Original Research

Orthopaedic sport medicine surgeons and fellows value immersive virtual reality for improving surgical training, procedural planning, and distance learning☆

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ABSTRACT

Objectives: Overall, the potential utility of immersive virtual reality (iVR) technology in orthopaedic surgery is promising. The attitudes of medical students and surgical trainees on virtual reality simulated surgical training have been overwhelmingly positive. However, further research and understanding of the attitudes of practicing orthopaedic surgeons and fellows are needed to appreciate its benefits for clinical practice. The purpose of this study was to establish the face validity of iVR technology by assessing the attitudes of Canadian orthopaedic surgeons on the value of iVR for surgical training, clinical practice, and distance learning.

Methods: Forty-three orthopaedic surgeons and fellows attended an iVR demonstration at an annual orthopaedic meeting. The view and audio from the lead headset were cast to a large screen so the audience could follow the procedure in real time. Immediately after the presentation, the audience members were asked to complete a paper questionnaire assessing their perceptions and attitudes toward iVR for use in orthopaedic learning, clinical practice and distance education and mentoring.

Results: iVR was perceived to be valuable for the field of orthopaedic surgery providing face validity for the technology. All 13 questions were rated with mean Likert scores of five or greater, indicating a positive observed value for all 13 questions. The respondents indicated that iVR had value (score of 5 or greater) in each questionnaire domain, with agreement ranging from 78% to 98% for teaching and learning, 66%–97% for clinical practice, and 88%–100% for distance education and mentoring questions.

Conclusion: This study has demonstrated that a group of Canadian sport medicine orthopaedic surgeons and fellows had favourable attitudes toward, and perceived that iVR has value in, orthopaedic surgical training, clinical practice and distance learning and mentorship. The potential for utilizing iVR technology for clinical practice, distance learning mentorship and global education appears promising.

Level of evidence: II.

What are the new findings?

- Face validity for the use of iVR for orthopaedics as Canadian sport medicine surgeons and fellows report favourable attitudes toward the technology.
- The greatest value was seen in the domain of teaching and learning, where over 84% of respondents perceived iVR to ‘have’ or ‘very likely to have’ value.
- The potential for utilizing iVR technology for clinical practice, distance learning mentorship and global education appears promising.

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INTRODUCTION

Immersive virtual reality (iVR) is a technology that enables users to enter a computer-generated environment with an authentic sensory experience, making them feel physically present in that space [1]. The goal is to immerse the user in a virtual world that feels as real as possible. This allows surgeons to replicate surgical procedures in a virtual operating room with the ability to have others in the room and communicate directly with them (Fig. 1). Headsets provide an interactive environment, including visual and auditory feedback, and handheld controls allow a user to manipulate the virtual environment with haptic feedback. iVR requires a stable internet connection, minimal hardware with low cost, commercially available headsets and only two square metres of space. Collaboration settings on the iVR can allow multiple users to be present in the same virtual space, eliminating the need for geographic proximity and making the potential use for distance education compelling. Consequently, the use of iVR in orthopaedic surgery has increased by over 300% since its introduction into general use [2].

In healthcare, iVR is advancing education for learners and educators through standardized, repeatable, and cost-effective simulated clinical education and training [3]. iVR is used in many settings, from patient education and guiding rehabilitation to workplace instruction for surgical device representatives and nursing, as well as procedural and situational education for trainees [1,4–7]. For orthopaedic trainees, the COVID-19 pandemic reduced the number of elective procedures and overall access to the operating room (OR) [8,9]. To combat the loss of surgical experience, many training institutions integrated iVR technology into their surgical procedure curriculum, allowing surgeons and trainees to practice and improve their technical skills in a controlled environment [3,10,11].

In clinical practice, iVR’s utility as a pre-operative planning tool allows surgeons to improve their understanding of complex anatomy, surgical approaches, and procedural steps in a virtual environment. Practicing new procedures and surgical techniques before working on live patients can reduce the surgical learning curve for surgeons, allowing them to improve their skills and competency in a controlled environment [12–18]. This approach has the potential to decrease errors and improve efficiency, ultimately improving surgical outcomes and patient care [3,7,13,18–23]. The growing use of iVR across multiple orthopaedic subspecialties is likely fuelled by this potential [21,24,25].

Overall, the potential utility of iVR technology in orthopaedic surgery is promising. The attitudes of medical students and surgical trainees to virtual reality simulated surgical training have been overwhelmingly positive [26]. However, further research and understanding of the attitudes of practicing orthopaedic surgeons and fellows are needed to appreciate the potential benefits of iVR for clinical practice [27]. The purpose of this study was to establish the face validity of iVR technology by assessing the attitudes of Canadian orthopaedic surgeons on the value of iVR for surgical training, clinical practice, and distance learning.

