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SHORT COMMUNICATION

Feasibility of eye-tracking technology to quantify expertise in ultrasound-guided regional anesthesia

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Abstract Ultrasound-guided regional anesthesia (UGRA) requires an advanced procedural skill set that incorporates both sonographic knowledge of relevant anatomy as well as technical proficiency in needle manipulation in order to achieve a successful outcome. Understanding how to differentiate a novice from an expert in UGRA using a quantifiable tool may be useful for comparing educational interventions that could improve the rate at which one develops expertise. Exploring the gaze pattern of individuals performing a task has been used to evaluate expertise in many different disciplines, including medicine. However, the use of eye-tracking technology has not been previously applied to UGRA. The purpose of this preliminary study is to establish the feasibility of applying such technology as a measurement tool for comparing procedural expertise in UGRA. eye-tracking data were collected from one expert and one novice utilizing Tobii Glasses 2 while performing a simulated ultrasound-guided thoracic paravertebral block in a gel phantom model. Area of interest fixations were recorded and heat maps of gaze fixations were created. Results suggest a potential application of eye-tracking technology in the assessment of UGRA learning and performance.

Keywords Regional anesthesia · Eye tracking · Visual attention · Education · Simulation · Ultrasound

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Short communication

Ultrasound-guided regional anesthesia (UGRA) requires an advanced procedural skill set that incorporates both sonographic knowledge of relevant anatomy as well as technical proficiency in needle manipulation in order to achieve a successful outcome. Arguably, experts must accumulate a substantial fund of knowledge and then deploy that knowledge through iterative practice, learning, and multiple successive trials until reliable technical performance and successful patient outcomes can be achieved. It is important to determine the manner and time in which procedural expertise is developed. Validated tools to differentiate between experts and novices have been developed and include checklists, global rating scales, hand-motion analysis, and multiple-choice testing; however, these tools can be labor-intensive to use and may not give a complete picture of expertise [1–6]. Understanding how to differentiate a novice from an expert in UGRA using a quantifiable tool may be useful for benchmarking learning milestones and for evaluating educational interventions that may influence the rate of developing expertise.

Exploring the gaze pattern of individuals performing a task has been used to evaluate expertise in many different disciplines, including medicine [7–9]. Visual processing incorporates both "visually salient" and "cognitively salient" points, and the performer's ratio of attention to these categories of points can be used as a marker for expertise. The novice may spend a greater proportion of time looking at visually salient points (areas that stand out regardless of importance) as compared to an expert who should focus on cognitively salient points (areas that are relevant to performing a task or identifying a structure). Experts also tend to focus on fewer locations in contrast to novices who shift

