Letters

RESEARCH LETTER

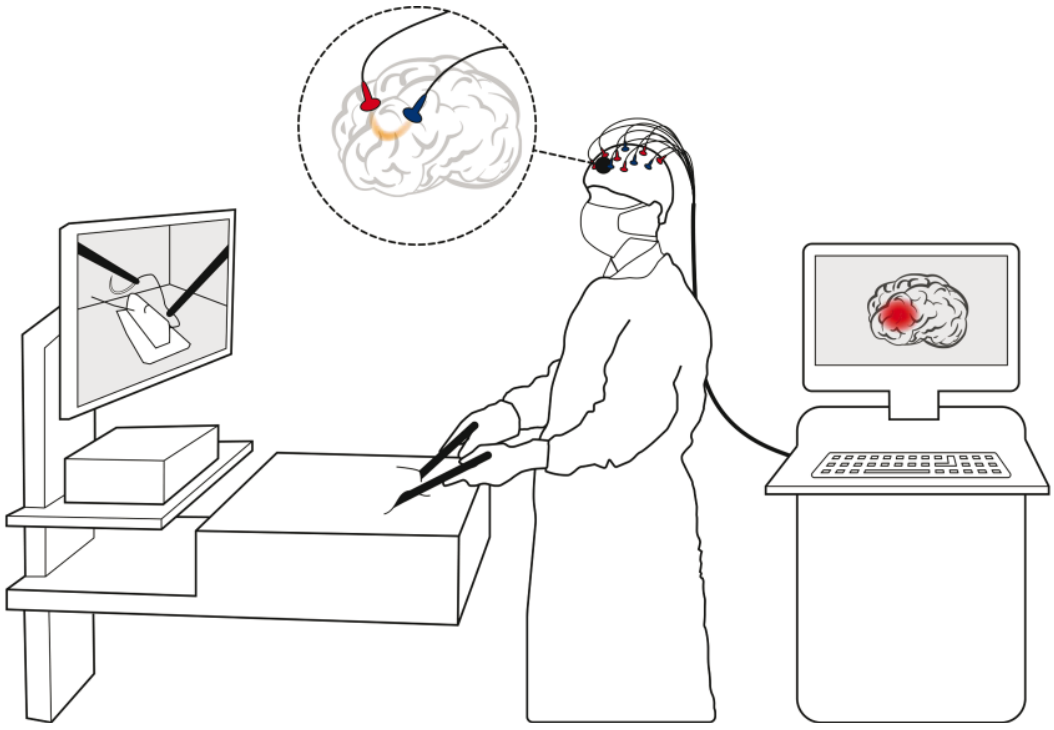
Persistent Prefrontal Engagement Despite Improvements in Laparoscopic Technical Skill

Teaching and assessment of laparoscopic skills are currently essential components of surgical training. The Fundamentals of Laparoscopic Surgery (FLS) is a widely adopted training program based on expert-derived benchmarks; technical skills are assessed and completion is a mandatory criterion for general surgery board certification in the United States.[1] However, is attainment of technical proficiency synonymous with being a safe surgeon? Intraoperative errors persist and are thought to be related to errors in cognition[2] as opposed to technical failure per se. The prefrontal cortex (PFC) is a brain region associated with attention and executive function serving as a scaffold to support novel task demands during effortful unrefined performance.[3] Studies examining cortical correlates of technical skills acquisition have observed predictable attenuation in PFC response alongside improvement in technical performance[4,5]; however, this has not been adequately tested for challenging laparoscopic skills.

Methods | The National Research Ethics Service Committee London-Fulham approved the study, and written informed consent was obtained from participants.

Forty-five participants of varying surgical experience were studied using a 44-channel optical-topographic device (ETG-4000; Hitachi Medical Corp) to monitor prefrontal responses during a laparoscopic suturing drill depicted in the **Figure**. To characterize frontal brain behavior over the time course from early learning to automation, both cross-sectional and longitudinal studies were conducted as follows: (1) a cross-sectional study compared PFC excitation in 35 surgeons (novices with 2 hours of training: n = 12; residents: n = 12; and experts: n = 11) and (2) a longitudinal study that tracked changes in PFC responses across 4 points as a second cohort of novices (n = 13) acquired suturing skills over a fortnight of practice (8 hours). Laparoscopic suturing skill was evaluated using the FLS framework (time and accuracy). Brain activation was inferred from task-evoked changes in cortical oxygenated (ΔHbO_2) and deoxygenated hemoglobin.

