increased use of helical computed tomography. At present, there are several methods for resecting impalpable tumours intraoperatively. However, the burden on the patient and facility, cost, exposure to radiation and need for additional interventional procedures are other problems associated with this modality. Hence, the development of an easy and less stressful intraoperative navigation system could play an important role. Wada et al. used a prototype convex probe ultrasound thoracoscope for localization [1]. We also hypothesized that real-time tissue elastography may be used to clearly visualize tumours in ex vivo lungs obtained from slaughtered pigs. In addition, we used the material, methyl cyclohexane as well as ultrasound gel, to achieve an adhesive bond, and a ping-pong ball and water as virtual lung tumours. They were clearly detected just below the lung in the normal mode and on elastography. On the other hand, their targets were also not detected in a deep measure in the lung. Intraoperative echo using elastography has little diagnostic benefit for detecting deep tumours. Therefore, further research is needed to obtain adequate data for assessing the clinical effectiveness of ultrasound for evaluating deeper lung tumours.

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Reply to Uramoto et al.

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We would like to thank Uramoto et al. [1] for their interest and comments regarding our study [2]. The imaging characteristics of ultrasonography are determined by the velocity of propagation and the attenuation of ultrasound [3]. The ultrasonic velocity in air-containing lung is much slower than those in other tissues. Also, an air-containing lung absorbs and scatters ultrasonic energy, resulting in high attenuation in the lung. Our hypothesis is that less ultrasonic waves would reach the tumour in air-containing lungs due to these unfavourable properties, and the reflected ultrasonic waves would also be impaired, therefore, likely causing the indistinct border of the tumour. Conversely, when the lung is completely deflated, the aforementioned phenomena would be minimal, leading to successful transmission of ultrasonic waves. This makes it exceedingly important for the probe to be firmly pushed against the lung surface for successful visualization of the tumour. Our results show that all detectable pseudo-tumours were visualized within 14 mm from the probe surface in ultrasound images [2].

Another issue is that the ultrasonic velocity of completely deflated lung parenchyma, especially when the lung is strongly compressed, can become similar to that of the tumour. This may also affect the result of indistinct tumour borders of deeply located tumours. Real tumour visualization in the rabbit model demonstrated distinct hyperechoic border of the tumours; however, imaging characteristics of ultrasound of the tumour and the deflated lung were similar to each other. Hence, further advances in technology is necessary to ensure tumour visualization in the lung with high image quality.

Elastography may be an option for lung tumour localization. This is a non-invasive imaging technology where the local tissue strains are calculated directly or indirectly in response to external mechanical stress [4]. It is clinically applied to plural organ cancer diagnosis, including breast, prostate, thyroid and pancreas; however, use for lung tumour localization is still under investigation. Uramoto et al. concluded that it has little diagnostic benefits for deeply located pseudo-tumours [1]. This was not encouraging; however, we still believe that there is room for improvement in their experimental settings. Firstly, were the lungs fully deflated? Again, air in the lung disturbs ultrasound images. It may affect elastography as well. The second concern is that their materials for pseudo-tumours may not be adequate for ultrasound evaluation as the probe needs to be pushed against the lung firmly. Real tumour evaluation would be more reliable. Lastly, target lesions for intraoperative localization should be located within 3–4 cm from the lung surface in the inflated lung. Our results showed that the depth in the deflated lung is less than half of that in the inflated lung. We believe that thoracoscopic ultrasound would be helpful for localization of tumours at a depth of 2 cm or less from the lung surface. We agree with the idea of elastography being applied to lung tumour localization and believe that further investigation is required to make any conclusions regarding the effectiveness of this technology in thoracic surgery.

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