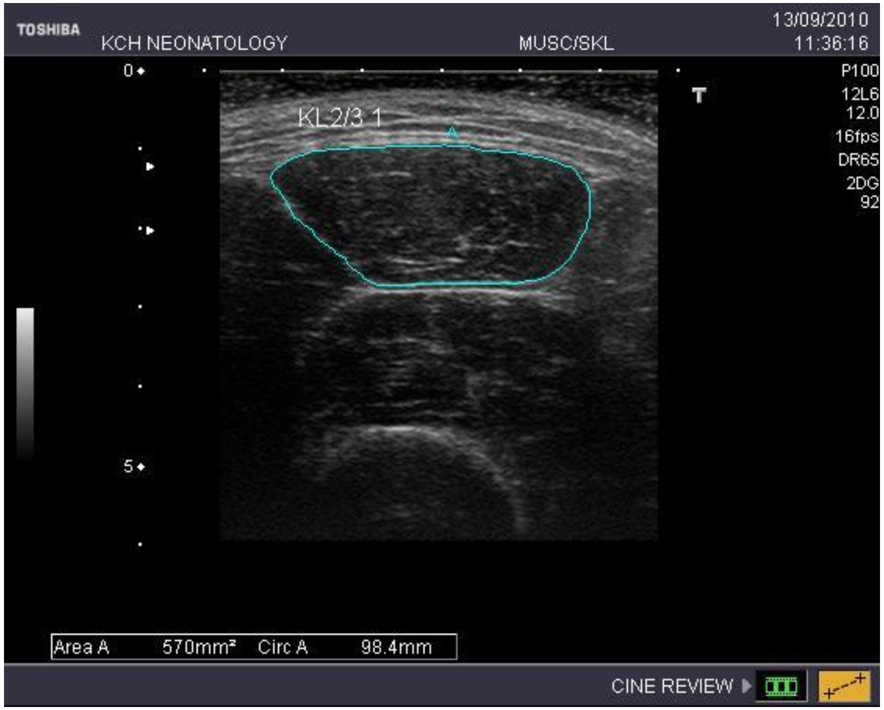




What parameters of muscle architecture can you measure?

