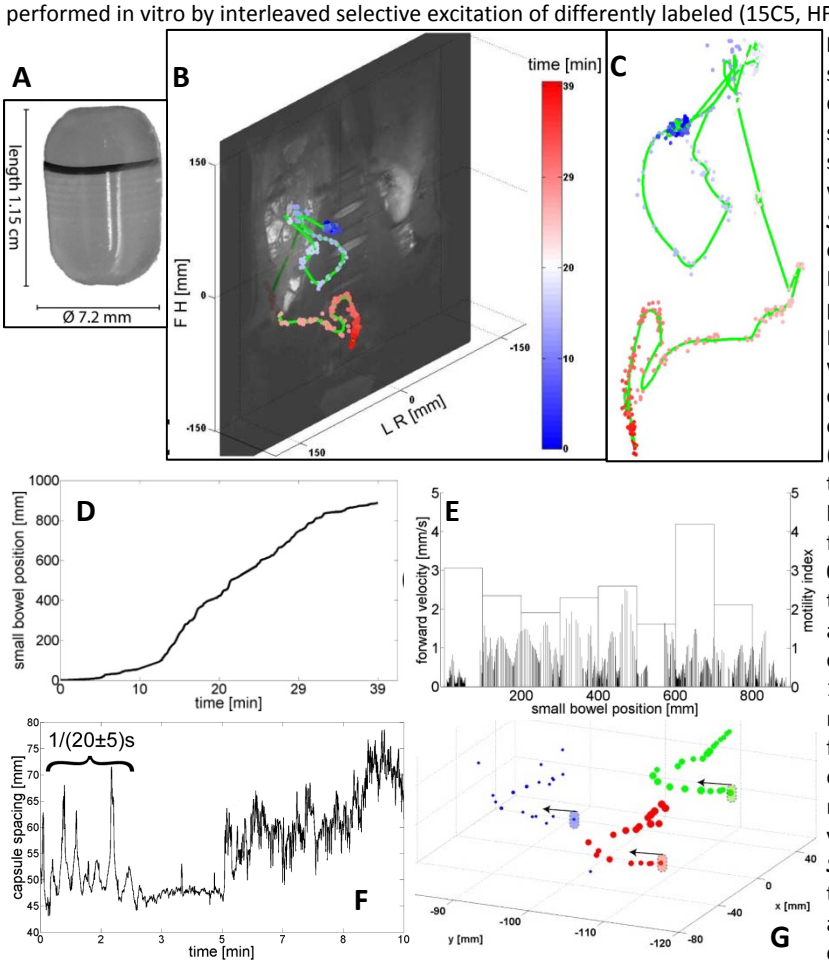
Visualization and quantification of intestinal transit and motor function by real-time tracking of 19F labeled capsules in humans

T. Hahn[1], S. Kozerke[1], W. Schwizer[2], M. Fried[2], P. Boesiger[1], and A. Steingoetter[1,2]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Division of Gastroenterology and Hepatology, University Hospital Zurich, Zurich, Switzerland

Introduction: The potential of PFCs in combination with ^{19}F MRI for the non-invasive detection of human gastrointestinal (GI) transit was highlighted in 2002 by Schwarz *et. al* (1). However, no quantitative description of physiology like capsule velocity and residence times could be shown. The aim of this work was to implement a combined ^{19}F and ^{1}H MRI framework enabling the co-registration of local intestinal motor function and transit assessed by ^{19}F MRI with anatomical ^{1}H MRI data, thereby demonstrating its potential for physiological and clinical GI MRI.

Methods: Biologically inert and impermeable 15C5 labeled capsules (^{19}F capsules) were developed. Capsule movement and gastric transit upon oral administration of one and two capsules in two subjects were monitored in real time by a ^{19}F projection imaging sequence using a 3T whole-body system equipped with a dual-channel ^{19}F transmit-receive surface coil. The projection sequence was a balanced SSFP sequence with phase- and slice-encode gradients switched off (TR/TE = 4.43/1.98 ms, 320mm FOV, 4mm resolution), a sinc-Gaussian RF pulse with BW of 1833 Hz and temporal resolution of 133ms. Gastrointestinal motor activity was computed from the detected capsule coordinates for 90cm long intestinal sections and over periods of 40 - 50min. In addition, multiple capsule tracking was performed in vitro by interleaved selective excitation of differently labeled (15C5, HFB, F-Decalin) 19F capsules.



Results: In vivo intestinal ^{19}F capsule tracking was successfully performed in both subjects on two study days. Capsule positions were reliably detected in the stomach by both the ^{1}H scout and ^{19}F projection sequence. Detection of intestinal ^{19}F capsule position was only feasible using the ^{19}F tracking sequence.

***Study day #1 (single capsule tracking)*:** The developed 19F capsule is displayed in Figure A. Figures B and C show the determined capsule positions and fitted intestinal course for one subject. Mean ± stddev SNR values of ^{19}F capsule positions were 17.1 ± 6.0. Figure D and E provide the calculated local intestinal residence times, corresponding forward velocities and motility indices (total distance traveled/aboral distance traveled) for the same subject. The analyzed intestinal section lengths were 0.85m and 0.89m and calculated forward velocities were 0.27mm/sec and 0.38mm/sec for subject 1 and 2, respectively. The total distances travelled by the ^{19}F capsules including all pendular movements were 3.15m and 2.34m and corresponding mean capsule velocities were 1.0mm/sec and 1.0mm/sec for subject 1 and 2, respectively. Subject 1 showed a larger variation in forward velocity over the entire intestinal section compared to subject 2. Despite intermittent higher maximum velocities in subject 1, the mean transit velocity and thus the transit were slower.

Study day #2 (dual capsule tracking): In contrast to the single capsule tracking, dual capsule tracking allowed for reliable assessment of breathing compensated intestinal peristaltic patterns by calculation of capsule distances over time, Figure F. Three phases of different pendular movements were detected during the first 10 min. During the early phase (0 - 2.5 min) a slow pendular movement was detected (frequency 1/(20 ± 5s)) while no regular pattern was detected for the second phase (2.5 - 5min). The third phase exhibited a mixture of fast and slow pendular movements.

In-vitro multi frequency experiment: Interleaved tracking of three differently labeled ^{19}F capsules proved feasible at a temporal resolution of 0.4 s as shown in Figure G. While the SNR values for HFB and 15C5 were comparable, the SNR of Perfluorodecalin was close to the lower detection limit.

Discussion: Single capsule tracking allowed the assessment of various functional parameters of intestinal physiology. Two approaches have been proposed for multiple capsule tracking. The first approach relied on additional reference data that has to be integrated in the post-processing to determine unequivocal capsule start and interim values in case of overlapping coordinates. The second approach made use of different 19F markers to identify differently labeled 19F capsules by a frequency adjustable 19F projection imaging sequence. Thus, the problem of unambiguous coordinate data is overcome at the expense of a decreased temporal resolution. The first approach was successfully validated in vivo by real time tracking of two simultaneously ingested 19F capsules using the 19F projection imaging sequence. In conclusion, the developed combined 19F and 1H MRI framework is feasible for the non-invasive visualization and quantification of human gastrointestinal motor activity and furthermore, provides important supplemental information that cannot be assessed by other existing methods.

References: (1) Magn Reson Med 2002;48(2):255-261