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Ultrasound in Emergency Medicine

ULTRASOUND-GUIDED CENTRAL VENOUS ACCESS USING GOOGLE GLASS

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☐ Abstract—Background: The use of ultrasound during invasive bedside procedures is quickly becoming the standard of care. Ultrasound machine placement during procedures often requires the practitioner to turn their head during the procedure to view the screen. Such turning has been implicated in unintentional hand movements in novices. Google Glass is a head-mounted computer with a specialized screen capable of projecting images and video into the view of the wearer. Such technology may help decrease unintentional hand movements. Objective: Our aim was to evaluate whether or not medical practitioners at various levels of training could use Google Glass to perform an ultrasound-guided procedure, and to explore potential advantages of this technology. Methods: Forty participants of varying training levels were randomized into two groups. One group used Google Glass to perform an ultrasound-guided central line. The other group used traditional ultrasound during the procedure. Video recordings of eye and hand movements were analyzed. Results: All participants from both groups were able to complete the procedure without difficulty. Google Glass wearers took longer to perform the procedure at all training levels (medical student year 1 [MS1]: 193 s vs. 77 s, $p > 0.5$; MS4: 197s vs. 91s, $p \leq 0.05$; postgraduate year 1 [PGY1]: 288s vs. 125 s, $p > 0.5$; PGY3: 151 s vs. 52 s, $p \leq 0.05$), and required more needle redirections (MS1: 4.4 vs. 2.0, $p > 0.5$; MS4: 4.8 vs. 2.8, $p > 0.5$; PGY1: 4.4 vs. 2.8, $p > 0.5$; PGY3: 2.0 vs. 1.0, $p > 0.5$). Conclusions: In this study, it was possible to perform ultrasound-guided procedures with Google Glass. Google Glass wearers, on average, took longer to gain access, and had more needle redirections, but less head movements were noted. © 2014 Elsevier Inc.

☐ Keywords—Google Glass; simulation; medical education; wearable technology; ultrasound

INTRODUCTION

Using bedside ultrasound to guide clinical procedures is quickly becoming the standard of care at most institutions worldwide. The use of ultrasound has been shown to decrease the risk for complications and improve success rates in performing many invasive procedures (1). Many institutions have portable ultrasound units that can be moved to the patient's bedside for use during clinical procedures (2). The ultrasound machine is typically placed to the side of the bed in close proximity to the region of the patient where the procedure is being performed. Given the standard positioning of the ultrasound machine, the practitioner performing the procedure often has to turn their head and redirect their visual field of focus back and forth between the ultrasound screen and the anatomical site where the procedure is being performed (Figure 1). Although the movements are generally very small, redirection of the field of focus can sometimes cause less experienced practitioners to momentarily lose complete focus over what their hands are simultaneously doing (3). It is not uncommon to

This study was exempt from our centers' Institutional Review Board.

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Figure 1. Physician turning his head to view the ultrasound machine screen during an ultrasound guided central-line placement.

note slight inadvertent movements of the hand and medical instrument when the practitioner's head is turned away from the actual procedure (3).

Recently, the concepts of wearable technology and augmented reality have been receiving increased media attention (7). Experts in medical education and clinical practice are beginning to explore and incorporate advanced medical technologies into their areas of expertise (4–6). Google Glass is a wearable computing device that features video recording, teleconferencing, and internet capabilities in addition to a novel head-mounted display. This display is an example of the concept of augmented reality in which a wearer's environment is supplemented by additional information generated by the device. Wearable technology such as Google Glass offers users the ability to visualize live feed from computer workstations, such as an ultrasound machine. The images and data are projected into the user's direct line of sight when they are wearing the apparatus on their head. Practitioners are starting to evaluate whether ultrasound-guided procedures can be performed using wearable technologies such as Google Glass (7–10).

This study attempted to evaluate whether or not medical practitioners at various levels of training could use Google Glass to perform an ultrasound-guided procedure, and to determine if there were any distinct benefits or advantages to integrating Google Glass into the procedure.

