DYNAMIC IMAGING OF A MINIPIG'S KNEE USING A MULTICHANNEL ARRAY AND A MOVEMENT DEVICE

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Introduction

MR studies of ruptured/operated cruciate ligaments in orthopedic animal models (Ref: 1) need dynamic imaging to establish the rupture with certainty and for their dynamic characterization. While techniques for static imaging of cartilages & ligaments in these models are established, dynamic imaging poses a difficulty in certain models, due to the nature/location of the cruciate ligaments and the fact that a real-time periodic movement of the anesthetized animal's knee is required, to obtain dynamic images. One such is the dynamic imaging of a minipig's knee. The curvature of the knee is shown in Fig. 1. It can be seen that the knee is connected to and surrounded by the abdominal muscles. During movement, the knee comes out of the muscles and there is a slight translational movement, away from the body. In its extended position, the knee is completely detached from the muscles. Due to the above facts, dynamic imaging is not possible with standard coils. In this work, the dynamic imaging of the minipig's knee, with high spatial and temporal resolution, at 1.5 T is achieved using a 13 channel receive array and a movement device (to enable a controlled periodic movement of the knee) synchronized with the imaging sequence. The characterization of the coil along with static images and snapshots of dynamic images are presented.

Methods

With due consideration to the curvature of the knee and the depth of the region of interest which are cruciate ligaments and articular cartilages, 11 rectangular loops of approximately 4 x 4 cm were distributed as shown in the layout (Fig. 2), with 2 additional small loops in the centre row for a rectangular sensitivity profile. The coil housing (Fig. 3) was shaped to the curvature of the knee and preamplifiers were housed in a separate box (to reduce weight on the minipig's knee), connected to the array elements by a custom-made flexible cable. The elements were tuned, matched and decoupled for operation at 63.6 MHz, the operating frequency of 1.5 T whole body MRI scanner. A device was constructed (Fig. 4), to aid the movement of the minipig's knee. The piston operated device, powered by pressurized air from a compressor, moves the hook (shown by blue arrow in Fig.4) in both directions, which in turn is attached to the minipig's foot (Fig. 5). The device is electronically timed for start of movement and a trigger (5 V voltage pulse) from the device to the scanner is used to synchronize the movement of the knee with the MR acquisition. The program of the sequence was altered to accept this trigger. An aluminium plate was attached to the hook, as shown in Fig. 4, to act as an eddy current break and prevent the fast recoil of the minipig's knee.

Fig. 1: Curvature of the minipig's knee – the knee is connected to abdominal muscles

Results

Fig. 6 shows the noise correlation of the array with an average correlation of 0.2 and a maximum correlation of 0.33 between any 2 elements. Fig. 7 shows a turbo spin echo image, with the posterior cruciate ligament of minipig's knee (PCL), marked by the red-arrow, in a resolution of 0.4 x 0.4 mm. The high SNR in the region of interest can be seen and this is essential to image the ligaments in motion. A comparison of root sum of squares reconstruction (Ref: 2) of gradient echo images of the constructed coil and an existing 8 channel standard coil (images not shown) show that the SNR from the new coil is 69% higher in the region of interest. The snapshots (Figures 8-10) from dynamic images (segmented FLASH, TR =4.8 ms, TE =2.3 ms, BW =391 Hz/pixel), show the ligaments during motion, with a temporal resolution of 20 ms (corresponding to 50 frames/second) and a spatial resolution of 1.16 x 1.16 mm.

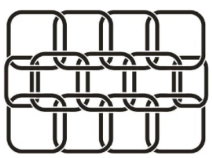

Fig. 2: Layout of the loops

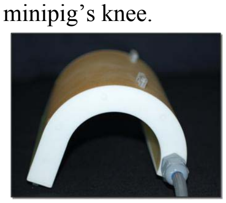

Fig. 3 Coil housing shaped for the minipig's knee

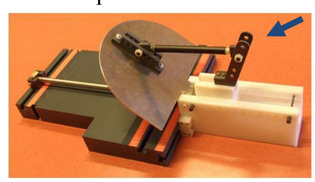

Fig. 4 Movement device - The minipig's knee is attached to the hook shown by blue arrow

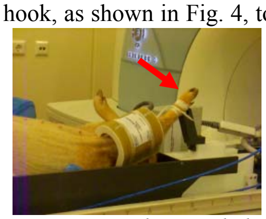

Fig. 5 Minipig's knee and the coil, with the foot of the minipig attached to the hook of the movement device

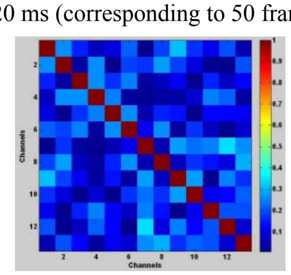

Fig.6: Noise correlation of the 13 channel receive array

Fig. 7: turbo spin echo of minipig's knee, TR = 2s, TE=18ms, slice thickness= 1 mm

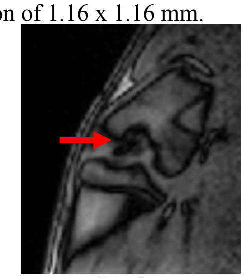

Fig. 8

Fig. 9

Fig. 10

SNAPSHOTS OF DYNAMIC IMAGES WITH A TEMPORAL RESOLUTION OF 20 MS. Fig. 8 shows the anterior cruciate ligament marked, and figures 9 and 10 show the PCL of minipig's knee. Please note that unlike a static image, it was not possible to capture the entire ligament in one slice during motion, due to the slight translation and rotation of the ligament.

Conclusion:

The 13 channel receive array, constructed for imaging the ligaments of minipig's knee provides static images, as shown, with high resolution in the region of cruciate ligaments. The movement device provides controlled movement of the minipig's knee in synchronization with the sequence. The dynamic imaging of a minipig's knee, in high spatial and temporal resolution, was achieved with this unique combination of the array, movement device and movement sychronised sequences. This can now be used to establish ruptures with certainty and to study their dynamic characteristics, which is especially important for studies related to tissue regeneration and therapy.

References: 1: Heymar et al., Biomaterials 29 1473-1483 2008 **2:** Kellman et. Al., MRM 54 1439-47 2005

Acknowledgements: Special thanks to BayStMWIVT and project 'Forzebra' (www.forzebra.de) funded by Bayerische Forschungsstiftung.