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A quantitative assessment approach of patch suturing in fetal surgery

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Introduction

Percutaneous fetoscopic patch coverage of spina bifida aperta [1] is a prenatal repair which consists of suturing a patch on the back of the fetus with a minimally invasive approach. Because of its complexity and its difficulty, high-fidelity training environments are demanded. Such training model was developed in previous work [2]. Skill Assessment on this training model is measured with clinical outcomes such as a patch watertightness test. Despite the effectiveness of the latter metric, it remains invasive and not transferable to the operating room. Due to the non-invasiveness of the instrument motion tracking system, we hypothesized that the motion-based skill metrics evaluated during the patch suturing could be a surrogate for the watertightness test.

The Spina-Bifida Patch Repair Trainer

The training model simulates the surgical steps of a standardized two-layer spina bifida fetoscopic repair in New Zealand rabbits (Fig.1). The abdominal cavity is insufflated with CO2 to mimic the insufflated uterus of the patient. The dilated stomach of the rabbit serves as a representation of the back of the fetus, allowing the trainee to practice suturing a patch watertightly.

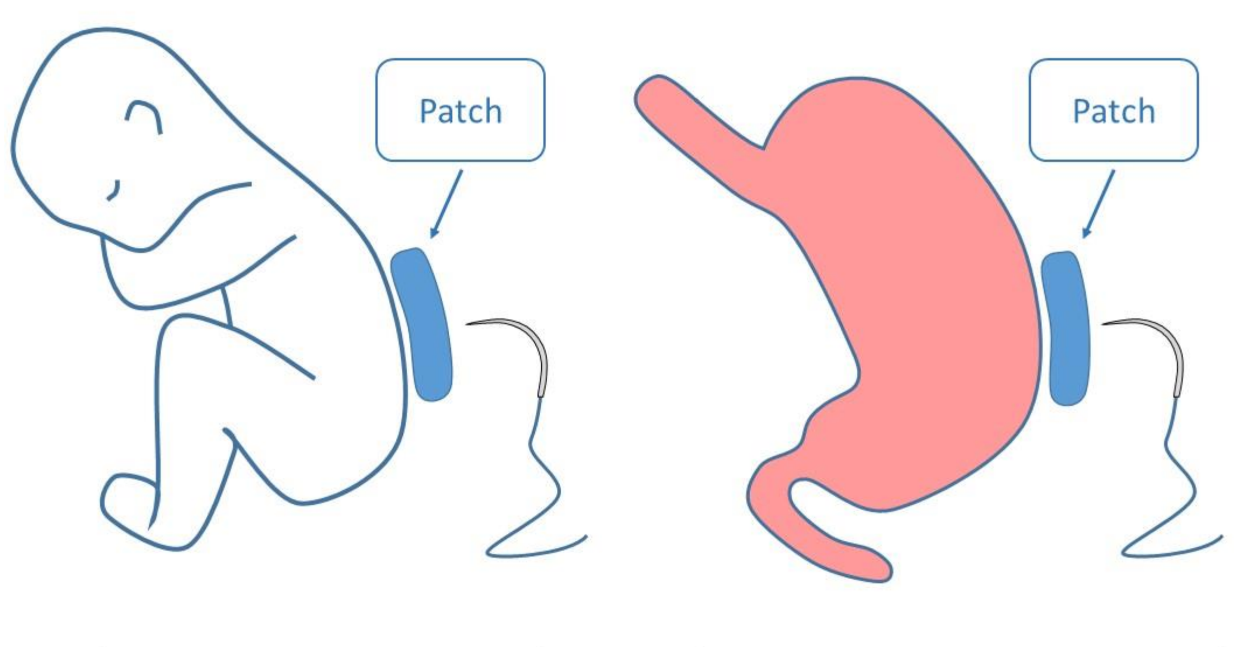


Fig. 1

Surgical Skill Analysis

One right-handed laparoscopic surgeon trained on 34 rabbits while being assisted by different endoscope assistants. A 6-DOF electromagnetic tracker was installed around the training model in order to capture the position of the different instruments over time (Fig.2). Classic motion-based skill metrics such as path length, volume occupied by the instrument, smoothness, etc.

