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Digital Reprocessing of Conventional High-Resolution Sonography-A Study in Standard Ultrasound Slices of the Shoulder Joint

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Abstract: Although digital imaging techniques are also available for ultrasound imaging with most of the modern machines, only contrast optimization is regularly used. The possible improvement in image quality by digital reprocessing with different filtering techniques was assessed. An independent sonography specialist assessed the shoulder of a healthy test person. Previously described and frequently used standard setup slices were used for this study. A video print was generated after every standard setup, the images were then reprocessed. The resulting edited sonographic images were investigated and judged by 5 experienced sonologists. Several combinations of sonographic views and digital enhancement techniques significantly improved image quality. In conclusion digital reprocessing can improve the quality of images in ultrasound studies of the healthy shoulder.

Key words: Ultrasonography, digital imaging, shoulder joint, digital reprocessing, standard setup slices

INTRODUCTION

Digital radiography offers various possibilities of processing and editing conventional radiographs for the user. In addition to contrast optimization, multiple different filter techniques are frequently used. The advantage of such techniques, for example improving image quality in the diagnosis of osseus lesions has been proven in studies (Ferrari and Winsor, 2005; Gravel *et al*., 2006). Although digital imaging techniques are also available for ultrasound imaging with most of the modern machines, only contrast optimization is regularly used (Shapiro *et al*., 2001). In the case of unequivocal ultrasound findings Magnetic Resonance Imaging (MRI) is frequently used to establish a diagnosis with a significant cost disadvantage.

Shoulder sonography is nowadays a standardised method to evaluate shoulder pathology including the rotator cuff, the long head of the biceps and the bursae. With high-frequency linear probes, the sensitivity in detecting total tears sized >0.5 cm >90% and in detecting partial thickness tears greater than one-third of the cuff substance is >75% (Hedtmann and Fett, 2002).

This study analyses the possibility of different digital imaging techniques on standardised healthy shoulder joints. The possibility of developing standard filter techniques for particular indications or specific questions to support diagnosis is to be verified is secondary aim of this study.

MATERIALS AND METHODS

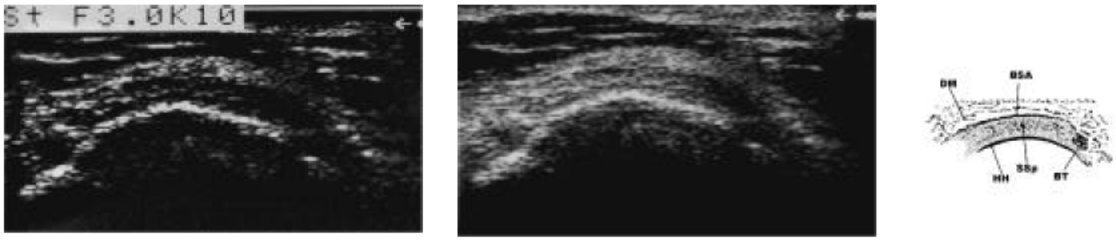
An independent sonography specialist with wide experience in shoulder ultrasound imaging assessed the shoulder of a healthy test person (Age 28, Height 181 cm, weight 78 kg). Previously described and frequently used standard setup slices were used for this study (Hedtmann and Fett, 1995). For this purpose a Plicker 9500 CS ultrasound imaging machine with a 7.5 MHz linear ultrasound head was used. For the visualization of the acromio-clavicular joint and the coraco-clavicular distance, a Proxon-precursor (23 mm) was added. The image quality of the displaying monitor was setup optimally.

A video print was generated after every standard setup. The optimal sonographic image quality setups were stored to the hard disk of the digital radiograph processing system diagnostiX 2048-Sono (Gemed, Freiburg, Germany) and by that digitally editing of the previously taken images was possible.

Standard sonographic views of the shoulder joint: Standard sonographic sectional planes were acquired, these have been extensively described in the literature and common practice in the diagnosis of shoulder pathology (Hedtmann and Fett, 1995, 2002; Heer *et al*., 2006; Mack *et al*., 1985; Middleton *et al*., 1986).

Standard positions: Ultrasound probe strictly parallel to the coraco-acromial line as reference position in:

- Neutral position of the shoulder joint (supraspinatus/ infraspinatus).