METHODS

This study was conducted with emergency medicine residents from a local academic teaching hospital and first- and fourth-year medical students from a local allopathic medical school. The emergency medicine residents participating in the study are enrolled in a postgraduate year (PGY) 1 to 3 emergency medicine residency program at a Level I trauma center that cares for 65,000 patients annually. The medical students participating in the study attend a 4-year allopathic program at a medical school located in a major metropolitan area. All subjects provided written consent for participation in this study. This study was granted exemption from our center's Institutional Review Board under The Code of Federal Regulations Title 45, Part 46, Protection of Human Subjects as "research on the effectiveness of or comparison among instructional techniques."

Each participant was asked to complete a pre-exercise survey that collected data including how many landmark-guided and ultrasound-guided central-line placements they had performed on live patients and mannequins, as well as their familiarity with the wearable computer Google Glass (Google Inc, Mountain View, CA). Participants were then asked to watch a video demonstrating the equipment available and the procedure they would be performing. The video demonstrated how to place an internal jugular central venous access catheter under ultrasound guidance in an ultrasound-compatible simulation task trainer (Syndaver, Inc., Tampa, FL).

Participants were then randomized into two groups: Google Glass group vs. Non-Glass group. The participants randomized into the Non-Glass group were instructed on how to perform an ultrasound-guided internal jugular central line using either a SonoSite Edge or M-Turbo ultrasound machine (SonoSite/Fuji, Bothell, WA). To standardize the approach, the ultrasound machine was placed just to the right of the central line task trainer and participants were asked to stand at the head of the patient and perform the procedure on the task trainer's right internal jugular vein (Figure 2).

The Non-Glass group participants performed the procedure by visualizing the ultrasound images displayed directly on the ultrasound screen (Figure 3A). Each participant performed an internal jugular vein cannulation first via the short-axis approach and again in the long-axis approach. Every procedure was recorded from two separate viewing angles focusing on the participant's hands and faces.

The participants randomized into the Google Glass group were also instructed on how to perform an

Figure 2. Ultrasound machine and central venous access task trainer for internal jugular vein cannulation.

ultrasound-guided internal jugular central line using a SonoSite Edge or M-turbo ultrasound machine (SonoSite/Fuji). The setup was exactly the same as the Non-Glass group, with the exception that the Google Glass group participants were asked to wear a pair of Google Glass and told to perform the procedure by visualizing the ultrasound images displayed on their Google Glass screen instead of the ultrasound screen (Figures 3B, 4, and 5). The ultrasound machine screen was not available for viewing by the Google Glass group participants in this arm of the study. Images from the ultrasound machine were transmitted to Google Glass via a novel connection developed specifically for this purpose. Each participant performed an internal jugular vein cannulation first via the short-axis approach and again using the long-axis approach. All procedures from this group were also recorded from two separate viewing angles focusing on the participant's hands and faces.

Following the completion of the exercise, the participants completed a short post-exercise survey that assessed their experiences using the Google Glass technology (if applicable), whether the technology facilitated or impaired the procedure, and whether they would use such technology in future medical practice.

All video footage was reviewed and analyzed by three independent observers. Statistical analysis was performed to assess for significance between groups using the nonparametric Mann-Whitney U-Test. A p value was considered significant if <0.05.

RESULTS

There were five first-year medical students (MS1), five fourth-year medical students (MS4), five PGY1 residents, and five post-graduate year 3 (PGY3) residents enrolled in the Non-Glass group. There were five first-year medical students (MS1), five fourth-year medical students (MS4), five post-graduate year 1 (PGY1) residents, and five post-graduate year 3 (PGY3) residents enrolled in the Google Glass group for comparison (Table 1).