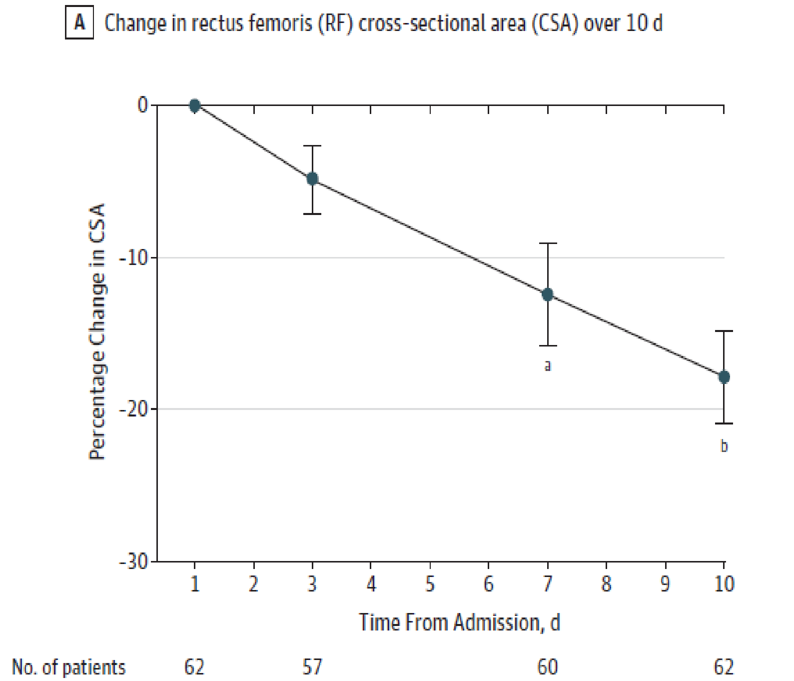
Cross-sectional area



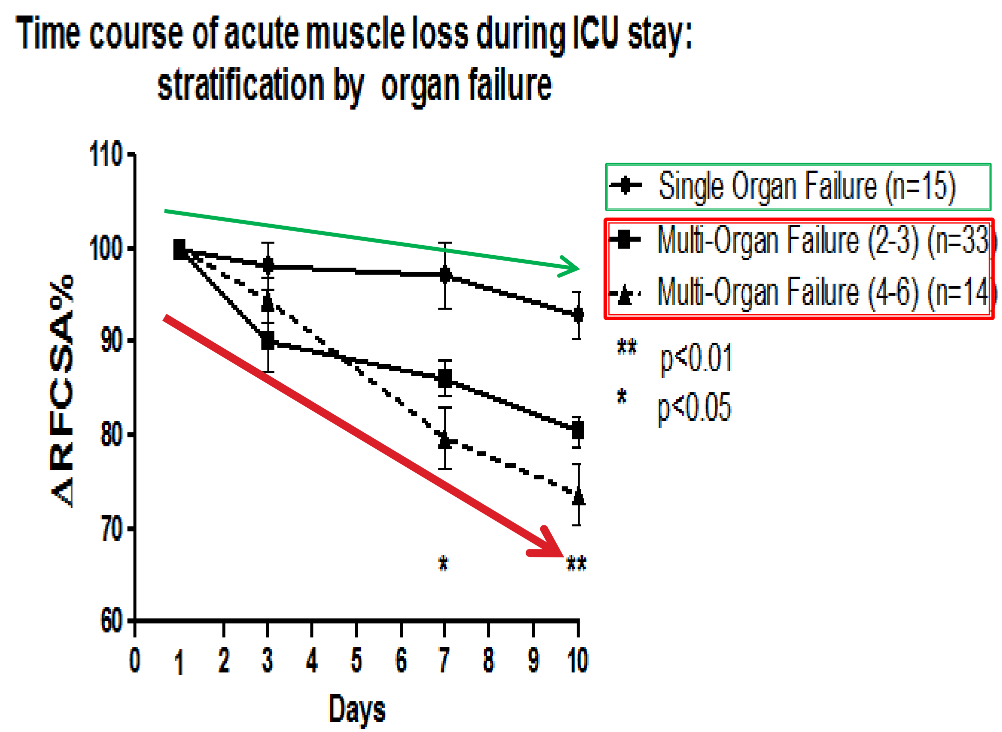


- Trace the inner echogenic muscle border

In critical illness….