METHODS

Setting and participants

An audience of 43 orthopaedic surgeons and fellows attending an annual sport medicine meeting were surveyed after attending an iVR demonstration. Ethical approval was not obtained for this study as it was a cross-sectional study of surgeons who participated voluntarily in a survey.

Materials

iVR technology (Precision OS, Vancouver, Canada) was used on stage by five orthopaedic surgeons to demonstrate a knee arthroscopy and anterior cruciate ligament reconstruction (Conmed Corporation Largo, US). The iVR technology allowed the demonstrators to exist communally and move about in a simulated operating room for the demonstration (Fig. 1). The surgeons could interact and speak with each other in the virtual space. The view and audio from the lead headset were cast to a large screen so the audience could follow the procedure in real time. Immediately after the presentation, the audience members were given a paper questionnaire assessing their perceptions and attitudes toward iVR. Survey responses remained anonymous.

Questionnaire design

The survey was created using a collaborative document and comprised 33 initial questions extracted from previous iVR publications [26,28,29]. Two authors reviewed and refined the survey to reduce the question list to 21 items, which was then reviewed by an orthopaedic surgeon with iVR expertise. The final questionnaire comprising 19 items was agreed upon to present face validity for the 3 areas of interest to be explored. These questions were categorized into 4 sections: demographics, teaching and learning, clinical practice, and distance education and mentoring.

The first six questions collected demographic information of the respondents, including age range, years and location of practice; academic or community practice setting; and access to iVR at their institution or home. There were 13 questions on how the participants perceived the value of iVR across three domains: teaching and learning (six questions), value to clinical practice (four questions), and distance education and mentoring (three questions). Responses were recorded using a 7-point Likert scale (1 = no value at all, 2 = very unlikely to have value, 3 = unlikely to have value, 4 = unsure, 5 = likely to have value, 6 = very likely to have value, and 7 = very valuable) [30].

Fig. 1. Graphics depicting the virtual space demonstrated by the surgeons. a) Top, demonstration of the ability of multiple persons to exist in the virtual space and communicate. b) Bottom, sample of the ability to demonstrate anatomy and surgical technique by removing the bone from the knee to assess femoral tunnel creation during a virtual anterior cruciate ligament reconstruction.
Statistical methods

Respondent’s demographics were collated and reported descriptively. Responses for each of the 13 questions on surgeons’ perception of iVR were grouped into their respective Likert score categories. A score of 5 or greater was considered positive for iVR’s value for orthopaedics as this was scaled as ‘likely to have value’ and 3 or less was considered negative for iVR’s value for orthopaedics as this was scaled as ‘unlikely to have value’. The questions were grouped by domains with means (M) and standard deviations (SD) calculated for each domain. To determine if the relationship between a positive impression of iVR was more likely among surgeons and fellows with access to iVR, a one-tailed two-sample t-test assuming equal variance was performed across each of the 13 questions. Statistical significance was set as p < 0.05.

RESULTS

A total of 43 practicing orthopaedic surgeons (n = 34) and fellows (n = 9) completed the questionnaire after watching the live iVR knee arthroscopy demonstration (Table 1). All participants had access before and after the session to experience and trial the iVR module. Overall, iVR was perceived to be valuable for the field of orthopaedic surgery. All 13 questions were rated with mean Likert scores of five or greater, indicating a positive observed value for all 13 questions (Fig. 2).

All three domains demonstrated mean Likert scores above five, indicating that orthopaedic surgeons and fellows perceived iVR as having value in training and learning, clinical practice, and distance education and mentoring (Table 2). The percentage of respondents who indicated that iVR had value (Likert score of 5–7) ranged from 78 to 98% for the teaching and learning domain, 66–97% for the clinical practice domain, and 88–100% for the distance education and mentoring domain.

The individual questions with the highest value on the Likert scale for iVR were for “teaching relevant anatomy” (M = 6.3, SD = 0.8) followed by “teaching/learning key surgical steps” (M = 6.2, SD = 0.8) and “practicing and teaching surgical approaches” (M = 6.0, SD = 0.9). More than 84% of the respondents indicated that iVR for teaching anatomy and teaching/learning key surgical steps would be “very valuable” or be “very likely to have value”. The questions rating iVR with the lowest value on the Likert scale were within the domain of clinical practice, with iVR rated as ‘likely to have value’ for “improving real-life surgical outcomes” (M = 5.19, SD = 1.12), “reducing surgical complications” (M = 5.07, SD = 1.14), and “improving workflow in my practice for planning and performing procedures” (M = 5.07, SD = 1.14). For these clinical practice questions, 32% of the respondents still indicated that iVR would be “very valuable” or be “very likely to have value”.