All video footage was reviewed and analyzed by three independent observers. The quantitative measures that were evaluated included (Figure 6):

1. Total time required to perform the procedure (TT): defined as the time from application of the ultrasound probe to skin to the moment of fluid "flash" in the syringe.
2. Time spent looking at the patient (TP): defined as the total amount of time the mannequin was the

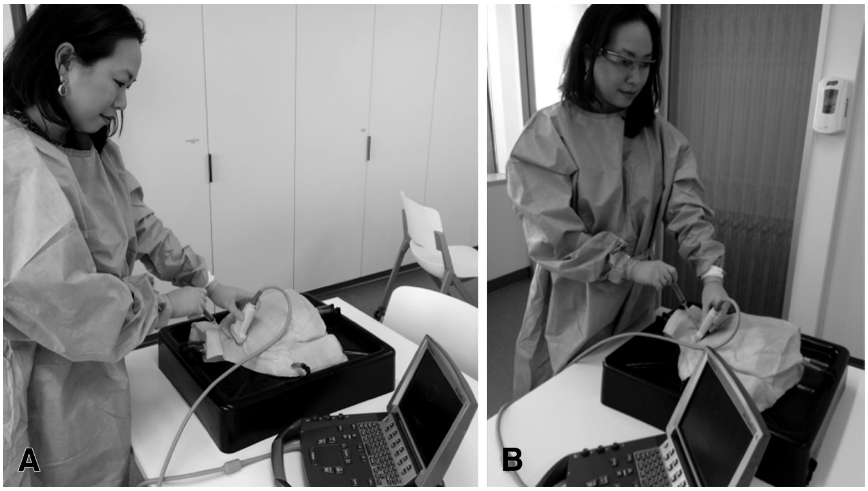

Figure 3. (A) The Non-Glass group performed an ultrasound-guided internal jugular vein cannulation by viewing the ultrasound images on the ultrasound screen. (B) The Google Glass group performed an ultrasound-guided internal jugular vein cannulation by viewing the ultrasound images on the Google Glass screen.

Figure 4. The ultrasound images were projected directly onto the Google Glass screen and viewable in the participant's upper right visual field.

main focal point of the participant's view based on assessment of the subject's head and eye position noted on video.

3. Time spent looking at the monitor (TM): defined as the total amount of time the participant spent looking at the ultrasound monitor or the Google Glass display based on assessment of the subject's head and eye position noted on video.
4. Number of looks at the monitor (NM): defined as the number of times the participant looked at the monitor (ultrasound monitor or Google Glass display) during the procedure based on assessment of the subject's head and eye position noted on video.
5. Number of needle redirections (NR): defined as the number of times the participant withdraws the needle and re-directs it or advances it at a different angle.

The Google Glass group on average took longer to perform the procedure (TT) at every training level (Table 1). This increased procedure time reached

Figure 5. A mockup representing the first-person view of a person wearing Google Glass during the simulated central-line placement.

Table 1. Summary of the Level of Expertise of Study Participants and Measurements Obtained in Both the Non-Glass and Google Glass Groups

	Mean no. of central lines performed on live patients before study		Mean no. of central lines performed on simulated patients before study		Mean total procedure time (s)		Mean time spent looking at patient (s)		Mean time spent looking at monitor (s)		Percentage of total time looking at monitor		Mean no. of looks at the monitor		Mean no. of needle redirections	
Group	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)	Glass (n = 5)	No glass (n = 5)
MS1	0.0	0.0	0.0	0.0	193	77	54	30	139	47	72	61	30.4	13.4	4.4	2
	$p > 0.05$		$p > 0.05$		$p > 0.05$		$p > 0.05$		$p \leq 0.05$*				$p > 0.05$		$p > 0.05$	
MS4	1.4	0.0	1.0	0.5	197	91	48	28	149	63	76	69	25.4	17.8	4.8	2.8
	$p > 0.05$		$p > 0.05$		$p \leq 0.05$*		$p > 0.05$		$p > 0.05$				$p > 0.05$		$p > 0.05$	
PGY1	5.0	0.8	2.4	2.8	288	125	78	45	210	79	73	63	14.0	21.6	4.4	2.8
	$p > 0.05$		$p > 0.05$		$p > 0.05$		$p > 0.05$		$p > 0.05$				$p > 0.05$		$p > 0.05$	
PGY3	26.0	28.0	18.2	17.0	151	52	48	23	103	29	68	56	28.4	14.0	2.0	1.0
	$p > 0.05$		$p > 0.05$		$p \leq 0.05$*		$p \leq 0.05$*		$p \leq 0.05$*				$p \leq 0.05$		$p > 0.05$	

* Values designate significant values.

