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Effect of alternative video displays on postures, perceived effort, and performance during microsurgery skill tasks

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ABSTRACT

Physical work demands and posture constraint from operating microscopes may adversely affect microsurgeon health and performance. Alternative video displays were developed to reduce posture constraints. Their effects on postures, perceived efforts, and performance were compared with the microscope. Sixteen participants performed microsurgery skill tasks using both stereo and non-stereoscopic microscopes and video displays. Results showed that neck angles were 9–13° more neutral and shoulder flexion were 9–10° more elevated on the video display than the microscope. Time observed in neck extension was higher (30% vs. 17%) and neck movements were 3x more frequent on the video display than microscopes. Ratings of perceived efforts did not differ among displays, but usability ratings were better on the microscope than the video display. Performance times on the video displays were 66–110% slower than microscopes. Although postures improved, further research is needed to improve task performance on video displays.

1. Introduction

Work-related musculoskeletal pain, fatigue, and discomfort can affect both the comfort of surgeons and their ability to complete surgical tasks; yet, the reported prevalence of musculoskeletal symptoms in the neck, back, and shoulders is as high as 87% among surveyed laparoscopic, ophthalmic, and general surgeons (Davis et al., 2014; Capone et al., 2010; Park et al., 2010; Sivak-Callcott et al., 2011; Szeto et al., 2009; Wauben et al., 2006). Furthermore, a survey of 130 ophthalmic surgeons who frequently used magnification, e.g., loupes and microscopes, showed that 9.2% of surgeons stopped operating due to neck pain (Sivak-Callcott et al., 2011). Due to the high cost of training and impending shortage in the surgical workforce (Williams et al., 2009), time away from work and reduced career longevity due to musculoskeletal pain can be a costly form of waste in the healthcare system.

Surgeons who perform microvascular surgeries, frequently done in the plastic, otolaryngology, and reconstructive surgery specialties (Jarrett, 2004), may be at additional risk for musculoskeletal symptoms. Although microsurgery can be performed with loupes or microscopes, surgeons who perform microsurgery frequently (i.e., maxillofacial, plastics, ophthalmologists, otolaryngologists, and neurosurgeons) predominantly use operating microscopes (Jarrett, 2004). Additionally, operating microscopes are used exclusively for procedures requiring high magnification, e.g., 0.5 mm vessels during finger replantation and neurosurgery. Previous studies observed that operating microscopes required surgeons to fixate over optical eyepieces (Fig. 1), constrained the surgeon's eye locations, reduced comfort, and forced surgeons to be in awkward positions (Franken et al., 1995; Ross et al., 2003; Yu et al., 2013). For example (Fig. 1), while adjustable operating microscopes can allow a surgeon to have upright neck posture (right surgeon, Fig. 1), the small patient work site, assisting surgeon's position, operating room table, and microscope working distance can constrain surgeon posture and can lead to neck flexed positions (left surgeon, Fig. 1). Finally, a vast majority of microsurgery is done from a standing position, since the operating room (OR) table components prevent sitting with the surgeon's legs underneath the table. Despite these ergonomic risk factors in microsurgery, current literature quantifying the impact of these workplace and microsurgical task constraints on surgeon postural demands is limited.

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Fig. 1. Microvascular anastomosis procedure performed by two standing surgeons, where constraints in microscope eyepieces, small patient site, and operating table can lead to a range of neck postures, e.g., upright (right surgeon) to flexed (left surgeon).

A preliminary study by Yu et al. (2013) found that microsurgeons remain primarily static (0.3 ± 0.4 movements per minute) while using the microscope compared to 5.5 ± 6.1 movements observed at rest. Another study rated postures of laryngologists performing microsurgery on an operating microscope and measured rapid upper limb assessment (RULA) scores of 4–5, indicating poor posture and potential risk for injuries (McAtamney and Nigel Corlett, 1993; Statham et al., 2010). Posture constraints were postulated to be responsible for the significant association observed between microscope use greater than three hours per week and the prevalence of cervical and thoracic pain reported among 339 surveyed plastic surgeons (Capone et al., 2010).