(a) (b) Legend

Fig. 1: Example of an ultrasound picture (here: Standard view, internal rotation) without (a) and with optimisation (b), legend: BT = Bizeps Tendon, Ssp = Supraspinatus tendon, HH = Humeral Head, DM = Delta Muscle, BSA = Subacromial Bursa

- Internal rotation of 45° (infraspinatus) (Fig. 1a)
- External rotation of 45°(supraspinatus)
- Dorsal lift off position with approx. 110° internal rotation (infraspinatus)

Extended standard positions:
Position D : Dorsal transversal (teres minor)
Position SU : Ventral horizontal (subscapularis)

Additional positions:
Position L: Lateral-frontal
Long biceps tendon longitudinal
Acromio-clavicular joint
Coraco-clavicular distance

These sections were then analysed by computer with various image editing algorithms. Following methods were used:

Methods of contrast optimisation:

- Contrast filtering (window technique): Distancing of grey scales pixel by pixel, line by line.
- Look up table method (Dale *et al*., 2001): Via change between the type of density, the contrast can be globally optimized either linearly, sigmoid, logarithmically or inversely.

Methods of filtering: According to the principle of the blurred mask (Bednarek and Rudin, 1991; Schofield *et al*., 2006) following filter techniques were used:

- High-pass filter: border elevation, detail improvement
- Low-pass filter: blur reduction
- Structural filter: border/edge image

A further variation of these filters was performed by different kernel sizes (0.5 to 10) and the enhancement factors (Factor 1.5 and 3).

Every setup frame was edited using these algorithms (Fig. 1b).

The resulting edited sonographic images were investigated and judged by five experienced sonologists who were unaware of the type of images they were evaluating. Each image was rated for definition of tissue planes, amount of speckle and other noise. For statistical evaluation, each image and its digitally re-mastered version was evaluated using a 5-point scale:

Points were given for image quality (1 = no improvement of image quality to 5 = marked improvement of image quality) while considering different questions/indications (e.g., judging the border layers or structural homogeneity) in comparison to the original sonographic images.

RESULTS

With solitaire contrast optimisation no significant distinct image quality improvement could be achieved. Several combinations of sonographic views and digital enhancement techniques including all filters used for visualisation of the biceps tendon failed to significantly improve picture quality. Following combinations reached statistically significant improvement ($p>0.05$):

- Standard position with neutral shoulder joint position: A good visualisation of the bursa border was achieved using the high-pass filter (Factor 1, 5; kernel size 9).
- Standard position with 45° internal rotation: A distinct improvement of image quality in regard to details of the bursa border layer was achieved by the structural filter (Factor 3,0; kernel size 10) in comparison to the original image.
- Standard position with 45° external rotation: Using the structural filter (factor 3,0; kernel size 10) a marked improvement of the bursa border layer judgement was seen.

- Position SU achieved equivalent results to Standard position with external rotation.
- Position D: Using the high-pass filter (factor 1,5; kernel size 10) the glenoid labrum was particularly good to judge.
- Position L: The high-pass filter (factor3,0; kernel size 10) achieved improved results in regard to the bursa border layer. The structural filter (factor 1,5; kernelsize 2) allowed an above average judgement of the supraspinatus tendon.

DISCUSSION

According to the results, different digital editing algorithms from those used for conventional x-ray imaging, are needed to optimize sonographic images.

Contrast optimization, that commonly plays a more important role than other filter techniques when judging osseus lesions, is of low value with sonographic images. In addition, the study showed that there is no standard setup for digitally editing shoulder sonographies that can be recommended in general. Moreover, particular filter techniques were shown to be especially helpful with specific indications or structures.

Using suitable filters, specific selective local frequencies can be amplified and thus details, such as borders, enhanced.

When regarding border zones, the high-pass filter and the enhancement of local frequencies through the structural filter achieved a clear improvement in detail visibility.

These filters also proved helpful when portraying the glenoid labrum, the supraspinatus tendon and the long biceps tendon.

When judging homogeneity, kernel sizes (2 and smaller) proved to be of great advantage.

The use of the low-pass filter, that enhances low local frequencies and thus leads to a reduction in image murmur, showed no improvement of image quality and is contra indicated when judging border zones.

In regard to these facts, digital editing of sonographic images is a sensible means to support image findings/diagnosis and quality safe guard this examination method.

The sonographic images constructed by the system diagnostiX 2048-Sono are available to the examiner on hard disk for quantative and qualitative image editing.

Before storing the sonographic images in an archive or on patient card, our examined filter techniques for specific indications should be documented for quality safe guarding.

It is feasible, that after integration of the according filters into the software, this step can be generated automatically.

This study has some limitations. Although the reviewers of each examination were unaware of the image type, blinding was difficult to achieve because of the substantial differences in image quality between conventional and edited images. Although there was a qualitative improvement in image quality, it has not yet been shown to improve the sensitivity or specificity of musculoskeletal sonography in shoulder pathology. An inspection and adjustment of the determined indicational filters to pathological findings and further standard setups is a task for future studies. Because musculoskeletal sonography is highly dependent on image quality and tissue-plane definition, digital reprocessing sonography represents an important development in the field.

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