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Abstract

A facile hydrogel system for perfect multimodal imaging and surgery practice

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Phantoms or tissue surrogates have become a necessary part in everyday medical practice. There are radiological phantoms, used for calibrating imaging instruments like ultrasound (US) and computer tomography (CT) machines. Their properties are precisely tailored to act as a benchmark for the calibration status of the respective instrument. These consist of a material with known contrast properties in a simple geometry like a cylinder.

Another type of phantom are the surgery practice phantoms, which are used in training. These are utilized to simulate a surgery and practice the procedure. Here, the material and geometry are more complex than for calibration phantoms since certain physiological circumstances have to be replicated.

Yet another level of phantoms is the design and fabrication based on real patient data. The objective here is to simulate one specific surgery that may be so complex that a trial on a phantom body may drastically improve the outcome of the surgery. These surgery practice phantoms hold the highest true-to-life level of all of the phantoms.

In the reality of medical practice, a combination of these requirements is necessary. The training of complex surgeries usually is preceded by radiologic imaging. To build the most realistic and suitable phantoms, the combination of true-to-life properties like CT contrast, US contrast and mechanical properties is necessary. The current phantoms cannot replicate this.

We show a facile system based on the hydrogel sodium-alginate and vegetable fat, for which the mechanical, US and CT properties can be tuned independently. The sodium alginate can be physically crosslinked by the introduction of divalent calcium ions (Ca^{2+}). By changing the concentration and crosslinking degree of alginate and the amount of vegetable fat addition, the density, elastic modulus, and shear wave velocity of the material system can be independently tailored to simulate the properties of specific tissue and organs. From this material system, we were able to build true-to-life surgery phantoms for laparoscopic surgery and the development of augmented reality applications. CT, US and mechanical measurements showed the versatility and accuracy of this system and indicated its use for building surgery training phantoms.

AUTHOR'S STATEMENT

Conflict of interest: The authors have filed a patent for this invention under the number DE 10 2022 133 558.5. Animal models: Indicate here under which approval you have carried out animal experiments. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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