Surgical knot training in ophthalmic surgery: Skill assessment with eye-tracking

D. Anastasiou[1], N. Singla[1], L. Raja[2], G.M. Saleh[1,2], D. Stoyanov[1], E. Mazomenos[1]
[1]Wellcome / EPSRC Centre for Interventional and Surgical Sciences, UCL, UK
[2]NIHR Institute of Ophthalmology, UCL, UK
dimitrios.anastasiou.21@ucl.ac.uk

Introduction

Suturing is a fundamental task in ophthalmic surgery. Training is necessary to master technical as well as cognitive skills and develop a high level of hand-eye coordination. Formulating novel objective measures of operational performance will be beneficial for training and computer-based image guidance. Capturing eye movements while performing surgical tasks can provide meaningful information to access operator's skill and overall performance. This study explores: eye tracking for developing performance metrics for suturing tasks and focuses on time-based metrics and the spatial distribution of fixations.

Materials and Methods

This study was conducted in the Royal College of Ophthalmologists (London, UK) during the training course "Introduction to Ophthalmic Surgery". We recruited 34 volunteers, 9 *experts* (faculty members) and 25 *novices* (trainees). All participants were asked to execute a single surgical knot on the training board, whilst wearing the eye-tracking glasses. A surgical knot consists of two major subtasks, which are needle passing (NP) and knot tying (KT), whose start and end moments are shown in Fig. 1. For capturing eye movements, the Tobii Pro Glasses 2 was used and deployed as shown in Fig. 2(a). Time-stamped gaze focus points are synchronized with the FoV video and overlayed (circle) as shown in Fig.2(b). Inspired from the literature [1],[2] for every recording we then calculated **i)** the total duration of the entire suturing task **ii)** the duration of the NP subtask, as well as **iii)** the duration of KT. These time-based metrics were further used for statistical analysis. Spatial distribution of gaze points and fixations were also investigated during the KT phase. The distribution of fixations [3],[4] is illustrated as a heatmap plot (Fig. 3), where one can observe significant differences between expert and novices. To quantify this distribution, *fixation sparsity* is introduced as the ratio of the total number of color- valued pixels (locations that we obtain fixations) in the heatmap divided by the image resolution 1080×1920.

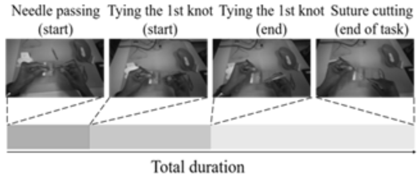

Figure.1. Annotation of a surgical suture task

Figure. 2. (a) Experimental Setup (b) Snapshot of video showing wearer's FoV with gaze focus

Figure. 3 Spatial distribution of fixations during knot tying (a) expert surgeon, (b) novice surgeon.

Results

Statistical analysis was performed with the Mann-Whitney U-test (p = 0.05 significance level). Results are summarized in Table 1.

Table. 1. Mann-Whitney U-test results with p = 0.05 significance level (two-tailed)

Dependent Variable	Median/Min/Max		p-value
	Experts $(n_e = 9)$	Novices $(n_n = 11)$	
Total duration	70.12/46.36/83.32s	98.08/55.56/191.28s	0.000382
Needle passing duration	19.04/35/16.32s	31.51/15.36/79.04s	0.009984
1st Knot tying duration	12.68/5.6/18.96s	17.56/5.859/40.24s	0.007934
Fixation sparsity	0.0362/0.0215/0.0486	0.0516/0.0216/0.0697s	0.000302

Conclusion and Discussion

Experts were found to be significantly faster than novices. Additionally, experts' fixations are clustered together in smaller areas indicating that they focus their gaze almost entirely on areas of interest (e.g., suture, tools), whereas novices' fixations are dispersed. It is evident that analysis of the spatial distribution of fixations can indicate areas of high/low interest, and patterns associated with levels of expertise. Future work will focus on developing novel eye-tracking features and examining their correlation with standardized manual assessment, and on machine learning algorithms for predicting surgical skills.

Acknowledgements

This work was supported by the WEISS at UCL (203145Z/16/Z, NS/A000050/1); Dimitrios Anastasiou is supported by an EPSRC DTP and ISAD award (EP/R513143/1, EP/T517793/1).

References

[1] Capogna E., et al., "Novice and Expert Anesthesiologists' Eye-Tracking Metrics During Simulated Epidural Block: A Preliminary, Brief Observational Report", *Local Reg*; 2020; 2020(13): 105-109.

[2] Causer J., et al., "Quiet eye training improves surgical knot tying more than traditional technical training. A randomized, controlled study", *Am J Surg;* 2014; 208(2): 171-177.

[3] Chainey J., et al., "Eye-Hand Coordination of Neurosurgeons: Evidence of Action-Related Fixation in Microsuturing", *World Neurosurg.*; 2021; 155:196-202

[4] Lee A., et al., "Identification of gaze pattern and blind spots by upper gastrointestinal endoscopy using an eye-tracking technique", Surg. Endosc;2021.