Nd:YAG laser based laparoscopic liver resection in a 1.0 Tesla high field open MRI: Evaluation of suitable dynamic MR sequences for image guided surgery

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Objectives: Intraoperative imaging is an essential tool to facilitate complex minimal invasive liver surgery[1]. We consider MR-guidance as a possible alternative to laparoscopic ultrasound. Aim of this study was to identify suitable interactive (dynamic) magnetic resonance (MR) sequences for real time MR guided laparoscopic liver dissection in a 1.0 Tesla high field open MRI Scanner. To simulate the interventional setting a newly developed MR-compatible endoscopy unit was installed inside the MR-room. Four dynamic sequences encompassing balanced steady state free precession (bSSFP), T1W gradient echo (GRE), T2W GRE and T2W fast spin echo (FSE) were analyzed regarding the image quality, artifact susceptibility and the performance of SNR and CNR. As a proof of concept MR-guided laparoscopic liver resection was performed in two healthy house pigs using the T2W TSE sequence.

Materials and Methods: The measurements were performed in a 1.0 Tesla open MRI unit (Panorama HFO, Philips Healthcare, Best, NL). The interventional equipment encompassed a MR-compatible high resolution camera, a non ferromagnetic laparoscope and a laser instrument for tissue dissection. During the intervention the MR and the endoscopic images were displayed on two separate monitors. Acquisition time, flip angle, echo time and repetition time are given at **Table 1.** Qualitative image analysis was performed by two experienced radiologists on a separate workstation by analyzing the MR images. As a proof of concept liver dissection was performed in two pigs. For access to the abdominal cavity two ports for camera, suction and irrigation and clipping were placed. Additionally a MR compatible gel port was introduced for intraabdominal manipulation. A left lateral liver lobe resection was performed and the pigs were sacrificed at the end of the operation.

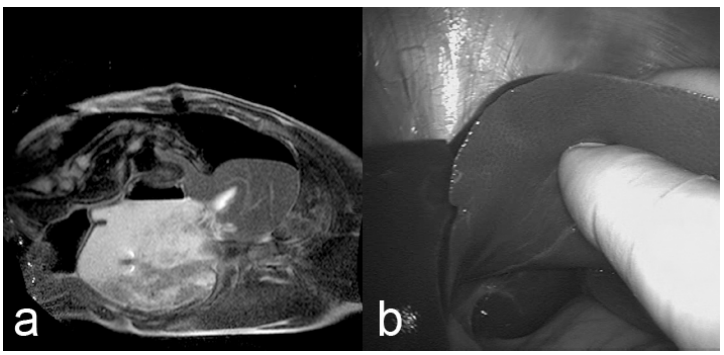
Results: The T2W TSE sequence (1.5 seconds/image) was considered superior due to an intraoperative SNR of 6.9 (±0.7) and CNR (vessel to parenchyma) of 5.6 (±1.7) in the interventional setting with a good delineation of small and large hepatic vessels during native and interventional mode as shown in **Table 1**. Furthermore the T2W FSE sequence produced a minimum of susceptibility artifacts[2]. The T1W GRE presented comparable vessel depiction with an elongated acquisition time and increased susceptibility artifacts. The bSSFP sequence allowed an almost 2 times faster image acquisition compared to the T2W TSE but revealed low SNR and very low CNR values with an active camera and showed pronounced susceptibility artifacts. Subsequently the dynamic T2W TSE sequence was used during the laparoscopic liver resection. Initial experience showed a good visualization of vessels during the dissection, which was helpful for intraoperative orientation.

Conclusion: Image guidance for interventional MRI during liver resection is best achieved with dynamic T2W TSE sequences due to good spatial and temporal resolution of intrahepatic vessels.The additional MR images offered simultaneous multiplanar real time visualization of the liver vessels during the intervention and thereby increased the anatomical orientation of the surgeon.

[1] Santambrogio, R., et al. Impact of intraoperative ultrasonography in laparoscopic liver surgery. Surg Endosc, 2007. 21(2): p. 181-8 [2] Boll, D.T., J.S. Lewin, J.L. Duerk, A.J. Aschoff, and E.M. Merkle, Comparison of MR imaging sequences for liver and head and neck interventions: is there a single optimal sequence for all purposes? Acad Radiol, 2004. 11(5): p. 506-15.

Sequence	Acquisition time	SNR liver	CNR liver	Artifacts	Image Quality	NEX	FA / TR/ TE	Vessel contrast
Intraoperative bSSFP	0.8	5.1 (±0.5)	3.0 (±0.4)	+++	+	1	35° / 4.6 / 2.3	white
Intraoperative T1W GRE	2.0	5.4 (±1.8)	4.1 (±1.4)	++	+++	2	15° / 12 / 7	white
Intraoperative T2W GRE	2.5	3.4 (±1.5)	1.7 (±1.1)	++	+	1	90° / 14 / 7	Black
Intraoperative T2W FSE	1.5	6.9 (±0.7)	5.6 (±1.7)	+	+++	1	90° / 1500 / 0.9	black/white

Table 1: Field of view (FOV) 350 x 280 mm; voxel size 2 x 2 x 8 mm; Matrix 176 x 140; Mean values and standard deviation of SNR and CNR measurements are shown. Susceptibility artifacts were rated on a five point scale encompassing no artifacts (-), minor artifacts (+), medium artifacts (++), major artifacts (+++) and no image (++++). Rating of image quality was based on a five point scale ranging from very good (++++), good (+++), sufficient (++), poor (+) to not visible (-).



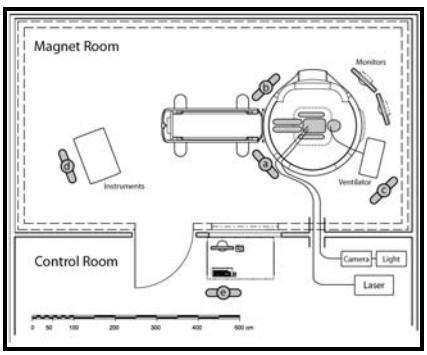


Figure 1: Intraoperative images during hepatic dissection. a) The MR monitor depicts the right hand of the surgeon which lifts the left lateral liver lobe. b) Corresponding endoscopic image. **Figure 2:** Simplified sketch of the open MR and control room. The surgeon and his assistant are displayed next to the patient (a, b) while the anaesthetist operates the ventilator at the patients head (c)