Table 1

Demographics of questionnaire respondents (n = 43).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number of respondents, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
</tr>
<tr>
<td>Less than 39</td>
<td>16 (37%)</td>
</tr>
<tr>
<td>40–49</td>
<td>16 (37%)</td>
</tr>
<tr>
<td>50–59</td>
<td>5 (12%)</td>
</tr>
<tr>
<td>60 or older</td>
<td>6 (14%)</td>
</tr>
<tr>
<td><strong>Years of Practice</strong></td>
<td></td>
</tr>
<tr>
<td>Fellows</td>
<td>9 (21%)</td>
</tr>
<tr>
<td>Less than 5</td>
<td>3 (7%)</td>
</tr>
<tr>
<td>5–10</td>
<td>13 (30%)</td>
</tr>
<tr>
<td>11–20</td>
<td>11 (26%)</td>
</tr>
<tr>
<td>More than 20</td>
<td>7 (16%)</td>
</tr>
<tr>
<td><strong>Setting of Practice</strong></td>
<td></td>
</tr>
<tr>
<td>Academic/University only</td>
<td>17 (40%)</td>
</tr>
<tr>
<td>Community/Private practice</td>
<td>15 (35%)</td>
</tr>
<tr>
<td>Both academic and community</td>
<td>11 (26%)</td>
</tr>
</tbody>
</table>

Table 2

Means and standard deviations of the Likert responses on a seven-point scale for the questionnaire domains.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching and learning (6 questions)</td>
<td>6.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Clinical practice (4 questions)</td>
<td>5.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Distance education and mentoring (3 questions)</td>
<td>5.9</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Fig. 2. Collated responses of the orthopaedic surgeons represented as percentages for the seven-point Likert scale for the 13 questions on the value of immersive virtual reality in teaching and learning, clinical practice, and distance education and mentoring.
Regarding access to iVR prior to this demonstration, 23 respondents (53.5%) had no access to iVR from either home or work. Of the remaining 20 individuals, five (25%) had access at home, 11 (55%) had access at work, and four (20%) had access at home and work. A relationship between access to iVR and the perceived value of iVR, was statistically significant for the items “teaching relevant anatomy” ($p = 0.018$), “reducing surgical complications” ($p = 0.048$), and “pre-operative planning for complex procedures” ($p = 0.039$).

DISCUSSION

This research study evaluating iVR has demonstrated that a cohort of surgeons and fellows perceived the technology as valuable for teaching and learning, clinical practice, and distance education and mentoring. The highest positive values on the 7-point Likert scale were observed in the teaching and learning domain, with slightly lower scores for application to clinical practice. Access to iVR at home or work was associated with a higher perceived value of the technology for use in orthopaedic surgery.

Limited surgical exposure and reduced clinical hours will continue to pressure educational institutions to broaden their medical training methods. The COVID-19 pandemic underscored the need to complement traditional surgical training with new learning modalities, such as iVR, for simulated operating rooms. In response, many medical training institutions have integrated iVR technology into their surgical curriculum, reflecting the increased acceptance of this technology [31]. Demonstrating the direct positive impact of integrating iVR into clinical practice on patient care is a more challenging task, but surgeons can envision the potential benefits.

Teaching and learning

In this study, surgeons and fellows perceived iVR to have the highest value for teaching/learning anatomy, key surgical steps, and surgical approaches. This finding is consistent with several studies amongst trainees that reported iVR to be especially helpful for understanding anatomy in three dimensions and preparing for complex surgical procedures with multiple repetitions [22,26,28,29]. Research has also demonstrated that iVR technology improves trainee performance and provides an engaging and realistic kinesthetic training experience compared to traditional surgical training methods such as reading manuals and watching videos [15,16,27,32–35]. The current gold standard for surgical education is the use of cadaveric donors to practice surgical procedures. While this method closely simulates a live patient, it faces challenges related to availability, cost, and ethics around the use of human specimens. Trials comparing iVR training to cadaveric training for orthopaedic procedures have demonstrated equal efficiency, knowledge and skill transfer improvement for those training with iVR [14]. In a randomized crossover noninferiority trial, Koucheki et al. demonstrated that iVR was, at a minimum, non-inferior to learning anatomy through cadaveric dissection [22]. One major benefit of iVR is the ability to, in an interactive setting, visualize different layers of the body, skin, muscles, and bones in three dimensions (3D). For surgical procedures, the ability to drill a pin and then use the iVR 3D feature to remove the bone from the ‘body’ provides immediate feedback as to the placement of the pin and the surrounding structures [6].