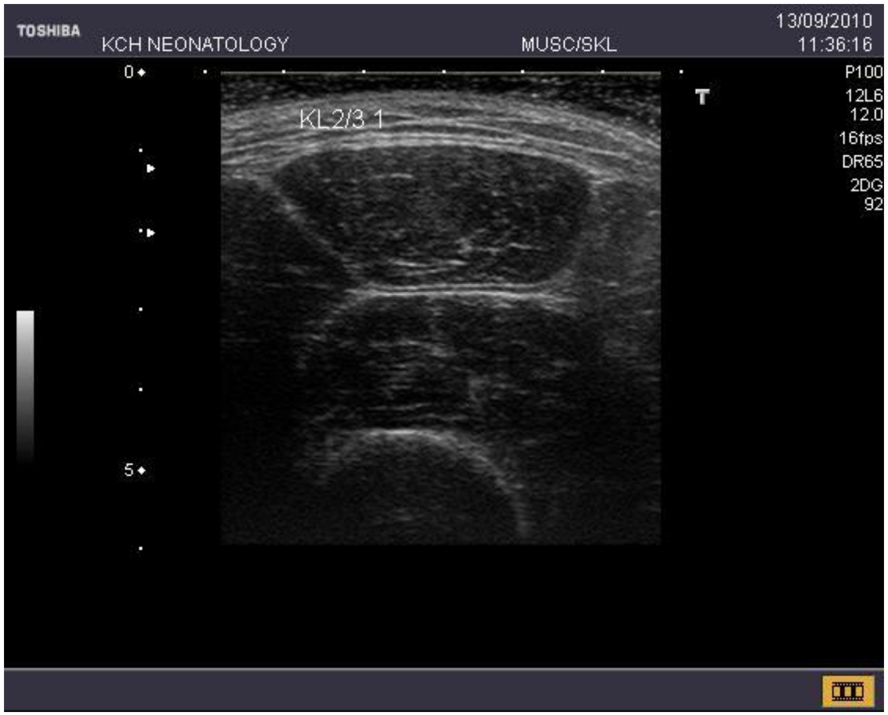


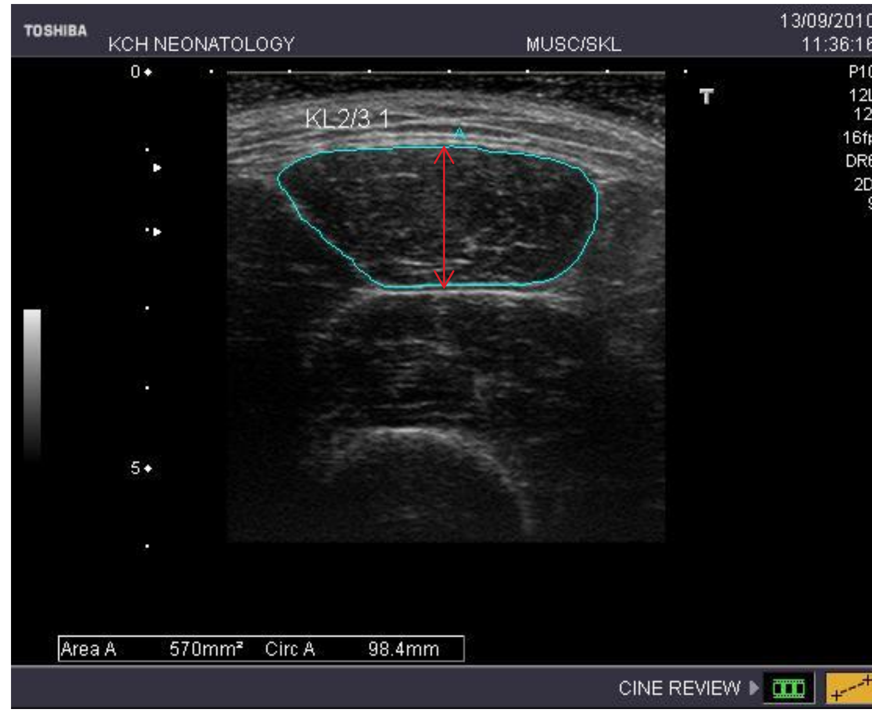
Summary data (dark circles) are expressed as medians and 95% confidence intervals.
[a] P=.002 for change from day 1 to day 7 by repeated measures 2-way analysis of varianc
[b] P<.001 for change from day 1 to day 10.



Puthucheary *et al*, 2013, JAMA, 310, 5, 1591-1600

Muscle layer thickness





- Identify (+/- trace) muscle border, and measure distance between

In critical illness....