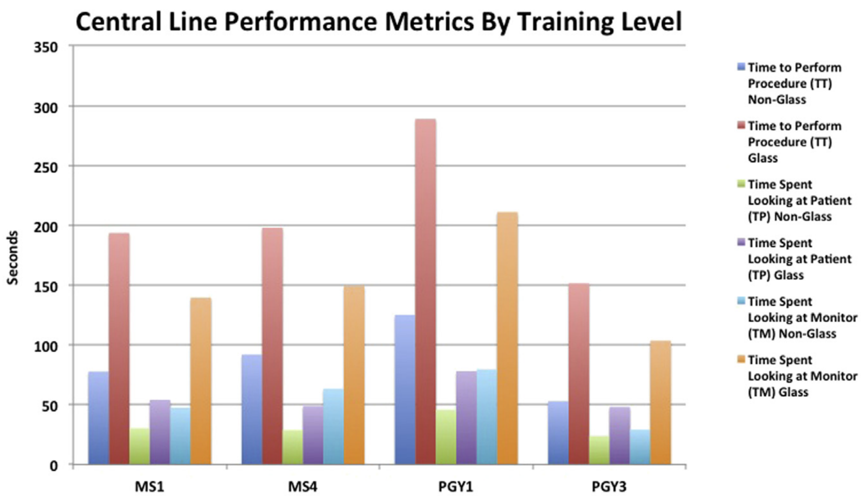

Figure 6. Google Glass and non-Glass groups performance metrics based on their level of training.

significance in the MS4 (197 s vs. 91 s, $p \leq 0.05$) and PGY3 (151 s vs. 52 s, $p \leq 0.05$) training levels. In the PGY3 training level, participants spent significantly more time focusing their gaze on the patient (48 s vs. 23 s, $p \leq 0.05$), as well as on Google Glass's monitor (103 s vs. 29 s, $p \leq 0.05$) compared to the non-Glass group. MS1 wearing Google Glass spent significantly more time (139 s vs. 47 s, $p \leq 0.05$) looking at the monitor compared with the non-Glass group. Both groups at all training levels had similar ($p > 0.05$) experience performing central venous lines on both live and simulated patients.

Analysis of the post-exercise survey showed that a majority of the respondents were not familiar with the concepts of augmented reality or wearable computing before the study (75% and 60%, respectively), although 73% reported some degree of awareness about the forthcoming Google Glass release. Among the subjects that were randomized to wear Google Glass, 87% reported that the device was comfortable to use for the purpose of ultrasound guidance. When asked the question, "How likely would you be to use ultrasound visualization through Google Glass as opposed to traditional ultrasound machine monitors?" 18% responded very likely, 35% moderately likely, 35% somewhat likely, 8% not very likely, and 5% not at all likely. Seventy-eight percent of respondents reported to being "very likely" to be interested in further research studies involving the use of Google Glass in medical simulation and education.

DISCUSSION

In this study, a total of 40 medical students and emergency medicine residents were asked to perform an ultrasound-guided internal jugular vein cannulation in one of two groups. Half performed the procedure while viewing the ultrasound images on the ultrasound monitor in the traditional methods currently utilized in training and practice. The other half performed the procedure while wearing Google Glass, whereby the ultrasound images were displayed in the upper right viewing screen in their line of sight.

Before this study, it has been hypothesized that wearable technologies such as Google Glass might be able to be used during ultrasound-guided procedures. Experts have discussed how it might be beneficial to have the ultrasound images projected in the practitioner's direct line of sight so as to minimize the amount of head turning required during the ultrasound-guided procedure. It has been postulated that decreased head movement should decrease the amount of needle movement during initial venipuncture attempts.

