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A catheter-mounted magnetic resonance detector coil for biliary imaging: first *in vitro* images

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Background

Biliary strictures & current diagnostic limitations

The incidence of cholangiocarcinoma (CC) is rising globally. CC has increased to become the commonest cause of death from a primary liver cancer in the UK[1]. Despite advances in CT & MR technology, the correct classification of biliary strictures as benign or malignant remains difficult. This is particularly so in patients with primary sclerosing cholangitis, the commonest known predisposing factor for CC[2]. Even ERCP with brush cytology has a low sensitivity for neoplasm detection[3]. Traditional axial MR systems have an external detector radio-coil built into the scanner gantry. However, the strength of the radio signal emitted by tissues being imaged decays exponentially with distance.

A MR system in which the detection radio coil is closely apposed to the tissue of interest could improve the resolution of images obtained and offer the ability to study tissue metabolism *in vivo* using MR spectroscopy (MRS). Our group has developed a prototype version of such a coil, designed such that it could be passed into the biliary tree via an endoscope to improve tissue conspicuity.

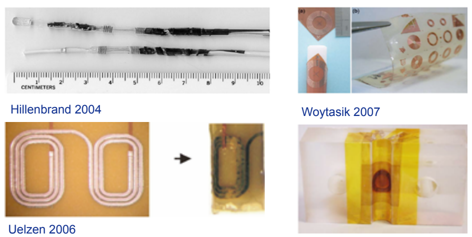
EPSRC Project Aims

- **Develop a micro-engineered MR receiver coil with sub-millimeter resolution**
- **Integrate this into a MR compatible biliary catheter**
- **Produce *ex vivo* high resolution biliary images**
- Integrate tissue sampling capability
- Build an MR compatible duodenoscope
- Develop a system to compensate for respiratory artefact
- Develop plans for a translational clinical study

Micro-coil requirements

- Cheap – single use
- MR compatible and sterilisable
- Watertight, electrically safe
- Flexible, to make turn
- Include fiducial material to identify position
- Allow tunability
- Allow access to catheter lumens
- Useable through biopsy channel of 3.2 mm
- Withstand deflection over bridge

Previous state-of-the-art microcoils



Hillenbrand 2004 Woytasik 2007 Uelzen 2006

Figure 1: Previous attempts at MR receiver microcoil fabrication by three other groups

Aims

- To confirm the utility of a prototype MR receiver micro-coil
- To collect quantitative resolution data
- To prove that the coil can function in wet conditions
- To confirm the potential to image anatomical detail in *ex vivo* tissue

Method

The microcoil is fabricated by electroplating 20μm thick Cu tracks onto 25μm thick polyimide. It is a 2-turn thin film device, tuned and matched at 63.8 MHz with discrete SMD capacitors. The microcoil is wrapped around the tip of an 8F biliary catheter and sealed with heat shrink tubing (Figure 2). Overall, the probe is 2.7mm in diameter and is fully MR compatible. The probe is pictured in Figure 3.

Microcoils of 30, 40 and 60mm have been fabricated. Later versions have shown an improved physical profile and imaging quality has also been improved.

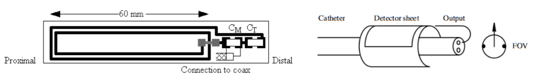


Figure 2: Microcoil design showing (a) Layout of Cu track and capacitors on film (b) application of film to catheter

Method continued

Images were acquired using a 1.5T GE Signa™ scanner, using the main body coil for excitation and the wrap-around microcoil probe for detection. The imaging parameters for these experiments are described in Table 1.

Range and resolution were established first, by placing the coil between a standard spherical water phantom and a cuvette containing resolution test samples in $CuSO_4$ solution. The micro-coil was located at the magnet isocentre and arranged parallel to the magnet bore. In Experiment 1 a nylon nut and bolt were imaged (Figure 4). The pitch of the teeth on the bolt is known to be 0.7mm.

In Experiment 2 uniformity testing was performed using a specially constructed rig to hold the microcoil probe immersed in copper sulphate solution. A sagittal scout image was obtained before axial images were acquired along the length of the probe (Figure 5).

