3.II - P 22

Imaging of meat structure by ultrasonic and magnetic resonance

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Background

High quality/price ratio is a constant demand from both meat producers and consumers. Therefore, there is a need for techniques which evaluate meat quality. It is well known that meat quality, tenderness in particular, is directly related to two components of the muscle, structure and composition. The two major structural components are the connective tissue and contractile fibres, and composition indicates water, fat and protein component. Magnetic Resonance Imaging (MRI) and ultrasonic imaging, which offer non-invasive and non-destructive insights, were used to study meat structure. These two techniques were combined to aid the development of ultrasonic methods which are well suited to the industry because of their real-time and portable aspects. Some ultrasonic parameters (speed, attenuation, backscattering) have been studied (Abouelkaram et *al.*, 2000) and global information has been extracted from ultrasonic images (Whittaker et *al.*, 1992; Brethour, 1994) to classify animals and muscles. However, little is known about local interpretation of ultrasonic imaging, because of the lack of understanding of the interaction between ultrasonic waves and muscle structure. Unlike ultrasonic imaging, MRI affords an excellent spatial resolution and spontaneous contrast between the different muscle components. Therefore, MRI can be used as a reference tool (Laurent W. et *al.*, 2000).

Objective

To develop a relationship between ultrasonic images and muscular structures, while using the MRI images as references.

Methods

A set of fourteen bovine samples taken from *Longissimus dorsi* (LD), *Semitendinosus* (ST) and *Triceps brachii* (TB) muscles were studied. These muscle types were selected for their high variability in structure and composition. These samples were imaged after 8 days *post mortem* with both of the imaging modalities. To ensure spatial localisation, a Plexiglas box with four notches of different heights was designed. Four each sample, images were recorded in the four different notches.

The ultrasonic bench used for imaging consisted of a prototype echograph "I-scan", designed in the Rheology laboratory and constructed by the I+TECH company (Clermont-Ferrand, France), and a temperature controlled water tank. This echograph included two 5 MHz transducers with a focal distance of 50 mm. With the motors attached to each transducer, it was possible to scan the samples by linear displacements with a step of 0.3 mm. For each image, 234 echographic lines were recorded during sample scanning. Each ultrasonic line was sampled at 26 MHz and stored in a 1702-point array, leading to a digitised image of 234 x 1702 points. This image corresponded to a region of interest (ROI) of 7x5 cm^2 with an expected maximal resolution of 0.5 x 1 x 1 mm^3.

The MRI images were acquired on a Biospec 47/40 spectrometer (Bruker, Karlsruhe, Germany) working at 4.7 T. A Chemical-Shift Selective Inversion Recovery sequence (CSS-IR) (Kaldoudi et *al.*, 1993) was adapted to generate two perfectly spatially registered images, where the signals coming from water protons (WS image) or from the lipid protons (FS image) were suppressed. Sequence parameters were $TR = 5000$ ms, $TE = 9.9$ ms, field of view = 7.68 cm, spatial resolution = 0.3 x 0.3 x 2 mm^3.

Results and discussion

Figure 1 shows a comparison between the FS and WS MRI images and the ultrasonic image of the same imaging plane. It illustrates a configuration in which the fatty tissue visualised by MRI is favourably oriented for the ultrasonic imaging. This tissue has a branch (black arrow) which was orthogonal to the ultrasonic beam, generating an intense echo in the image. The branch underlined by the grey arrow, which had an orthogonal orientation near the top of the sample before bending, was also detected. The branch pointed at by the white arrow does not show up in the ultrasonic image because its orientation is almost parallel to the beam. This does not mean that the information does not exist in the image signals, but that using only the image can lead to an incorrect interpretation. The exploitation of local parameters, such as those obtained from texture analysis (Haralick et *al.*, 1973) or other ultrasonic parameters (Abouelkaram et *al.*, 2000), can provide useful information for a correct image interpretation. These types of parameters are currently explored in order to provide information on the sample which may not be obviously visible on the image.

Another cause of invisibility of structure on ultrasonic images is the scanning plane localisation. Indeed, if the position of the transducer was not carefully adjusted, correspondence between ultrasonic and MRI modalities did not occur systematically. Figure 2 shows a situation where the structures seen in the MRI images cannot be retrieved in the ultrasonic image. This shows a typical lack of precision in the scanning plane localisation and emphasises that precision is very important because of the quick changes in the meat structure between contiguous scanning planes. When intra-musclar variability is too high it can cause a lack of visual correspondence. To illustrate the variability of connective tissue, ten contiguous slices of 2-mm thickness were imaged in MRI, allowing investigation of the fatty tissue structural changes on distance of 2-cm. The result is presented in Figure 3 and shows well the variability of the fat component of the connective tissue.