In our study, we found that it was definitely feasible to incorporate Google Glass into the placement of an ultrasound-guided central venous catheter. Through a specialized connection designed specifically for this purpose, we were able to construct a means by which the images acquired from the ultrasound machine were clearly visible on Google Glass. Participants randomized to the Google Glass group were all able to successfully complete venipuncture of the internal jugular vein in both short-axis and long-axis attempts under ultrasound guidance using only the images displayed on Google Glass.

Although a majority of this study's participants were not familiar with wearable technology or augmented reality before the study, every subject was able to complete the procedure without difficulty. Furthermore, a vast majority of participants reported in the survey being at least somewhat likely to use Google Glass again in central-line placement, the device being comfortable to wear, and being interested in participating in future Google Glass studies.

In this pilot study, participants were randomized into either the Google Glass group or the Non-Glass group. Based on our self-reporting survey, the MS4s and PGY1s randomized into the Google Glass group tended to have more experience performing central lines in live patients than their counterparts in the Non-Glass group, but this difference was nonsignificant. As expected, in both groups, most MS1s had no experience placing a central line in live patients or simulated patients before this study. The PGY3s that were randomly selected for our study had all completed, on average, > 40 central lines in both live and simulated patients before this project.

In our study, the participants randomized to the Google Glass group generally took longer to perform the procedure and performed more redirections of the needle as compared to those at their level of training in the Non-Glass group. This difference in total procedure time was statistically significant in the MS4 and PGY3 training levels, while no statistical significance was found between groups regarding needle redirections. Those in the Google Glass group also spent more time looking at the ultrasound monitor images as compared to those in the Non-Glass group at their same level of training. This may be due to the fact that the Google Glass group participants were using new technology that they were unfamiliar with and were more cautious in their approach during the procedure because of the new apparatus. None of the Google Glass participants have ever used wearable technology before, and this was their very first exposure to Google Glass. The Google Glass participants may have taken more time to learn how to focus on and interpret the ultrasound image being displayed on the Google Glass screen during the procedure. Because the ultrasound images were projected onto the Google Glass screen via a wireless connection, the speed of the connection may have also contributed to the longer procedure times in the Google Glass group. When we analyzed our data to look at the percentage of total time participants looked at the monitor or screen during the procedure, the average time was similar across both groups. The Google Glass participants spent more time looking at the ultrasound image compared to the Non-Glass group, and it took them longer to advance or redirect their needle based on the image being projected onto the Google Glass screen.

None of the participants wearing Google Glass were noted to move their heads laterally during their venipuncture attempts. In order to visualize the position of their needle on ultrasound, they merely had to glance slightly upward to the right to see the Google Glass screen or adjust their gaze within the field of view offered by Google Glass. Given the ease of viewing the ultrasound image wearing Google Glass, it may be possible that participants may have instinctively evaluated and re-evaluated their needle position multiple times when wearing Google Glass. By comparison, all participants randomized to the Non-Glass group had to turn their heads laterally several times throughout the procedure in order to view the ultrasound screen, and then lower their head to obtain a view of their needle placement on the simulated patient's neck.

It is important to note that novice users performing ultrasound-guided procedures will often turn their attention back and forth between the ultrasound image and the anatomic site where they are performing the procedure. With time and practice, experts at performing ultrasound-guided procedures can successfully puncture the vessel by viewing the ultrasound image alone. In our study, the most experienced users had only performed, on average, 28 central lines on live patients and 18 central lines on simulated patients. Many of our participants may not have mastered the skill of successfully entering the target vessel by watching needle trajectory on the screen during the entire puncture attempt.

All 40 participants in this study were able to successfully cannulate the internal jugular vein using ultrasound guidance in both the short-axis approach (out-of-plane approach) and long-axis approach (in-plane approach). The first- and fourth-year medical students and the third-year residents took longer to successfully cannulate the vein using the long axis approach in both the Google Glass and Non-Glass groups. The first-year residents of this study took approximately the same amount of time to cannulate the vein in both in-plane and out-of-plane approaches.