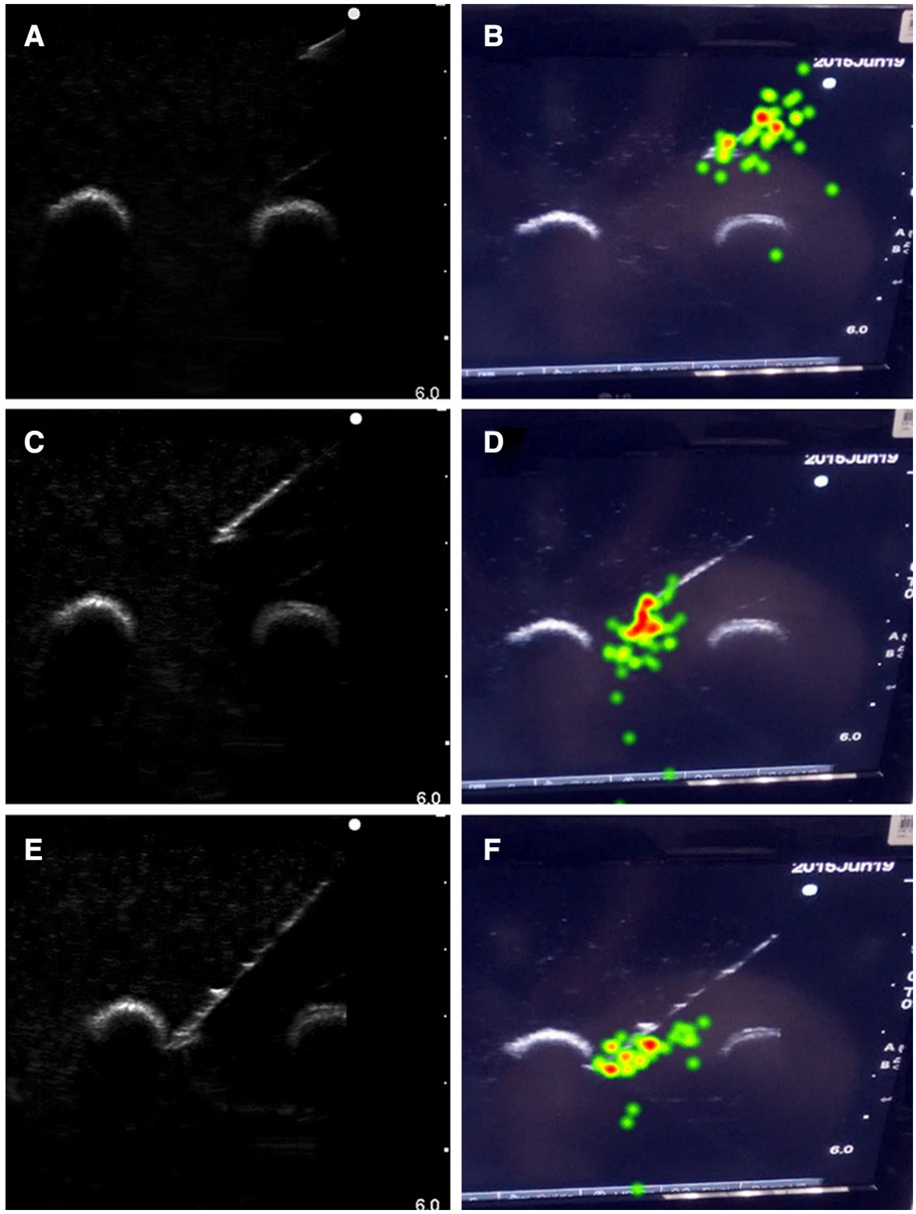

Fig. 1 Expert performance of a thoracic paravertebral block as visualized by ultrasound and gaze-fixation heat map at three stages: (1) initial needle insertion (**a**, **b**); (2) needle midway between insertion and the simulated thoracic paravertebral space (**c**, **d**); and (3) needle entry into the simulated thoracic paravertebral space (**e**, **f**)

gaze more often and to more locations [10–12]. The use of eye-tracking technology has not been previously applied to UGRA education, so our group sought to establish its initial feasibility for this indication.

After obtaining Veterans Affairs' research committee and IRB approval with waiver of informed consent, we collected eye-tracking data from one expert (over 10 years of regular advanced UGRA clinical experience) and one novice (non-physician with no UGRA clinical experience) while performing a simulated ultrasound-guided thoracic paravertebral block with a 20-gauge Touhy-tip needle (B Braun, Bethlehem, PA, USA) in a gel phantom model (Blue Phantom Lumbar Puncture and Spinal Epidural training model BPLP210, CAE Healthcare, Sarasota, FL, USA). Trial 1 (expert) involved collection of gaze data using a 26-inch external monitor connected to a portable ultrasound machine (M-Turbo, SonoSite, Bothell, WA, USA) to create a representative heat map for the procedure. To do this, we generated individual heat maps for three predetermined phases of the procedure: (1) initial needle insertion; (2) needle midway between insertion and the simulated thoracic paravertebral space; and (3) needle entry into the simulated thoracic paravertebral space (Fig. 1). Heat maps use different colors (green–yellow–orange–red) to visualize the amount of time a subject fixates on a particular area (green least-red most). Trials 2 and 3 (expert and novice, respectively) used the screen on the ultrasound machine rather than an external monitor to simulate actual clinical practice. Eye-tracking data were acquired using the Tobii Glasses 2 Eye Tracker (Tobii Technology, Danderyd,

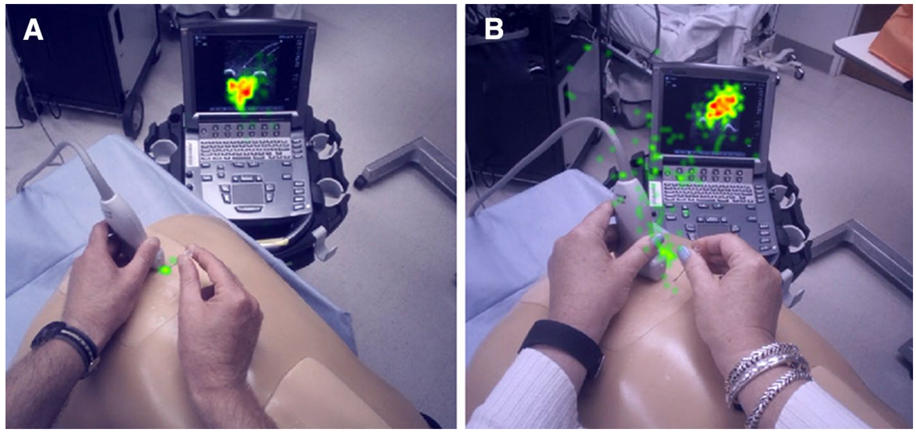

Fig. 2 Representative heat maps of a simulated ultrasound-guided thoracic paravertebral block performed by an expert (**a**) and a novice (**b**)

