PhacoTrainer: Artificial Intelligence Dashboard for Surgical Performance Feedback

I. **Specific educational aims**: We propose the development and evaluation of an artificial intelligence (AI)- enabled dashboard capable of delivering automated surgical feedback to enhance surgical training. This will improve surgical training by enabling surgeons to receive performance feedback in a standardized, objective manner which scales beyond traditional 1:1 preceptor to trainee feedback. As part of this ongoing project, dubbed “PhacoTrainer,” we have developed a preliminary dashboard to which users can upload cataract surgical video and receive granular feedback on the time spent on each step, special techniques used, and occurrence of complications, based on AI computer vision analysis.[1] Since then, we also developed additional models which pinpoint the location of major instruments and anatomical landmarks in cataract surgery.[2] **Aim 1** is to enhance our current dashboard to include new performance metrics derived from AI detection of instrument and anatomical landmarks, including instrument total path length, area covered, and maximum velocity. **Aim 2** is to prospectively correlate AI surgical performance metrics with real-time surgical learning in ophthalmology residents. The expected outcome is a more fully-featured online dashboard which can be used by any cataract surgeon, nationally and internationally, to track performance and enhance surgical education. This project supports funding priorities by bridging the disciplines of ophthalmology and artificial intelligence and by developing an application which will live on beyond the funding period and be openly accessible to any user, which will also potentially increase access to high-quality surgical feedback in low-access areas.

II. **Project rationale**: The mainstay of surgical training is case-by-case, one-on-one, real-time feedback from preceptor to trainee. Videos of many types of surgeries, such as cataract surgery, are routinely captured by trainees, providing an opportunity to subsequently review for learning opportunities. However, it is difficult to review many hours of video to obtain additional performance feedback, and difficult to track granular and quantitative performance metrics, including time spent on important steps of surgeries, usage of advanced techniques for complex cases, optimal positioning of instruments, and rates of complications**. Deploying algorithms to automate tracking of surgical performance and provide feedback through analysis of surgical videos would augment surgical training and may ultimately improve surgical outcomes**. In developing areas where experienced surgical preceptorship may be scarce, automated analyses of surgical video could be a vital avenue for surgical feedback.

We previously developed high-performance deep learning models to understand cataract surgical video.[1,2] Cataract surgery is the most commonly performed surgery in the United States[3], and it cures vision loss by replacing the cloudy natural lens of the eye with a clear lens implant through a precise operation involving manipulations of micrometer-thick tissues under microscopic magnification.[4] Like many other surgeries, speed, efficiency, and optimal instrument positioning limits the damage to surrounding tissues which contributes to poor outcomes and postoperative vision loss. Thus, surgical time as well as instrument motion are important indicators of surgical performance. Based on our initial model which recognizes 13 major steps of cataract surgery from surgical video,[1] **we developed a version 1 (v1) surgical performance dashboard**, consisting of an online web application to which surgeons can upload videos and receive granular feedback on time spent on each step of surgery, use of special techniques, and occurrence of complications while tracking their performance over time. A link to a video demonstrating the v1 dashboard is here. We then **developed additional deep learning segmentation models** to detect the location of 8 classes of surgical instruments and important eye structures, including the instrument tooltip and the pupil center, with great accuracy.[2] Using this information, we calculated AI-enabled surgical metrics related to tracking the location of these landmarks, including total path length, area covered, and maximum velocity of various surgical instruments and the pupil. **We validated that these tool-based AI surgical metrics were correlated with surgeon skill,** distinguishing between randomly selected resident trainee surgeries and attending surgeries, and correlating with masked expert assessments of surgical skill on a validated scoring system. These additional AI metrics are ready to deploy to a version 2 of our surgical dashboard. **Our preliminary work demonstrates our capabilities in developing and deploying deep learning models for surgical feedback, and that the addition of metrics related to tool and anatomical landmark tracking would provide additional valuable surgical performance information.**

III. **Approach**: We will enhance our PhacoTrainer dashboard application, creating a version 2 (v2) by deploying our segmentation deep learning models for tool and anatomical landmark tracking. We will add summaries of instrument total path length, area covered, and maximum velocity, visualized over time on the summary metrics page and on the individual video display pages. Users will be able to view and explore each individual video's timeline of events, view the associated video and metrics, and "turn on" instrument tracking views of their video. This will involve updates to the custom-designed Heroku front-end and to the Google Firestore database back-end, as well as adding our new deep learning algorithms to the current ones which are running on a cloud-based virtual machine.

IV. **Timeline and plan for implementation**:

2023-2024	**Oct/ Nov**	**Dec/ Jan**	**Feb/ Mar**	**Apr/ May**	**Jun/ July**
Aim 1: Update dashboard by adding tool-tracking metrics					
Aim 2: Evaluation of version 1 dashboard with ophthalmology residents					
Aim 2: Prospective evaluation of version 2 dashboard with ophthalmology residents					

V. **Anticipated work product**: The completion of this aim will expand and further develop our platform for AI-enabled automated surgical feedback for ophthalmology, producing a fully-featured web application that provides performance metrics based on surgical time, complications used, advanced steps, and tool and eye landmark tracking. This platform can be made broadly available to any users to enhance surgical training. It is our long-term goal that this platform will become an educational tool available to and used by all ophthalmic surgical trainees in the U.S, and potentially worldwide to improve surgical performance.

VI. **Evaluation plan:** We will recruit Stanford ophthalmology residents to upload their corpus of cataract surgical videos to the v1 dashboard, from which metrics related to time spent on each surgical step, complication rate, and use of advanced techniques will be calculated. We will track the change in these performance metrics as they correlate with the increasing case number of the residents. We hypothesize that overall surgical time will decrease as residents gain more experience, but that certain individual key steps (capsulorhexis, wound creation, phacoemulsification) will decrease in time in a more pronounced fashion than others. We will perform linear regression to correlate surgical times with surgical case count. This type of analysis is novel, as it has never been performed for more than one resident before.[5] As version 2 of the dashboard in Aim 1 becomes deployed in the latter half of the funding period, a stretch goal will be to correlate tool-tracking performance metrics with increasing surgical case count. We will also solicit qualitative feedback on the dashboard usability, bugs, and additional desired features before planning to disseminate for a larger group of users.

VII. **Dissemination of results**: We plan to submit this project for presentation at the AIMI AI+Health conference. We anticipate continuing to submit manuscripts for peer-review and publication in high-impact journals in our field such as Ophthalmology, Translational Vision Sciences and Technology, and others. We also plan to present this work at the American Academy of Ophthalmology and the Association for Research in Vision and Ophthalmology, which are two of the largest ophthalmology conferences, as well as cross-disciplinary symposia including Mobilizing Computable Biomedical Knowledge.

References:

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