

# Shearwave elastography in musculoskeletal disease

## (Basic physics and technical points)

Hee Jin Park

Kangbuk Samsung hospital, Sungkyunkwan university

### I. Basic physics

#### 1. Principles

Shear wave: transverse components of particle displacement (which are rapidly attenuated by the tissue)

Shear wave propagate with a velocity ( $c$ )

$E$  = stiffness (kPa),  $c$  = shear wave velocity (m/s),  $\rho$  = density (kg/m<sup>3</sup>)

Therefore,  $E \propto c^2$

#### 2. Image analysis (SWE)

Transducer was placed on the skin without tissue compression.

All patients were instructed to hold their breath for 5–10 seconds.

The rectangular color box was positioned at the area covered by the lesion.

Blue and red colors signified softness and hardness of the lesion, respectively.

A circular ROI (0.2–3 cm<sup>2</sup>) was placed within the most representative portion of the lesion and adjacent subcutaneous fat tissue, similarly to the SE images.

### **3. Merit**

Provide quantitative elastic information

Produce a real-time elastogram

No compression → more objective than SE

Problem: not suitable for superficial lesion because, certain depth of ultrasound penetration is needed for shear waves to be produced

Two methods: ARFI (acoustic radiation force impulse) and SSI (supersonic shear imaging)

## **II. SWE vs strain elastography (SE)**

### **1. Limit of SE**

Different pressure (manual compression) → different displacement

Different lesion depth → different displacement

Different probe alignment by operator → different displacement

### **2. SE : lack of quantitative measurements**

need various methods for the assessment

semi-quantitative measurements (strain ratio)

qualitative (visual) assessment (patterns, scores or grades)

confusion in the interpretation of the findings

lack of reproducibility

difficulty in comparing the results from different studies, even if the same technique (SE)

### **3. Strain ratio (SR)**

two regions of interest (ROIs) are drawn over the target region and the adjacent reference region

SR = strain of normal tissue / strain of lesion

SR > 1: lower strain (higher stiffness, hard) than the normal tissue

SR < 1: higher strain (lower stiffness, soft) than the normal tissue

## **III. Reproducibility**

### **1. Up to date**

Intra-user repeatability : good ~ very good (intra-class correlation coefficient [ICC] > 0.6) in the majority of studies on both tendons and muscles.

However, still many discrepancies in inter-user repeatability

Good to very good in gastrocnemius, tibialis anterior, supraspinatus muscles, flexor pollicis longus, quadriceps

Fair to moderate ( $0.2 < \text{ICC} < 0.6$ ) for the abdominal wall muscles, Achilles tendon, patellar tendons

### **2. Tissue heterogeneity**

MSK tissues are inherently heterogeneous.

Liver, skin, breast tissues are relatively homogeneous when compared to

tissues in the MSK.

These findings are exacerbated on axial imaging vessels are more difficult to visualize and included in the field of view

Multidirectional muscle fibers (ex. Bipennate)

### **3. Muscle direction**

Transducer position is a important modifiable variable when performing SWE.

Shear waves propagate more readily along muscle fibers when the transducer is oriented longitudinally, rather than perpendicular or at a 45° oblique angle to the tendon

SWE measurements obtained parallel to the muscle fibers increase, as expected, with increasing tensile load.

Shear waves propagate more quickly along the parallel (unipennate) muscle fibers of the biceps brachii, resulting in high SWS when imaged in the longitudinal plane and a significantly lower SWS when imaged in the transverse plane.

### **4. Tissue activity**

Muscles can contract.

Stiffness of muscles increases during contraction.

Day-to day variations in measurement

### **5. Tissue depth**

Soft tissue --- little change

Hard tissue --- quite change

## **6. Underlying bone (reflective corridor)**

Inhomogeneity within the supraspinatus tendon and overlying deltoid muscle, with low SWV (blue) and high SWV (red) measurements present in the same muscle and tendon

## **7. Transducer pressure**

Traditional ultrasound scanning, the transducer applies firm, consistent pressure to the skin surface.

When working with SWE, however, transducer pressure should be avoided or standardized as applied pressure compresses tissues below the surface.

Tissue compression increases SWS measurements in all tissues

10% more compression doubles SWE measurement

Recommend -- consistent, light transducer pressure or a mounted transducer should be used during SWE imaging.

## **8. Patient position**

SWE are affected by joint position

Strain of a tendon affects SWS measurement and even small changes in joint position may result in large changes in strain.

Place participants with no tension.

## **IV. Reproducibility of soft tissue tumor**

The SWE values were quite different between more superficial locations with a more curved or pointed surface (e.g., the face) and deeper locations (e.g.,

the buttock, but not statistically significant).

→ May have led to the lower reproducibility of SWE values of epidermal cysts.

The strain ratio on SE and the shear wave velocity ratio and elasticity ratio on SWE were not always related.

Furthermore, the elasticity ratio on SWE had the lowest reproducibility.

→ Therefore, obtaining the velocity ratio or elasticity ratio on SWE of epidermal cysts may not always be necessary.

## V. Points

Specific diseases or tumors cannot be diagnosed based solely on SWV.

Even at the same anatomical location, the velocity value changes depending on the transducer direction.

SWV is fundamentally different from HU.

## References

- ▣ RadioGraphics 2017; 37:855–870
- ▣ Ultrasonography 2019;38:2-12
- ▣ J Biomech 2013;46:2381-2387.
- ▣ Ultrasound Med Biol 2010;36:789-801.
- ▣ Ultrasonography 2017;36:185-197.
- ▣ Ultrasound Med Biol 1998;24:1437-1447.
- ▣ Ultrasonography 2025; 44:372-379

▣ Ultrasonography. 2022; 41:698-705.