Fig. 2

Clinical outcomes were also measured and reported previously [2] : operation Time (OT), OSATS score and watertightness test (WT) (Fig.3). The metric of interest in this paper is the watertightness of the patch which was measured at the end of the surgery by inserting fluorescein under the patch by accessing the inside of the stomach. The fluid was injected with a pressure of 30cmH2O.

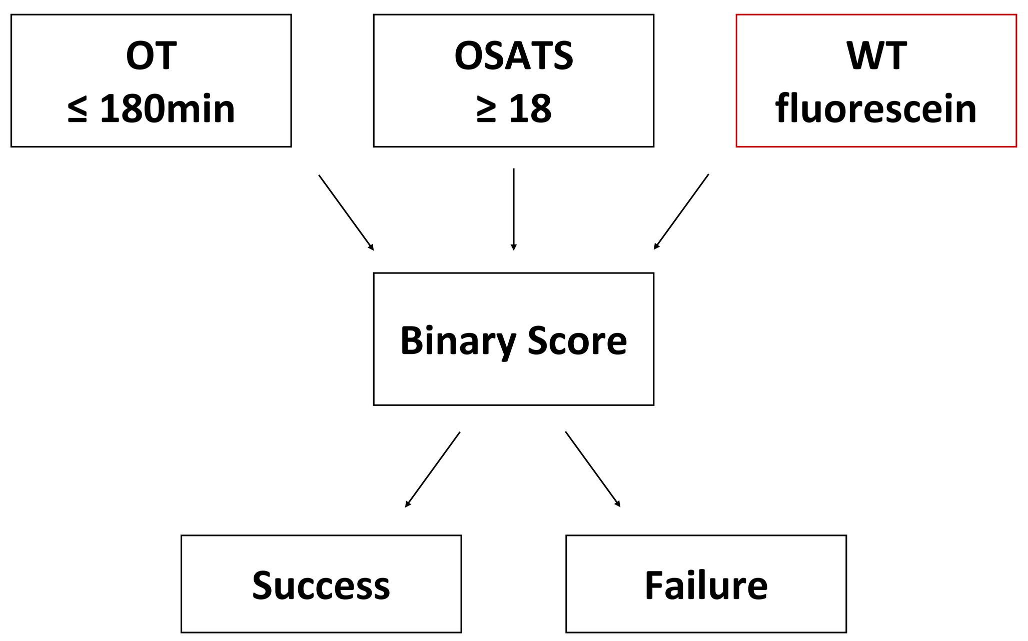
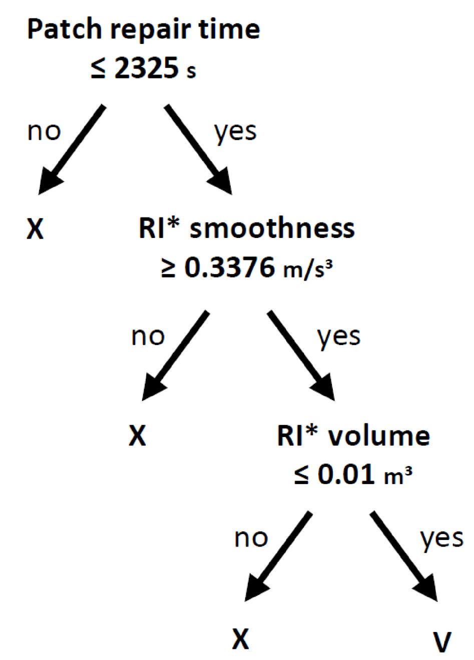
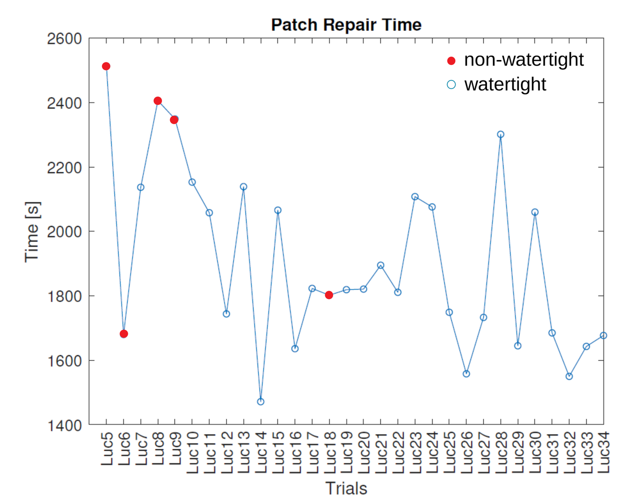