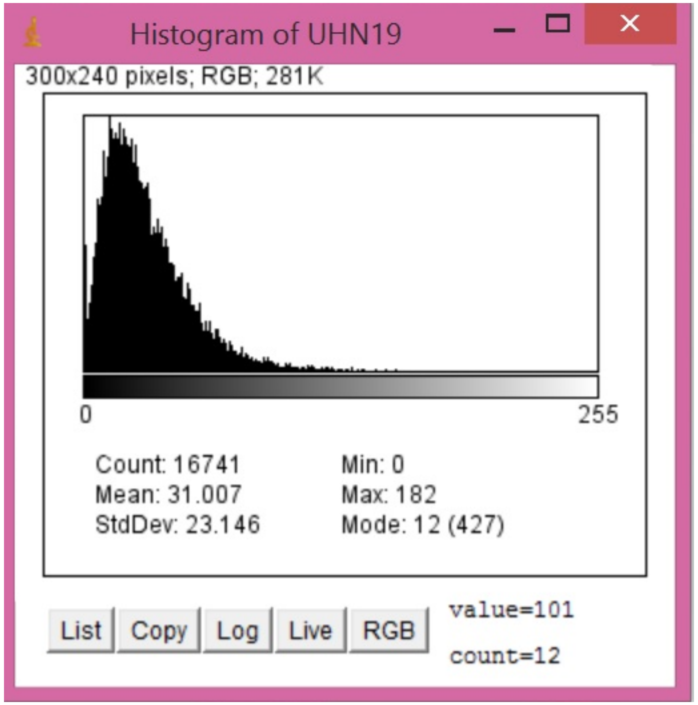
- 6.0 (2.0–9.2)%loss/day; negative correlation with ICU LOS (max–min $r = -0.978$ to -0.919, $p < 0.001$ to $p = 0.027$ Campbell *et al*, 1995, Am J Clin, Nutr, 62, 533-9
- 1.6 (0.2–5.7)%loss/day; negative correlation with ICU LOS, $r^2 = -0.953$, $p < 0.001$ Reid *et al,* 2004,Clin Nutr, 23, 273-280
- Significant reductions associated with ICU LOS

Gruther *et al,* 2008, J Rehabil Med, 40, 185-189

- MLT reduced compared to healthy across upper and lower limb muscle groups ($p \leq 0.001$)

Baldwin *et al*, Physical Therapy 2014, 94, 68-82

Echointensity



- Measure of the grey-scale of the image; may reflect muscle composition
- Increased echogenicity = whiter appearance; muscle becomes more homogenous
- Can also be measured subjectively using the Heckmatt grading scale

In critical illness….

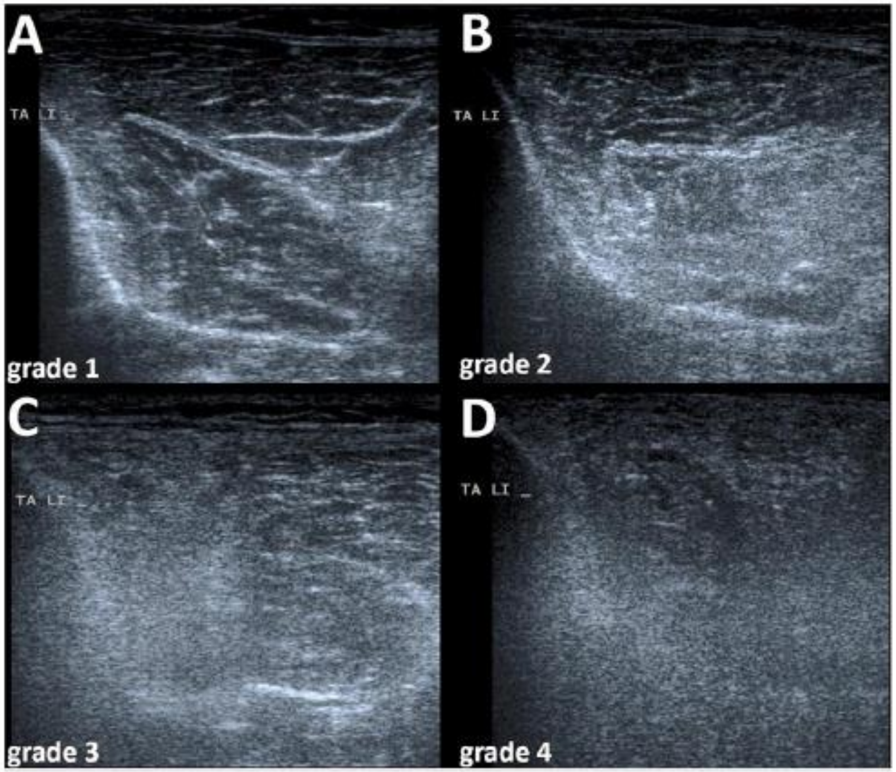


Figure 1 Ultrasonic cross-sections through the tibialis anterior muscles showing different grades in echogenicity as defined by the Heckmatt score [23]. (A) Normal echo intensity with starry-night aspect with distinct bone echo in a healthy control. **(B)** Increased echo intensity with normal bone echo in a septic patient at day 4. **(C)** Increased echo intensity with reduced bone signal in a septic patient at day 14. **(D)** Increased echo intensity and loss of bone signal in a septic patient at day 14.