Conclusions

In this work, characterisation of muscle structure from ultrasonic images taking MRI as a reference tool has been investigated. A device was built to ensure spatial localisation of the ultrasound and MRI planes. In situations where structures identified on the FS and WS MRI as fatty connective tissue had a non-parallel orientation to the ultrasonic beam, these structures clearly showed up in the corresponding ultrasonic image as a bright structures. The structures oriented in the beam direction were not visible on the ultrasonic image. Moreover, in spite of the care taken to obtain the same imaging plane in both modalities, it seems that the high variability of this tissue morphology is sometimes sufficient to make comparison unachievable. The use of ultrasonic parameters, or texture analysis features, in complement to echography should enhance structure detection and help give a correct image interpretation.
The use of MRI has interesting potential for the local study of the structure of the connective tissue in terms of composition and organisation. The MRI technique is therefore a useful tool to help develop of ultrasonic techniques which are well known for their practical aspects (rapid, non-destructive, cheap). Another potential of the MRI and ultrasound techniques is the 3D exploration which seems nowadays to be among the few means to take into account intra-muscular variability. For this field also, ultrasound development could be accelerated by the use of the MRI as a reference tool.

Acknowledgements: This work has been supported by the European Union (AIR project CT96-1107).

Pertinent literature

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Figures

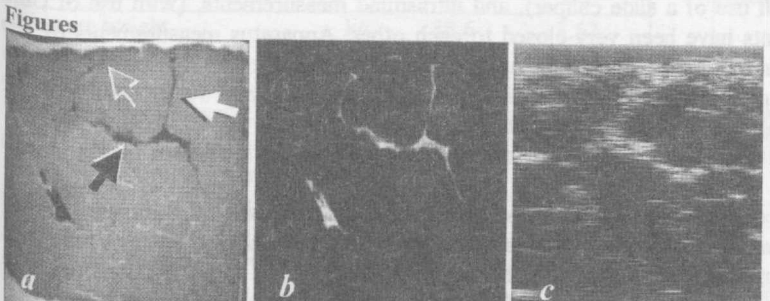

Figure 1. Images obtained at the same location of a ST muscle by (a) MRI with FS, (b) MRI with WS, (c) echography.

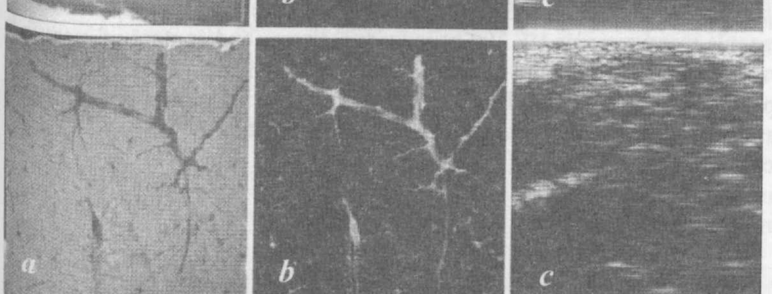

Figure 2: Images obtained at the same location of a TB muscle by (a) MRI with FS, (b) MRI with WS, (c) echography.

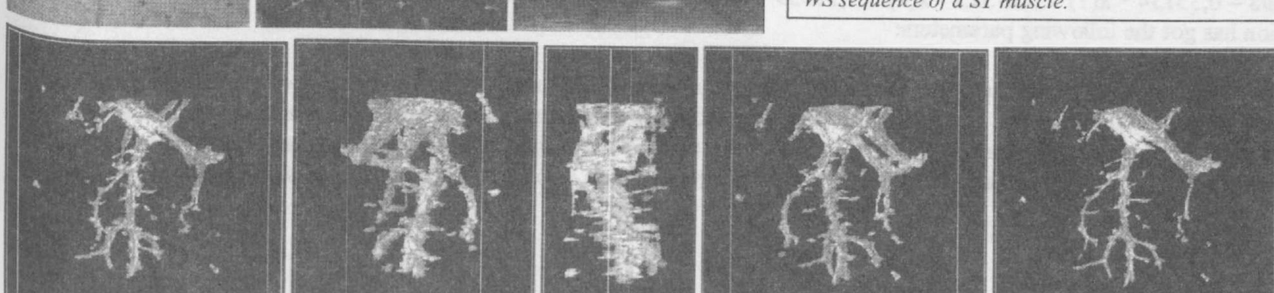

Figure 3. Three-dimensional reconstruction of the fatty tissue from ten contiguous slices obtained with a CSS-IR WS sequence of a ST muscle.