Development of hydrogel models that can be used for advanced surgical training

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Introduction

Designing and preparing highly simulated biological tissue and organ models, and constructing artificial simulation systems with suitable physical and chemical properties and biological structure to promote surgical training have important practical value for improving doctors' surgical skills and implementing precision medical procedures.

Methods

First, through image processing technology, the human CT data is edited and optimized and the design is improved, and the template that meets the actual needs is obtained and converted into a printable format, and the optimized design of each organ mold is produced by 3D printing. Secondly, the 1799 type polyvinyl alcohol (PVA) powder was dissolved into a colorless and transparent clear solution by magnetic stirring at 90°C, and different amounts of solutions were taken according to different organs for preparation. Powders such as aluminum and silicon oxide are used to adjust the overall acoustic performance of the gel. The sound speed of the gel is adjusted by adding substances such as ethylene glycol or glycerol to achieve the basic clinical value. Different proportions of aqueous dyes are added for solution rendering according to different organ models. , in clinical surgical bleeding treatment, electrocoagulation is usually used for carbonization coagulation, and the mechanism of carbonization coagulation is caused by the denaturation of protein. Therefore, the content of protein is added and adjusted in the hydrogel to simulate the real tissue reaction. When the solution is uniform as a whole, inject it into the dirty mold until it fills the entire mold. Then put the whole mold into minus 20°C to freeze for 10-16h, then take it out and thaw it at room temperature for 4-10h, and freeze-thaw cycles 1-4 times according to the difference of organs, so as to obtain organ models with similar performance. Finally, the model is demolded. For ordinary solid organ models, demoulding can be carried out under the wetting of deionized water, and non-solid organ models need to undergo post-processing such as removing the inner core. In addition, considering the characteristic requirements of different organ models, we began to explore the acrylamide and sodium alginate composite hydrogels. We found that the composite hydrogels have good mechanical properties and can almost fully meet the mechanical requirements of any soft tissue. The effect is more obvious and realistic in the coking and carbonization effect of electric knives and other instruments.

Conclusions

The hydrogel model proposed in this study can be used for actual operation of various surgical instruments and basic acoustic inspection in preoperative planning and surgical training. Observation and operation are carried out under the detection, and the overall acoustic properties basically meet the clinical requirements, and are similar to the properties of the real human organ model.

Results

The prepared hydrogel model is set as a reference standard with the test results of the fresh organs of the isolated pig or the actual test results of the human body, and the physical and chemical properties such as mechanical properties, acoustic properties, antibacterial properties, and microstructure of the developed model are characterized respectively Analyze and adjust against reference standards. The optimized model is used by surgeons for basic surgical operation experience and electrical instrument cutting, etc., and has been well evaluated by doctors. They believe that the operation using the hydrogel model is very similar to the real operation, and the operation experience is comparable. The previous silicone material model is better and can be easily trained multiple times.

(a) Ultrasonic knife electrocoagulation carbonization

(b) Surgical ultrasonic knife cutting

(c) Hydrogel liver model

(d) Hydrogel pancreas model

(e) Ultrasound observation of hydrogel images

(f) Pancreatojejunostomy hydrogel model