iVR enables surgical trainees to independently enhance their surgical competencies and track their improvements with key performance metrics [15]. In a randomized clinical trial to evaluate if iVR improves learning effectiveness, senior residents were randomized to learn a reverse shoulder arthroplasty in iVR or by surgical video [16]. This study demonstrated that iVR had face, content, construct and transfer validity and improved learning efficiency by 570% for a complex surgical procedure [16]. An example of performance monitoring and improvement for a resident was outlined in a case report about learning how to pin a slipped capital femoral epiphysis using iVR [36]. The resident monitored their performance and repeated attempts until the virtual performance metric showed an improvement exceeding 90%. This improvement was accompanied by a decrease in surgical time and fluoroscopy use. This case report is consistent with findings that priming for a surgical procedure with iVR improves performance in both technical and non-technical skills during the actual surgical procedure [18,37,38].

Clinical practice

As medical training institutions have integrated iVR technology into the surgical curriculum, surgeons are increasingly able to use this technology to improve clinical practice and patient care [3]. Consistent with this, the surgeons and fellows in this study, reported the potential value of iVR, for reducing surgical complications and improving clinical outcomes. iVR allows surgeons to independently improve surgical literacy, practice complex procedures, learn new techniques, and reinforce their skills in a risk-free environment. Clinically, this could enable practicing surgeons to improve competency in new procedures or those they perform less frequently [13]. iVR has potential advantages for pre-operative surgical planning by using modalities such as computed tomography and magnetic resonance imaging to create a virtual 3D model that is patient-specific. This would enable surgeons to practice and manipulate the model to prepare for complex surgical procedures [3, 20–23]. Although it is more challenging to demonstrate a direct effect on patient care from the use of iVR in clinical practice, the potential benefits to practicing surgeons are becoming increasingly apparent.

Distance education and mentoring

The delivery of surgical education globally is challenging due to the obstacles presented by economics, politics, language, and culture. Despite these difficulties, the surgeons and fellows in this study indicated the potential value of iVR for surgical mentorship and access to teaching in different locations and countries. The results of this study suggest the scope of teaching and mentoring could extend beyond traditional face-to-face interactions. Using iVR, individuals from numerous locations worldwide could interact in the same virtual environment and communicate instantly to discuss procedures and anatomy from their homes or hospitals. Although cadaveric learning remains the gold standard, access, expense, and ethics make wet labs an option for the few, not the majority, of surgeons. Once iVR is ubiquitous, surgeons will have equal access to high-quality, simulated clinical experiences and mentorship, regardless of their geographical location and medical institution [3]. As such, iVR holds substantial potential to create a more equitable landscape for trainees, educators, and mentors across the geopolitical landscape.

Limitations

There are some limitations to this study. The respondents did not actively participate in the iVR experience. Although in the same room, they observed the interactions on a screen, having a different experience than the user, specifically the lack of haptic feedback and the feeling of being sensation immersed in a virtual environment. This study involved a relatively small sample of participants representing only one country. Respondents were all orthopaedic surgeons and fellows interested in and practicing sport medicine and arthroscopy. This group of sub-specialists may have different views that may not be generalizable to all orthopaedic surgeons. The iVR demonstration was limited to knee surgery; however, it is reasonable to extrapolate these findings to other anatomical areas. Finally, the data gathered was limited by the scope of the questionnaire, and there is a possibility that additional valuable skills or concepts were not included or captured.

CONCLUSIONS

This study demonstrated the face validity of iVR for use in orthopaedic surgery among a group of Canadian sport medicine orthopaedic surgeons and fellows interested in and practicing sport medicine and arthroscopy. This group of sub-specialists may have different views that may not be generalizable to all orthopaedic surgeons. The iVR demonstration was limited to knee surgery; however, it is reasonable to extrapolate these findings to other anatomical areas. Finally, the data gathered was limited by the scope of the questionnaire, and there is a possibility that additional valuable skills or concepts were not included or captured.

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surgeons and fellows. The surgeons’ responses demonstrated favourable attitudes and a positive perceived value of iVR in orthopaedic surgical training, clinical practice, and distance learning and mentorship. The highest value scores were observed in the teaching and learning domain. The perception of higher value for using iVR in orthopaedic surgery was associated with access to the technology at home or work. The potential for utilizing iVR technology for distance learning, mentorship and global education appears promising.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. Laurie Hiemstra reports a relationship with Smith and Nephew Inc that includes: funding grants, speaking and lecture fees, and travel reimbursement. Laurie Hiemstra reports a relationship with CONMED Corp that includes: consulting or advisory, speaking and lecture fees, and travel reimbursement. Laurie Hiemstra is on the advisory board (unpaid) and has stock options in PrecisionOS. Laurie Hiemstra is on the executive and board of ISAKOS and the Canadian Orthopaedic Association. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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