Sweden) and analyzed using the Tobii Glasses Analysis software ((Tobii Technology, Danderyd, Sweden). The Tobii Glasses 2 utilizes the pupil center corneal reflection (PCCR) technique to determine gaze. It uses near-infrared illumination to create reflection patterns on the cornea and pupil. Two image sensors are then used to capture images of the eyes and the reflection patterns which are used to estimate the position of the eye in space as well as the point of gaze. The area of interest (AOI), which for this project was defined as the tip of the advancing needle, was noted and the number of AOI fixations (number of times that the subject looked at the needle tip) was then calculated in conjunction with gaze data. Finally, we collected the time in seconds to complete the task (needle tip inserted into the paravertebral space).

Both subjects completed the objective (ultrasound-guided insertion of the needle into the simulated paravertebral space). The expert achieved the objective in 94 s (Trial 2) while the novice took 257 s (Trial 3). The expert had 174 fixations in the AOI (1.85 fixations per second) compared to 220 fixations in the AOI by the novice (0.86 fixations per second; Fig. 2). Qualitatively and quantitatively, the expert's heat map revealed greater fixation on the target AOI (needle tip) when compared to the novice's heat map, which showed a more scattered distribution and more fixations in the upper right side of the ultrasound screen when attempting to locate the needle tip. The expert's heat map also showed a brief fixation on the skin of the model at time of needle entry as compared with the novice subject's heat map, which showed multiple fixations on the skin and ultrasound probe (Fig. 2).

Eye-tracking technology may offer the "missing link" in quantifying the acquisition of expertise in UGRA and other procedural specialties in medicine. It may provide measurable outcomes that can potentially be used to compare the UGRA performance between different levels of expertise, establish benchmarks or milestones in UGRA based on specific metrics, and compare the effectiveness of educational interventions; however, further prospective research is warranted. The preliminary results of this feasibility study, while not conclusive, are consistent with prior eye-tracking work in which the expert exhibits more efficient and effective gaze behaviors. Experts tend to demonstrate fewer fixations and fixate for a longer period of time in the area of interest in contrast to novices, which tend to shift their gaze more often and to more locations [10, 11]. Experts also fixate on a target for a longer period of time prior to taking an action with subsequent improved accuracy. This observation is termed the "quiet eye period" (QE); QE training has been deployed in various different fields including surgery, sports, and firearm training and can result in improved technical success [8, 9, 13, 14]. We also observed that when performing an ultrasound-guided regional anesthesia procedure, the novice demonstrated greater gaze fixation on the hands and ultrasound transducer to achieve in-plane needle guidance when compared to the expert, who is able to readily align the needle and ultrasound plane while looking solely at the ultrasound screen. By understanding how expert and novices differ in their approach to a procedure, educational programs can be modified to facilitate transfer of skill so that the novice can more efficiently achieve mastery. Eye tracking gives invaluable insight into what the expert is looking at and as a surrogate for what the expert may be thinking. Eye tracking potentially may be used to assess expertise in UGRA and provide additional information on milestone assessment of trainees [6].

There were several limitations of this brief technical report that included: (1) there were only two subjects, one novice and one expert; (2) the trials were performed in a simulated environment with a part-task training model; (3) the heat mapping required selecting predetermined points of the procedure potentially reducing usefulness of a dynamic event, in this case movement of the needle into position; and (4) not every participant can be properly calibrated using the eye-tracking device. This project only focused on the technical aspects of needle manipulation and visualization for a regional anesthetic block. Future studies should include a greater number of subjects or different training levels, validate eye-tracking data against other established measurement tools, evaluate attentional deployment during a regional anesthetic, and study the interpretation of procedure-specific sonoanatomy to better evaluate how novices and experts differ.

In summary, we were able to demonstrate the feasibility of using eye-tracking technology to measure performance during UGRA. Further work is needed to validate this tool as a method to assess milestone achievement in UGRA and other procedural disciplines.

Compliance with ethical standards

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Conflict of interest Dr. Mariano has received unrestricted educational program funding paid to his institution from Halyard Health (formerly I-Flow; Lake Forest, CA, USA) and B Braun (Bethlehem, PA, USA). These companies had absolutely no input into any aspect of the present study conceptualization, design, and implementation; data collection, analysis and interpretation; or manuscript preparation. None of the other authors has any personal financial interests to disclose.

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