In Experiment 3 images were acquired with the microcoil catheter placed in the cystic duct of a butchered porcine liver (Figure 6)

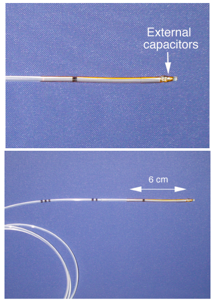


Figure 3: Fully assembled 60mm microcoil catheter

Experiment	1	2a	2b	3
Microcoil length	35mm	35 mm	35 mm	35mm
Object	Bolt	Immersion test	Immersion test	Porcine liver
Sequence	T_2-weighted 3D GRE FRFSE	Localiser - offset	T_2-weighted 3D GRE FRFSE	T1-weighted 2D SE
TR (msec)	33	6.82	33	400
TE (msec)	15	2.45	15	12
Flip angle (°)	10	30	10	90
No of slices	28	-	28	18
Slice thickness (mm)	1.2	-	1.2	3
FOV (mm)	80 x 40	-	80 x 40	80 x 80
Pixels in Slice	256 x 224	256 x 128	192 x 160	192 x 160
NEX	6	3	4	2

Table 1: Imaging parameters for each experiment

Experiment 1 – resolution testing

Scanning a resolution test sample produced images showing entire 10mm deep cuvettes, together with a similar depth of water phantom. Within the cuvette, the nylon bolt can be clearly seen. Resolution is adequate to discriminate individual teeth on the bolt (Figure 4).

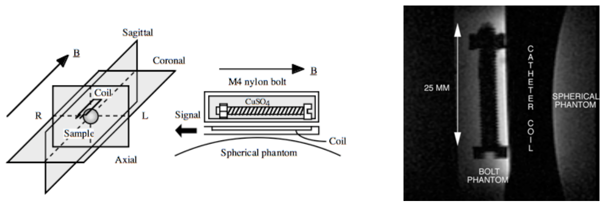


Figure 4: (a) Experimental set-up 1 with nylon bolt in and (b) image acquired

Experiment 2 – uniformity testing

Figure 5b shows a sagittal image from a localiser scan. The microcoil can be seen running vertically, together with the support rod and co-axial wire. It is not clear why the field of view is distorted, and this aspect requires further investigation.

Figure 5c shows 28 consecutive axial slices along the microcoil. The central dark area represents the 8F catheter. The signal is highly uniform along the length of the coil. Degradation is apparent in the early images, where the coil is attached to the support. Two small defects can also be seen along the length of the coil, due to the the coil conductors. These are either material artefacts or represent coil reception pattern.

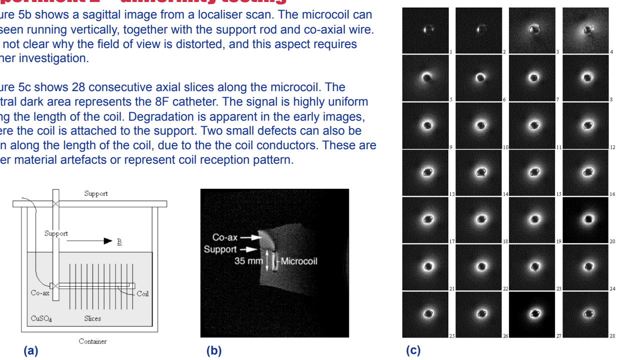


Figure 5: Uniformity testing (a) Experimental set-up 3 (b) Sagittal scout view of probe (c) axial imaging along length

Experiment 3 – *ex vivo* liver imaging

Imaging of porcine biliary tree revealed anatomical detail to a radius of more than 1.5cm, 360° around the coil, along 3.2cm of its length. Branching bile ducts and blood vessels can be visualised in the images obtained.

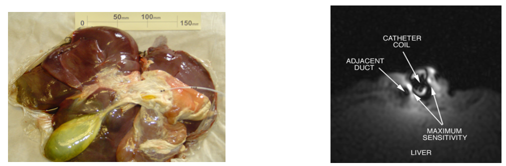


Figure 6: (a) Experimental set-up 4, porcine liver with (b) the image acquired

Conclusion

The MR probe developed by our group can reliably produce images of a resolution of at less than 1mm and field uniformity is excellent. The probe can demonstrate anatomical detail in meat models. It is waterproof. Further work to enhance the utility of the probe is required, but the clinical and research potential is substantial

Further microcoil projects

- Migrate project from 1.5T to 3T scanner
- Add magnetic resonance spectroscopy capability
- *Ex vivo* imaging of diseased animal tissue
  - Woodchuck, veterinary specimens
- Linkage of imaging, histological and cytological findings
- *Ex vivo* imaging of diseased human tissue
- *In vivo* human study
  - Oesophageal imaging with NGT
  - Integration of field modifier
  - Biliary imaging via PTC or naso biliary system
- Integration of non magnetic duodenoscope (built)

References

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