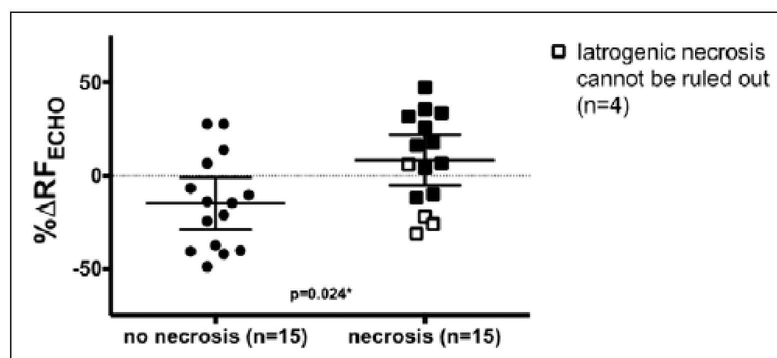
Grimm *et al*, Crit Care, 2013, 17, R227

- Significant reductions in grey-scale SD over 14 days in RF and TA muscles; indicative of myopathy

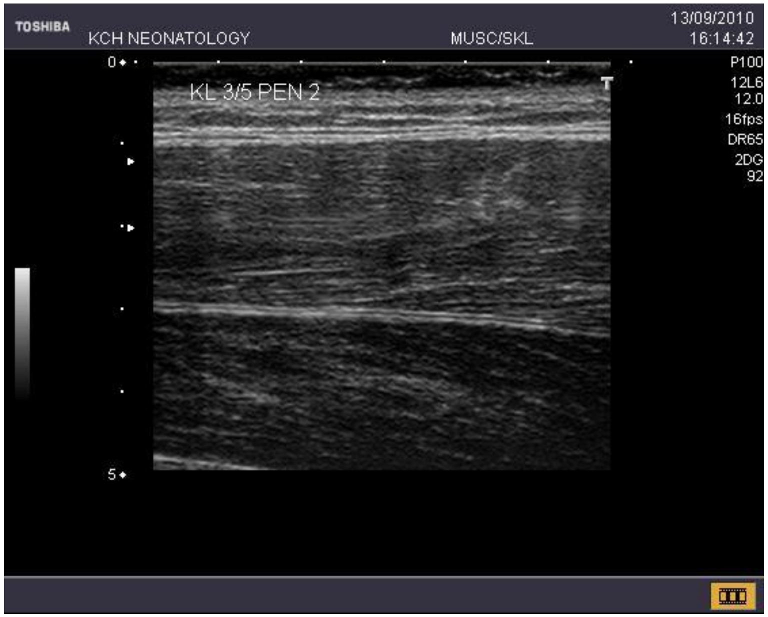
Cartwright *et al*, Musc Nerv, 2013 47, 225-259

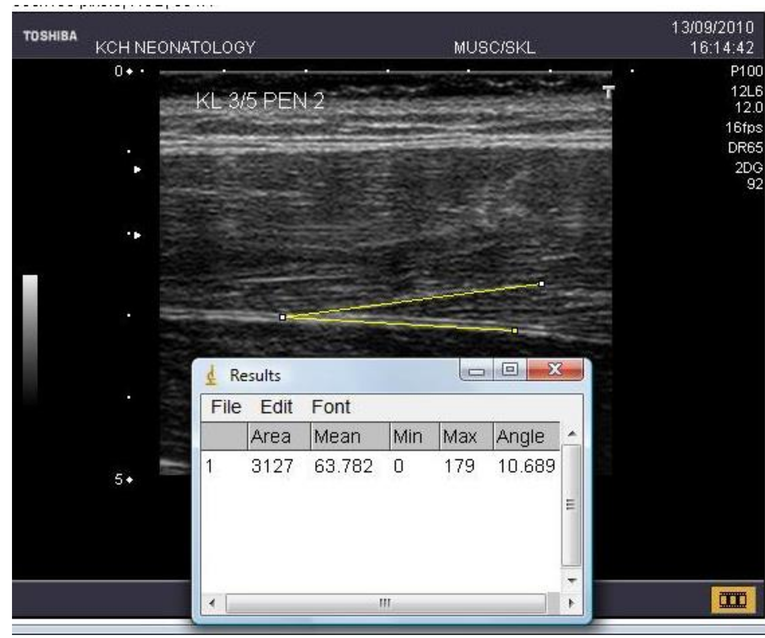
- Change in echogenicity greater in patients who developed muscle necrosis