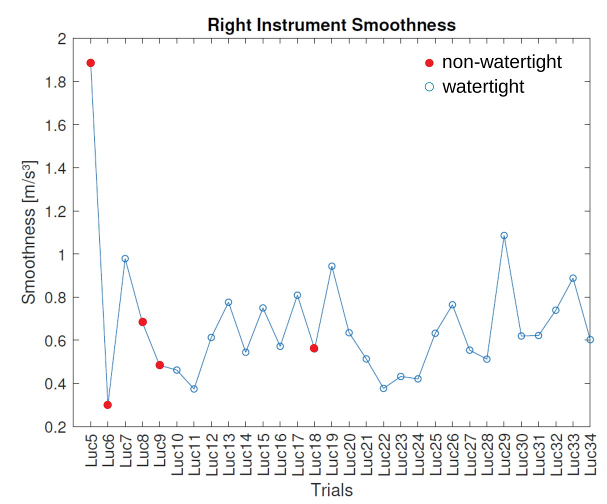
Fig. 3

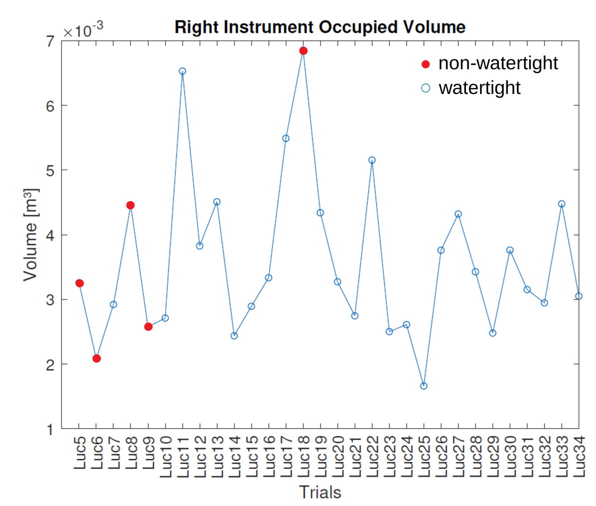
Surrogate for watertightness test

A classifier was built to predict the watertightness of the patch. The MATLAB program (Mathworks, Natick, MA, USA) was used to apply a coarse decision tree with the Gini's diversity index as splitting criterion on a set of 37 metrics (e.g. time, instrument path length, smoothness, mean speed…). The algorithm was trained with a cross-validation approach (leave-out one technique). Three metrics revealed to be discriminative : patch repair time, right-instrument (RI) smoothness and RI occupied volume.









Cross-validation performance (leave-out one technique) revealed to have 92% True Positives and 40% True Negatives values. This classifier benefited from a high sensibility but suffered from a rather low specificity, which made it suitable for a screening test.[3]

Conclusion

Instrument motion-based skill analysis was performed on a 34 rabbits operated by a unique surgeon. These preliminary results showed that this approach could be a potential screening test for assessing the watertightness of the sutured patch. We believe that in order to obtain a diagnostic test, i.e. higher True Negative values, another approach must be envisioned. Future work will focus on investigating the relationship between image analysis of the sutured patch and its watertightness.

Acknowledgments

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