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''Bones in *Silenz*'': A new T1-weighted SILENZ sequence evaluating the bone in MRI

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For several years, the use of musculoskeletal MR imaging has increased as a method to obtain comprehensive visualization of bones, soft tissues, and joints. The only downside to this musculoskeletal MR imaging was the anatomical description of the bone. Here, we propose an imaging technique, demonstrating the bones' edges, using the Silent Scan's T1w Fat Sat sequence.

This technique provides not only a rapid isotropic 3D sequence similar to protonic density ponderation on which the cortical bone and water appear in hyposignal, but also a real hope for robust automatic bone segmentation. Leading to an easy non-irradiant and readily new method for evaluating the bone shapes that could be very useful for surgery planning needs.

Silenz is one of the first sequences that recovers the signal of the Free Induction Decay pulse, using a rapid coverage of k-space with radial center out data acquisition between radiofrequency, with one-by-one acquisition of multiple intersecting spokes placed like an ''urchin'' and read following a spiral path in time that includes all segments. To avoid apparition of noise, the gradient steps are small, approaching repetitive gradient ramp used in gradient-echo sequences, and ramp up and down of gradients are eliminated between the spokes. Such rapid acquisition is possible thanks to the ultra-fast switching

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RF capabilities (instantly permutated from transmit to receive mode) and special use of stable system power electronics as coils and high bandwidth RF pulse. These parameters define the General Electric (GE) ''zero echo-time imaging'', in which as explained no echo is recovered, and provide a heavily proton density weighting imaging due to the low flip angle. By combining it with an inversion preparation pulse one can generate T1w images compatible with Fat Sat technique.

The T1w SILENZ sequences has shown promising results for generating the necessary clinical contrast while reducing the scanner noise to near ambient (< 3dB(A) above ambient) levels [1].

Our MR acquisition of shoulder bone and knee segmentation was performed using the Silenz Scan sequence on the GE Optima™ MR450w 1.5 T GEM and the 16-channel large flex coil array wrapped around the joint.

To obtain isotropic 0.9 mm slices, a sequence with a FOV including the entire scapula lasts approximately seven minutes while the knee acquisition lasts approximately four minutes. Placed in ventral decubitus position for the shoulder acquisition, the patients are less likely to move, thereby minimizing motion artifacts.

The T1w of this sequence provides a very good contrast between the cortical bone, which is in hyposignal, and the peripheral structure of the bones, i.e., muscles, tendons, and fatty and fibrous support tissue, all of which are revealed in strict isosignal. By providing a contrast that depicts the cortical bone, it becomes easy to visualize the bone structures in the same way as X-rays for example, and can be suitable for standard bone measurements. (Fig. 1) Individualizing the cortical bone facilitates segmentation. This acquisition helps to easily extract bones from other structures in a manual way, thereby reducing what is otherwise a very time consuming procedure [2].

While CT remains the reference study to obtain bone anatomic description, an advanced post-processing [3], coupled with the use of the zero echo-time imaging technology could lead to robust semi- or automatic segmentation. (Fig. 2) By this way, we could avoid X-ray modalities that expose patients to ionizing radiation, obtain suitable data [4,5] and expand the application of this new sequence to a variety of needs.

The first aim is to generalize this technique to other joints and bones, where DICOM data could be as exportable to be 3D-printed or virtually augmented [6], or to fit perfectly as prosthesis to the patient's bone shape [7]. Such technique can guide and facilitate every surgery that needs bone measurements and valuable 3D appreciation or virtual guiding (preoperative planning, training, navigation during surgery, templates, robotics) [8,9]. The second aim is to pursue further studies to get additional segmentation of muscles, tendons and ligaments by coupling a zero echo-time sequence to other sequences (Dixon based FSE...) [10].

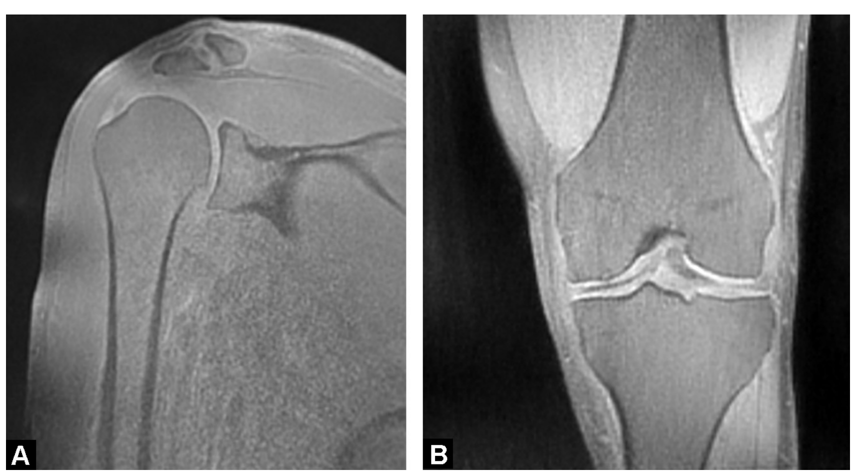

Figure 1. MRI T1 Fat Sat SILENZ sequence: A. Coronal reformat of the right shoulder. B. Reformat of the left knee, notice the cartilage in hypersignal.

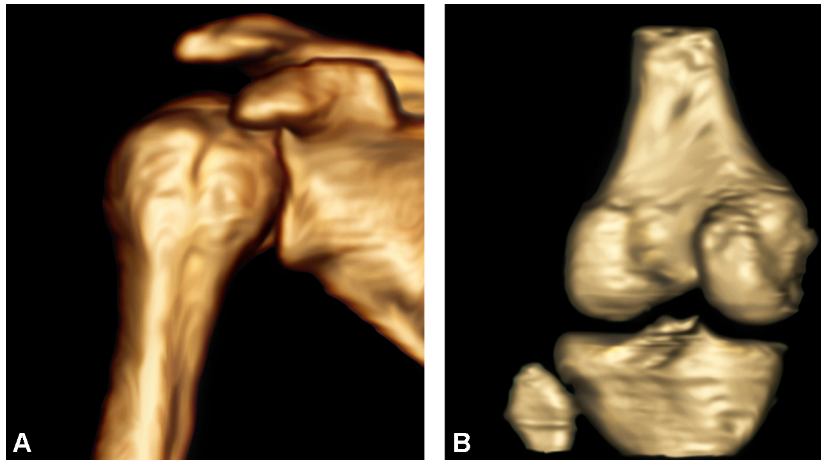

Figure 2. Volume rendering using data from SILENZ acquisition: A. Posterior sagittal view of the right shoulder, manual segmentation for about 120 minutes. B. Oblique posterior view of the left knee, semi-automatic segmentation (using post-processing anisotropic filtering, and a region growing segmentation tool) for about 8 minutes.

Disclosure of interests

Perez B.: employee as musculoskeletal MR advanced applications specialist at GE Healthcare. The authors (J. Ognard, V. Burdin, R. Ragoubi Hor, E. Stindel, D. Ben Salem) declare that they have no conflicts of interest concerning this article.

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