A Novel Drill Set for the Enhancement and Assessment of Robotic Surgical Performance

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Abstract

Background: There currently exist several training modules to improve performance during video-assisted surgery. The unique characteristics of robotic surgery make these platforms an inadequate environment for the development and assessment of robotic surgical performance.
Methods: Expert surgeons (n=4) (> 50 clinical robotic procedures and > 2 years of clinical robotic experience) were compared to novice surgeons (n=17) (< 5 clinical cases and limited laboratory experience) using the da Vinci Surgical System. Seven drills were designed to simulate clinical robotic surgical tasks. Performance score was calculated by the equation Time to Completion + (minor error) x 5 + (major error) x 10. The Robotic Learning Curve (RLC) was expressed as a trend line of the performance scores corresponding to each repeated drill.
Results: Performance scores for experts were better than novices in all 7 drills (p<0.05). The RLC for novices reflected an improvement in scores (p<0.05). In contrast, experts demonstrated a flat RLC for 6 drills and an improvement in one drill (p=0.027).
Conclusion: This new drill set provides a framework for performance assessment during robotic surgery. The inclusion of particular drills and their role in training robotic surgeons of the future awaits larger validation studies.

Robotics facilitates video-assisted surgery by offering a 3-D imaging system, camera stability, wrist-like instrument navigation, motion scaling, and improved ergonomics [1, 2]. These characteristics improve operator performance on standard laparoscopic bench models and also allow for steeper learning curves among novice surgeons [3-6].

Nonetheless, the robotic surgery environment requires familiarity with the device’s innate lack of haptic feedback and altered grip strength control. Smooth coordination of the camera with the arms via seamless manipulation of the masters and the foot pedals must also be learned. These unique characteristics of robotic surgery demand novel drills in order to train surgeons and to appropriately assess their robotic surgical performance.

Methods

Expert surgeons (n=2, total 4 sets of drills) (> 50 clinical robotic procedures and > 2 years of clinical robotic experience) were compared to novice surgeons (n=17) (< 5 clinical cases and limited laboratory experience) using the da Vinci Surgical System (Intuitive Surgical, Mountain View, CA, USA). Seven drills were designed to simulate clinical robotic surgical tasks in a box trainer using instruments specific for each drill. After an introduction to the robot, each subject was allowed to practice each drill once. Each drill was repeated 5-6 times depending on the specific drill. Time to completion, minor errors and major errors were recorded. Performance score was calculated by the equation Time to Completion + (minor error) x 5 + (major error) x 10. Larger scores corresponded to worse performance. The Robotic Learning Curve (RLC) consisted of a trend line of the performance scores corresponding to each repeated drill. Data was analyzed with the Friedman Test and Mann-Whitney U Test.

Drills

Drill 1: Precision Beads – Large beads are transferred between two cups alternating hands.
Drill 2: Simple Rope Pass – Rope made of large beads is passed from nondominant to dominant hand grasping at pre-determined beads.
Drill 3: Russian Roulette – Pins are transferred from an outer to inner circle alternating hands. The camera must be adjusted for adequate visualization.
Drill 4: Mobile Precision Beads – Small beads are dropped through a hole in a mobile disk.
Drill 5: Beaded String Pass – Similar to Drill 2 but with small beads.
Drill 6: Minefield – Needle from a 6-0 Prolene suture is passed through loops in a pre-arranged pattern. The camera must be adjusted for adequate visualization.
Drill 7: Suturing – 2-0 Vicryl suture is placed within a target area. One surgeon's knot and 3 square knots are tied.

Results

Performance scores for experts were better than novices in all 7 drills (Table 1, $p<0.05$).

Table 1. Mean Performance Scores

Groups	Drill 1 Precision Beads	Drill 2 Simple Rope Pass	Drill 3 Russian Roulette	Drill 4 Mobile Precision Beads	Drill 5 Beaded String Pass	Drill 6 Minefield	Drill 7 Suturing
Novices	59.9	90.4	112.6	177.0	167.1	214.4	95.9
Experts	40.2	49.5	75.0	143.6	143.7	144.6	61.7
p-value	<0.001	< 0.001	<0.001	0.017	0.036	< 0.001	<0.001

The RLC for novices reflected an improvement in scores ($p<0.05$), but did not reach statistical significance in Drills 6 & 7 (Figures 1-5). In contrast, experts demonstrated a flat RLC for 6 drills and an improvement in Drill 3 ($p=0.027$).

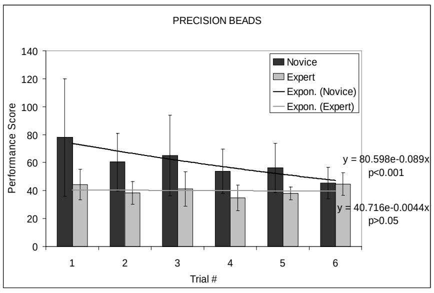

Figure 1. Precision Beads

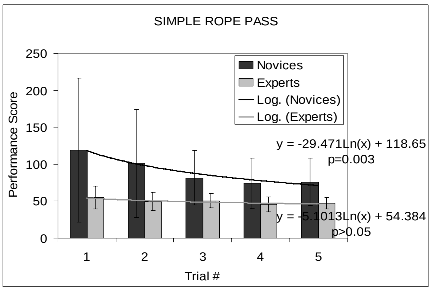

Figure 2. Simple Rope Pass

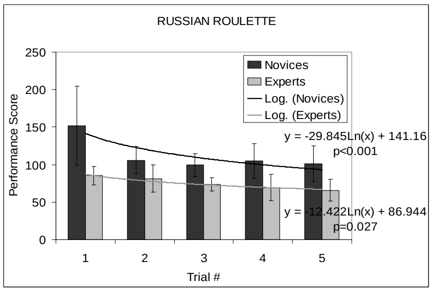

Figure 3. Russian Roulette

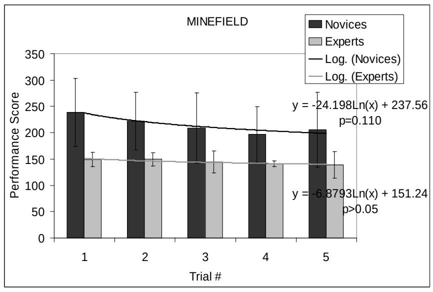

Figure 4. Minefield

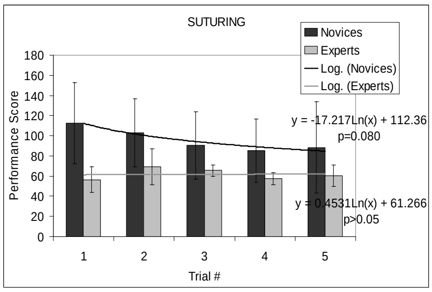

Figure 5. Suturing

Discussion

This new drill set provides a framework for performance assessment during robotic surgery. Experts performed better at each drill, but novices approached their scores at the end of the drill set indicating a relatively steep learning curve. Drills will be evaluated in future studies using video-linked time and motion analysis through da Vinci system's API (Application Programming Interface). The inclusion of particular drills and their role in training robotic surgeons of the future awaits larger validation studies.

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