Puthucheary et al, Crit Care Med, 2015, PAP



Pennation angle





- Angle of insertion of muscle fibres into muscle aponeurosis

In critical illness....

- No known data from existing studies in critical illness

- ? Usefulness
- Can be used to derive physiological cross-sectional area albeit not easily in all muscles
- No relationship with anthropometric parameters (Shrikrishna et al, 2012, ERJ, 40, 5, 1115-1122)

How robust is the technique?

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SYSTEMATIC REVIEW

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Doa El-Ansary
René Koopman
Linda Denehy

Assessment of impairment and activity limitations in the critically ill: a systematic review of measurement instruments and their clinimetric properties

- Excellent intra-rater reliability
- Inconsistent relationship with strength
- Sensitive to change over time

- Overall, strongest tool for assessment of muscle mass

Clinical significance

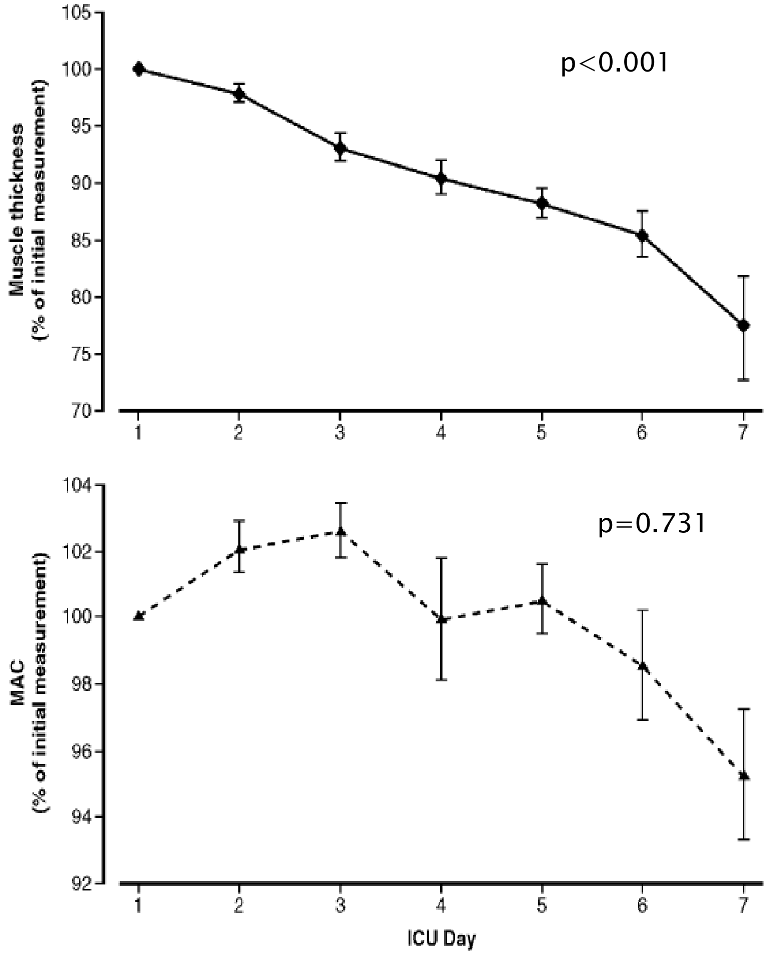
- Technique able to characterise negative effects on peripheral skeletal muscle architecture associated with critical illness
  - Single time-points and longitudinally
- Meta-analyses of data not possible due to study variability
  - What further effect of confounding factors?
- Relationship between muscle wasting and functional outcome not known
  - ?threshold of clinically significant muscle loss
  - Contemporaneous force and image data, mapped to function