Figure. A Participant's Brain Activity Monitored During Performance of Laparoscopic Surgical Task



The image illustrates the experimental set-up of a participant performing laparoscopic suturing and knot tying. Prefrontal cortex activity was recorded by a 44-channel optical topographic system. Emitters (red) and detectors (blue) detect cortical activity when placed over a region of interest.

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Results | Superior technical performance was observed in experts compared with residents (median [interquartile range (IQR)] FLS scores: experts = 487 [53] and residents = 400 [90]; Mann-Whitney *U* test *P* = .01; Bonferroni correction threshold *P* < .02), who in turn outperformed novices (median [IQR]: 2 hours training = 316 [74]; Mann-Whitney *U* test *P* < .001). Deliberate practice led to significant improvements in technical performance (median [IQR] FLS scores: initial session with 2 hours training = 302 [128], midsession with 5 hours training = 421 [86], and final session with 8 hours training = 471 [40]; Friedman *P* < .001) followed by skill stabilization when assessed at retention (median [IQR]: 1 month after cessation of practice = 468 [56]; Wilcoxon signed-rank *P* = .81). At practice termination, technical skills among experts and trained novices could not be differentiated (*P* = .01; Bonferroni correction threshold *P* < .008).

An inverse association was observed between the grade of the surgeon and PFC activation (ΔHbO_2; median [IQR]: novices = 10.19 [21.75] µm × cm, residents = 7.46 [12.57] µm × cm, and experts = 1.56 [11.37] µm × cm; *P* ≤ .001). Despite progression toward near expert levels of suturing skill, additional training failed to lead to progressive PFC attenuation (ΔHbO_2; median [IQR]: initial = 8.08 [19.95] µm × cm, midsession = 7.67 [21.12] µm × cm, and final session = 7.77 [17.91] µm × cm; retention = 8.88 [19.92]; *P* = .07). At practice termination, suturing evoked a response that was on average 4 to 5 times greater among trained novices than expert laparoscopists, despite similarities in suturing skill.

Discussion | Laparoscopic proficiency criteria based on experts' motor behavior or technical skill, such as time and accuracy, reflect a 1-dimensional performance assessment. Current data suggest that despite attaining these benchmarks, residents need significantly more attention than experts, and hence may not have internalized or automated the task. Although comparison with a control task where all participants were considered experts would be ideal, identifying a compatible task with similar properties is not trivial. It also should be acknowledged that functional near infrared spectroscopy data may be influenced by systemic effects, such as stress-induced changes in heart rate and respiratory physiology (alkalosis),[6] although the latter would tend toward a reduction in oxygenated hemoglobin contrary to the observations in the present study. An extended longitudinal study is necessary to determine at what point in practice attentional demand is offloaded, PFC recruitment is attenuated, and the task is internalized.

Kunal Shetty, MRCS

Daniel Richard Leff, FRCS, MS, PhD
Felipe Orihuela-Espina, PhD
Guang-Zhong Yang, PhD, FREng
Ara Darzi, FRCS, FRS

Author Affiliations: Hamlyn Centre for Robotic Surgery, Imperial College London, London, England.

Corresponding Author: Ara Darzi, FRCS, FRS, Department of Surgery and Cancer, 10th Floor, QEQM Wing, St Mary's Hospital, London W21NY, England (a.darzi@imperial.ac.uk).

Published Online: March 30, 2016. doi:10.1001/jamasurg.2016.0050.

Author Contributions: Drs Shetty and Leff had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Drs Shetty and Leff are joint first coauthors and contributed equally to this work.
Study concept and design: Shetty, Leff, Yang, Darzi.
Acquisition, analysis, or interpretation of data: Shetty, Leff, Orihuela-Espina, Yang.
Drafting of the manuscript: Shetty, Leff, Orihuela-Espina.
Critical revision of the manuscript for important intellectual content: Shetty, Leff, Yang, Darzi.
Statistical analysis: Shetty, Orihuela-Espina
Administrative, technical, or material support: Leff.
Study supervision: Leff, Yang, Darzi.

Conflict of Interest Disclosures: None reported.

Funding/Support: This work was supported by the Academy of Medical Sciences (starter grant to Dr Leff), Imperial Cancer Research UK, and the Imperial College National Institute for Health Research Biomedical Research Council.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Contributions: We gratefully acknowledge Kumuthan Sriskandarajah, MRCS, Muzzafer Chaudhery, MRCS, and Shaun Dole from Imperial College London for their assistance with recruitment and data collection. We also thank Matthew Harrison, MEng, from the Helix Centre, Imperial College London, for his help on illustrations. They did not receive compensation for their contributions.

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