Movement Consistency by Optical Tracking Correlates with Surgical Expertise

Fraser Anderson, Daniel W. Birch, Pierre Boulanger, Walter F. Bischof

Introduction

This study presents a novel method of automatically assessing surgical expertise that can be used to automate the evaluation of surgical skill and provide the surgeon with more detailed feedback. Automated, objective evaluation is essential for understanding surgical dexterity and ensuring surgeons are competent before entering the OR and throughout their careers. Previous research has identified simple measures such as path length and motion smoothness, and has developed complex models analyses using Hidden Markov Models (HMMs) that can be used to discriminate expert surgeons from novices. These approaches cannot provide very useful feedback to trainees and are typically not able to reliably distinguish between high levels of surgical skill.

We have developed a new method of evaluating surgical proficiency by measuring the consistency of a surgeon's movements. This method is capable of identifying surgical skill for simple movements and identifying how movements differ. This method has the potential to increase the accuracy of current evaluation methods and provide much more detailed feedback to trainees.

Methods and Procedures

Ten participants performed five simple interrupted sutures on synthetic tissue using a pair of instrumented laparoscopic needle drivers. Each of the recorded stitches was segmented offline into *surgemes* (the individual movements that comprise the suturing task). The movement of the needle drivers and the force and torque applied to them were recorded and used to calculate the curvature of the trajectory and the energy between the tooltips and synthetic tissue. The curvature and energy signals from each surgeme were cross-correlated between stitches to measure movement consistency.

Results

For simple surgemes, experts performed similar movements. These similarities were reflected in the cross correlation of the curvature and energy signals. Surgical skill was evaluated by comparing the cross correlations to a bootstrapped noise model. Participants with high skill had a high correlation (e.g., 8 of 10 significantly correlate $p < 0.05$). Participants with lower skill level had more varying movements on the simple surgemes and the cross correlation values were lower (e.g., only 2 of 10 significantly correlate $p < 0.05$). This method also provides qualitative information on where and how the gestures differed within a surgeme. Sections of the gesture with low correlation were indicative of low skill, and could be used to guide further training.

Using this information, the surgeon could view their movements on a screen, with sections exhibiting low skill highlighted. This information could also be used by virtual reality training systems to provide haptic guidance to correct a surgeon's movements. The data could be viewed directly to understand why the movements differ, as curvature and energy are intuitive concepts to understand when visualized. Contrary to HMMs, this method of analysis can be applied any surgical task without extensive training of the system and does not use complex statistical modeling.

Conclusions

We have presented a method of automatically analyzing surgical gestures for skill assessment and training purposes. We have found that the method is capable of analyzing simple surgemes and providing an objective skill evaluation and detailed feedback. Further work in automated segmentation will likely improve the effectiveness of this method and make it robust to more complex movements.