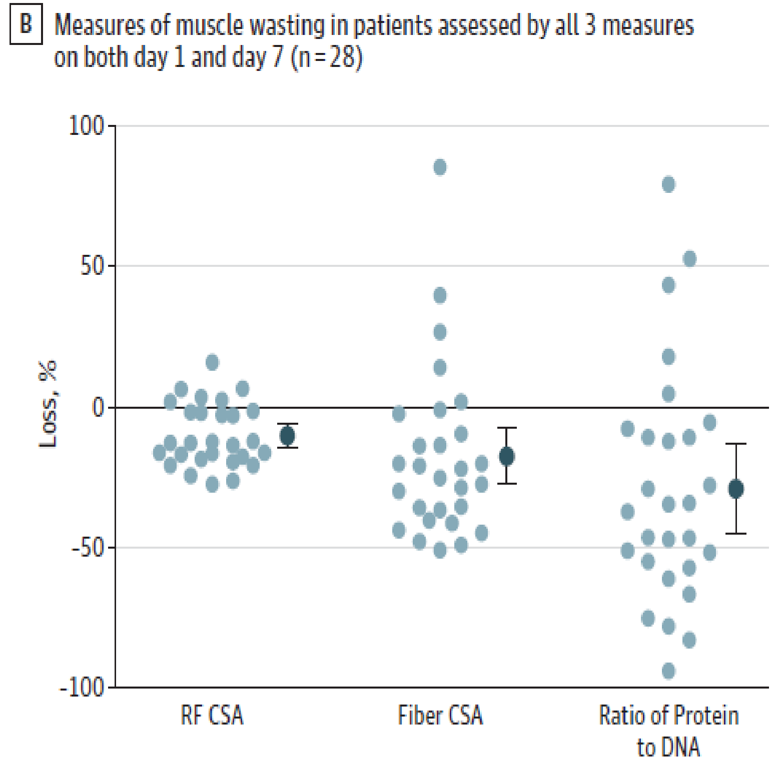
Technical considerations

- Technique feasible and safe
- Evidence of clinimetric properties
  - But not across all parameters and only in isolated muscle groups
- Currently lack of standardised reporting
  - Operating procedures
  - Make and model of machine
  - Transducer
  - Settings
  - Muscle groups and measurement points
- Superiority over other clinically simple measures e.g. limb circumference
- Underestimates change detected histologically

Vs. arm circumference

Vs. Fibre CSA and Pr:DNA





Puthucheary *et al*, 2013, JAMA, 310, 5, 1591-1600

Reid *et al,* 2004,Clin Nutr, 23, 273-280

Future direction

- Minimum reporting detail
  - Enhance rigour of technique through uniformity of application
  - Facilitate meta-synthesis of data
  - Standardised operating protocols
- Further determine relationship between muscle wasting and contractile function i.e. force-generating capacity
- Validate against ‘gold standard’ imaging techniques
- Characterise the temporal deterioration and ?recovery in muscle architecture throughout the continuum of recovery
- Determine relationship between US data with clinically relevant functional outcomes sequentially along recovery trajectory

Conclusion

- Increasing profile as a tool for evaluating changes in peripheral skeletal muscle architecture during critical illness
- Pragmatic advantages, and available evidence of psychometric robustness, confirm its clinical utility
- Further investigation in certain aspects to corroborate against muscle biopsy data
- Standardisation of protocol detail to improve external validity

Ultrasound for the Assessment of Peripheral Skeletal Muscle Architecture in Critical Illness: A Systematic Review

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Connolly *et al*, Crit Care Med, 2014, 43, 4, 897-905

Thankyou.....

- Questions???

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