Generally speaking, most individuals who learn how to perform ultrasound-guided procedures first learn how to do the procedure in the short-axis approach. This approach is typically easier, given the wider field projected on the ultrasound screen. The in-plane approach provides the advantage of seeing the entire needle shaft and tip and their direct relationship to the anterior and posterior vessel walls throughout the procedure. Although often more advantageous, the in-plane approach is more technically difficult to perform because it is easy to lose sight of the needle if the ultrasound beams are not aimed directly over the needle during the procedure. As seen with the medical students and third-year residents in this study, the in-plane approach took a bit more time to perform and likely took a few more adjustments to completely visualize the needle during the venipuncture attempts.

In this study, we found one group of participants that appeared equally comfortable with the in-plane approach and the out-of-plane approach in both the Google Glass and Non-Glass groups. It is important to note that our cohort of first-year residents were taught to perform ultrasound-guided procedures using the in-plane approach at the onset of their training and therefore may have the advantage of being more comfortable with this approach, given the amount of practice they have had with it before this study.

Our study has shown that it is feasible for practitioners at various levels of training to learn how to perform an ultrasound-guided procedure using Google Glass. Future studies will need to be performed on a larger scale to determine how much exposure and practice it takes for individuals to become comfortable and proficient using this new wearable technology. We hypothesize that with time and practice, individuals will be able to perform procedures efficiently using Google Glass and will minimize the amount of extraneous movement required during the procedure. We also hope to see new applications developed that will capitalize on the potential benefits offered through wearable technology. Future directions may include developing anatomic overlays or position tracking guidance systems that can be integrated into the wearable technology so that patient safety and comfort is maximized during all clinical procedures.

Limitations

Our study was limited by the small sample size of participants recruited to participate in data collection. Future studies should be designed to incorporate a larger number of participants from multiple centers and areas of expertise.

Google Glass itself had several technical limitations. The wireless connection between the Google Glass unit and the ultrasound machine consistently exhibited a time delay (lag) of around 1 s. Google Glass's limited battery life complicated data collection by requiring multiple breaks between subjects to charge. Google Glass also would produce noticeable heat to the point of mild discomfort the longer the unit was streaming the ultrasound feed.

Our study was also limited to the evaluation of one particular type of wearable technology. As more wearable computers become available to practitioners and medical educators, we should be able to explore their benefits, disadvantages, and ability to be incorporated into practice and teaching. Head-to-head studies will be important in the evaluation of these new educational and clinical adjuncts.

The authors also acknowledge that the technical expertise necessary to deploy Google Glass would be lacking from most medical institutions without introductory training and wireless infrastructure modification. In addition, the current inability to encrypt the video connections makes the use of Google Glass in clinical care limited at this time, due to the Health Insurance Portability and Accountability Act in the United States.

CONCLUSIONS

Medical trainees and practitioners with various levels of experience can integrate wearable technology into their clinical practice and successfully perform ultrasound-guided procedures using Google Glass. Future studies and research are underway to evaluate the potential of incorporating such advanced medical technologies into medical training and clinical practice.

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ARTICLE SUMMARY

1. Why is this topic important?

Wearable technology is part of a forthcoming wave of smart devices that will profoundly affect the practice and teaching of medicine. There are few practical examples in the literature of these technologies being integrated into clinical practice and education.

2. What does this study attempt to show?

This study provides one of the first demonstrations of the use of a wearable computer in a simulated ultrasound-guided procedural exercise as it attempts to show that ultrasound-guidance through wearable computer Google Glass offers a convenient and effective alternative to traditional ultrasound monitors while performing a simulated central venous catheter cannulation.

3. What are the key findings?

Subjects using Google Glass for ultrasound-guided central venous catheter cannulation took longer to complete the procedure than subjects using traditional ultrasound guidance. A large majority of subjects found Google Glass to be a comfortable and convenient means of receiving ultrasound guidance.

4. How is patient care impacted?

This study establishes the feasibility that Google Glass and similar technologies may be used for ultrasound-guided procedures in the future and may allow for fewer instances of gaze redirection while performing procedures like central venous catheter cannulation, thereby minimizing the risk of inadvertent needle shift or misplacement.