In Vitro Study of a Tethered Micro-ultrasound Capsule Endoscopy and 3D Image Reconstruction

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Background, Motivation and Objective

Capsule endoscopy (CE) enables remote, minimally invasive observation of the gastrointestinal (GI) tract. However, as clinically available capsule endoscopy devices only use optical imaging, it is limited to viewing only the gastrointestinal mucosal surface preventing the acquisition of information within the lumen wall. Micro-ultrasound using high frequency (> 20MHz) ultrasound can provide ~10 mm penetration below the tissue with about 40-120 μm imaging resolution. Micro-ultrasound capsule endoscopy (μUSCE), with this deep imaging capability, is thus a complementary solution to the VCE. This paper describes an *in vitro* study of a μUSCE device and demonstrates 3D images of porcine small intestine.

Statement of Contribution/Methods

The prototype of μUSCE device consists of a micromotor, an electromagnetic ring and an ultrasound transducer based on $LiNbO_3$ single crystal. The micromotor rotated the transducer continuously for sectional scanning. During the scanning, the transducer emitted ultrasound vertically through an acoustic window in the capsule shell and received echoes from the wall of the surrounding lumen tissue. After reaching the position of interest, the capsule was pulled back by a motor stage with constant speed to scan a certain segment of the small intestine. The capsule shell was made of acoustic friendly materials and a tether was provided for power supply and data communications. An *in vitro* study was performed in porcine small intestines to demonstrate the device's effectiveness.

Results/Discussion

The fabricated device was 10 mm in diameter and 35 mm in length, which is consistent with commercial VCE devices for clinical use. The center frequency of the ultrasound transducer is 40 MHz, and the focal distance of the transducer is ~6 mm. Several segments of porcine small intestines were used for the experiments. The μUSCE device is able to collect ultrasonic echoes during the scanning. Examples of reconstructed 2D and 3D images of the small intestines are shown in Fig. 1a and Fig. 1b, respectively, giving clear difference of the lumen layer structure and outline of the intestine. *In vivo* experiments will be conducted in the follow-up research.

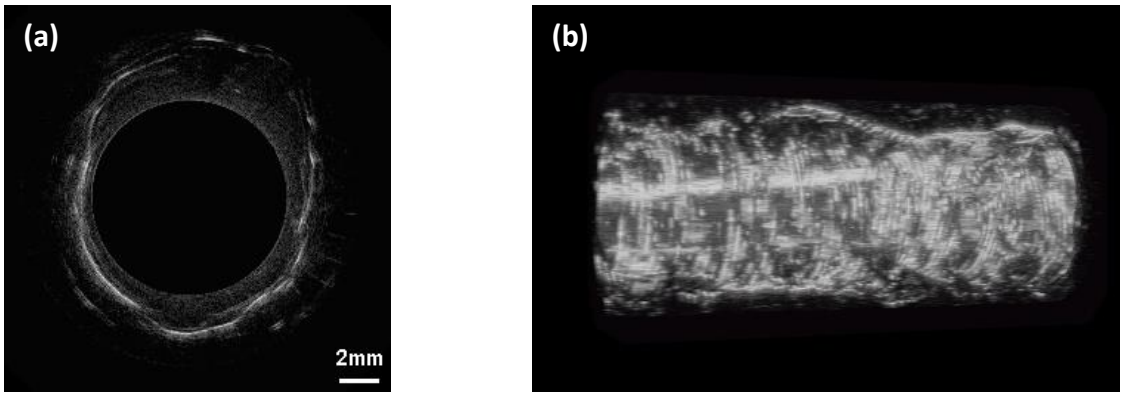

Fig.1 (a) 2D ultrasound image of porcine small intestine and (b) 3D ultrasound image of porcine small intestine *in vitro.*