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Operative skill: quantifying surgeon's response to tissue properties

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ABSTRACT

Background: The aim of this study was to investigate how tissue characteristics influence psychomotor planning and performance during a suturing task. Our hypothesis was that participants would alter their technique based on tissue type with each subsequent stitch placed while suturing.

Materials and methods: Surgical attendings ($n = 6$), residents ($n = 4$), and medical students ($n = 5$) performed three interrupted sutures on different simulated materials as follows: foam (dense connective tissue), rubber balloons (artery), and tissue paper (friable tissue). An optical motion tracking system captured performance data from participants' bilateral hand movements. Path length and suture time were segmented by each individual stitch placed to investigate changes to psychomotor performance with subsequent stitch placements. Repeated measures analysis of variance was used to evaluate for main effects of stitch order on path length and suture time and interactions between stitch order, material, and experience.

Results: When participants sutured the tissue paper, they changed their procedure time ($F(4,44) = 5.14$, $P = 0.017$) and path length ($F(4,44) = 4.64$, $P = 0.003$) in a linear fashion with the first stitch on the tissue paper having the longest procedure time and path length. Participants did not change their path lengths and procedure times when placing subsequent stitches in the foam ($P = 0.910$) and balloon materials ($P = 0.769$).

Conclusions: This study demonstrates quantifiable real-time adaptation by participants to material characteristics during a suturing task. Participants improved their motion-based performance with each subsequent stitch placement indicating changes in psychomotor planning or performance. This adaptation did not occur with the less difficult tasks. Motion capture technology is a promising method for investigating surgical performance and how surgeons adapt to operative complexity.

1. Introduction

Traditional studies evaluating learning curves in surgery use operative time, complications, and patient-centered outcomes as assessment measures [1–3]. Additionally, these studies tend to be conducted over long periods of time on the order of months or years [1–3]. However, adjustments in technique and improvements in psychomotor performance may happen on a

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shorter time scale and possibly within a single operative case. Understanding the type and rate of changes in motor performance during a procedure may help design targeted learning opportunities. Technology-based performance measures provide the potential for conducting more fine grained and objective analyses of learning in surgery.

There is a growing body of literature on the use of motion tracking technology to evaluate technical skill in surgery [4–9]. Motion tracking-based metrics have been shown to correlate with experience [6], final product analysis [7], and observer-based global rating scales [5,6]. Additionally, research has demonstrated significant improvement in motion tracking-based metrics (time, path length, and number of hand movements) after a training course [10]. These improvements in motion tracking-based metrics correlate with global rating scores of surgical technical skill providing construct validity for use of these measures to evaluate changes in performance over time [10]. Interestingly, most of this work has focused on how students or residents' performance changes with experience level rather than on how surgeons adjust their technique intraoperatively to adapt to task complexity. Motion tracking technology may provide an objective means for assessing a surgeon's adaptability to complex and changing task conditions.

Our prior work has demonstrated evidence of validity for motion tracking-based metrics (total procedure time, path length, and idle time) to differentiate performance based on task complexity using the variable tissue simulator [11]. The aim of this present study was to investigate how tissue characteristics influence psychomotor planning and performance during a suturing task. Specifically, we were interested in identifying changes in performance with each subsequent stitch placement. Our hypothesis was that participants would alter their technique to improve performance with each subsequent stitch placed while suturing.

2. Materials and methods

2.1. Setting and participants

Medical students ($n = 5$), junior residents (postgraduate years 1–3) ($n = 4$), and attending surgeons ($n = 6$) participated in this study. Study participants were asked to complete a suturing task on the variable tissue simulator without time restrictions. Data on participants' performance were collected using video recordings and an optical motion tracking system. No feedback on participants' performance was provided. Participants did not have prior experience on the variable tissue simulator. This study was approved by the University of Wisconsin–Madison Social and Behavioral Sciences Institutional Review Board.

2.2. Variable tissue simulator

Participants performed three interrupted sutures on different materials presented on the variable tissue simulator [11]. This simulator was designed to provide three simulated tissue types of varying difficulty as follows: foam (dense connective tissue), rubber balloons (artery), and tissue paper (friable tissue) (Fig. 1). The suturing task involved placing three interrupted instrument-tied 3-0 Prolene (Ethicon, Somerville, NJ) sutures to approximate two pieces of material. Prolene was selected for added complexity because its tendency to have memory requires additional suture management. In prior work, performance on the variable tissue simulator was differentiated by experience level according to path length and total procedure time [11]. Additionally, this prior work demonstrated suturing on tissue paper (friable tissue) was the most difficult task with participants taking longer path lengths and more time to complete.

2.3. Motion tracking system and measures

An infrared-based optical motion tracking system (Visualeyez 3000; Phoenix Technologies, Inc, Burnaby, BC, Canada) captured performance data from both the participants' hand movements. Four light emitting diodes were attached to each of the participant's hands at specified locations on the dorsum of the second digit phalanx, first digit metacarpal, mid-hand, and distal forearm [11]. Data were sampled at a frequency of 180 Hz and filtered with a dual-pass second-order Butterworth filter with a cutoff frequency of 7 Hz.

Motion tracking data were analyzed for total procedure time and path length. Total procedure time was defined as the time from when participants' hands left the neutral starting position to when the tail of the third stitch was cut. Path length was defined as the three-dimensional distance both hands traveled during the total procedure period. In this present study, path length and total procedure time were segmented by each individual stitch placed to investigate changes in psychomotor performance with subsequent stitch placements. The stitch was defined to start when the participant loaded the needle in the needle driver and ended when both sutures tails were cut.

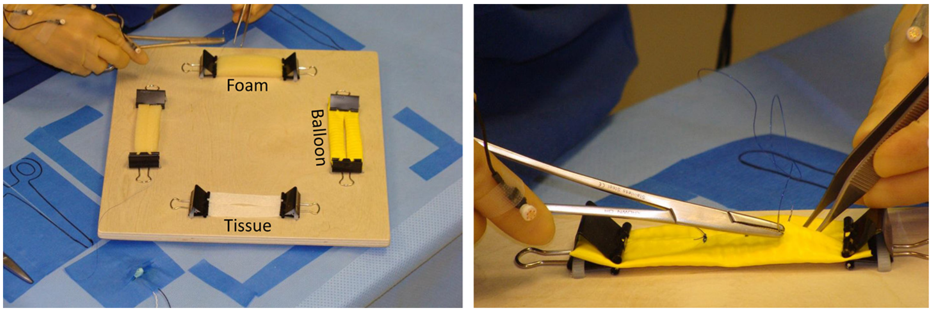

Fig. 1 – Variable tissue simulator. (Color version of the figure is available online.)