Alternative video displays to traditional loupes and operating microscopes have been proposed to 1) reduce the physical demands of microsurgery, 2) allow surgeons to select comfortable postures, and 3) improve team communication (Chen et al., 2012; Franken et al., 1995; Gorman et al., 2001; Nissen et al., 2011; Yu et al., 2015). Although performance times were longer using video displays (Cheng et al., 2012; Nissen et al., 2013), these pilot studies showed 1) video displays can be successfully used during live microsurgery and 2) 50–75% of surveyed surgeons viewed the comfort and education potential of video displays favorably (Franken et al., 1995; Gorman et al., 2001). However, the posture benefits from alternative displays were merely speculated by these previous studies, and quantitative measurements are needed to compare the impact of microscope and video displays on postures.

To address microsurgery performance limitations observed by previous studies using 2D video displays (Gorman et al., 2001; Nissen et al., 2011), a recent study suggested that stereoscopic displays may reduce the observed performance gap between video and conventional microsurgery (Jianfeng et al., 2014). However, the performance benefit of stereoscopic video systems over non-stereoscopic systems in surgery is still currently under debate and warrants further investigation (Bilgen et al., 2013; Gurusamy et al., 2011; Hofmeister et al., 2001; Kong et al., 2010; Munz et al., 2004). Quantitative and controlled studies on the effect of stereo and non-stereoscope alternative displays on posture stresses and perceived effort are needed to assess the potential musculoskeletal health and performance benefits of implementing alternative video displays over traditional microscopes.

The purpose of this study is to measure the effect of stereoscopic video displays in reducing physical risk factors that may contribute to musculoskeletal fatigue and injuries during simulated microsurgery skills tasks. In contrast to conventional microscopes, it is hypothesized that video displays will allow users to:

1) Assume more neutral and less static postures,
2) Reduce perceived efforts, and
3) Improve task performance, i.e., completion time and errors.

Findings from this study will quantify the impact of video displays and microscopes on postures, perceived efforts, and task performance for microsurgery skills tasks and provide guidance on the application of video displays for improving postures in the operating theatre and in other jobs that require optical magnification.

2. Methods

A laboratory study was conducted to determine how posture, perceived efforts, and performance were influenced by different magnification displays.

2.1. Subjects

This study was approved by the university's institutional review board and informed consent was obtained from 16 university students with no prior surgical experience. Participants were recruited through university email lists and included students from both engineering and medicine. Mean age of the participants was 22 ± 2 years old. Mean BMI was 22 ± 3.6, and mean height was 170 ± 10 cm. All subjects were right-handed, 50% were males, 63% wore corrective lenses, 81% had experience with microscopes, and 44% had experience with 3D displays.

2.2. Displays

Four displays were tested in this experiment (Fig. 2): 1) non-stereo microscope (Micro2D), 2) stereoscopic microscope (Micro3D), 3) non-stereoscopic video display (Video2D), and 4) stereoscopic video display (Video3D). Although non-stereo microscopes were not used in surgery, it was tested to compare the effect of stereoscopy and investigate whether the additional cost of 3D translates to improved performance. To simulate Micro2D, participants wore a concave eye patch that occluded vision of one eye while using a binocular microscope (Scienscope™ Model XTL-V). The 3D video system streamed real-time interlaced video, at $<$100 ms lag, to a 101.3 cm 3D high-definition television (Samsung UN40C7000WF) from two synchronized microscope eyepiece cameras (Premiere Microscope MA87N) mounted on the binocular microscope. Both participants and study team members were able to view the video in 3D, using Samsung wireless shutter glasses. The 2D video system was created using the tele-macro video stream from a video camera (Sony DCR-SX83) positioned 64 cm above work site that was viewed on the flat-panel display without 3D glasses.

Field-of-view for all displays was calibrated to 38 mm $\times$ 38 mm. This range was larger than the 1–4 mm diameter vessels during microsurgery (Yu et al., 2014) and was within the field of views range (16.5 mm–180 mm in diameter) of commercial surgical microscopes (Leica Microsystems©). The optical microscope and the 3D video system were positioned as shown in Fig. 2a and b. Standing postures were more typical in microvascular surgeries and thus focused on in this study. The starting table height was adjusted so that the microscope eyepieces were between the tip of the nose and eyes of each participant. Although microscope positioning in an operating room varies based on patient anatomy and leads to head postures ranging from upright to flexed, this starting position was designed to control for differences in participant heights and to simulate task conditions and postures within the range observed in the field, e.g., Fig. 1. The distance to the flat panel