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Orthopaedic Sport Medicine Surgeons and Fellows Value Immersive Virtual Reality for Improving Surgical Training, Procedural Planning, and Distance Learning

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Abstract

Background

Overall, the potential utility of iVR technology in orthopaedic surgery is promising. The attitudes of medical students and surgical trainees on VR 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.

Purpose

The purpose of this study was to assess the attitudes of Canadian orthopaedic surgeons and Fellows on the value of iVR for surgical training, clinical practice, and distance learning.

Methods

Forty-three orthopedic surgeons and Fellows attended a VRthrscopy™ Knee Module (Conmed Corporation, Largo, USA) demonstration. 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 or use in orthopaedic learning, clinical practice and distance education and mentoring.

Results

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 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 78-98% 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 orthopedic surgeons and Fellows had favourable attitudes towards, and perceived that iVR has value in, orthopaedic surgical training, clinical practice, and distance learning and mentorship. The potential for utilizing iVR technology for distance learning, mentorship and global education appears promising.

**Key Words:** virtual reality, surgical education, orthopaedic, orthopaedic surgery, immersive virtual reality, distance education, mentorship, teaching

**What are the New Findings**

- Canadian sport medicine surgeons and Fellows have favourable attitudes toward immersive virtual reality (iVR) for orthopaedics.
- 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.
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. 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 commercially available headsets and only two square metres of space. Collaboration settings allow multiple users to be present in the same virtual space. This feature eliminates the need for geographic proximity 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 and procedural and situational education for trainees. [1, 4-7] For orthopaedic trainees, the COVID-19 pandemic significantly 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 safe and 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 fueled 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 on VR simulated surgical training have been overwhelmingly positive [26], but further research and understanding of the attitudes of practicing orthopaedic surgeons and Fellows are needed to appreciate its benefits for clinical practice. [27] The purpose of this study was to assess the attitudes of Canadian orthopaedic surgeons and Fellows on the value of iVR for surgical training, clinical practice, and distance learning.

Methods
Setting and Participants

An audience of 43 orthopedic surgeons and Fellows attended a VRthrscoy™ Knee Module (Conmed Corporation, Largo, USA) demonstration using PrecisionOS iVR at the 2022 Canadian Arthroscopy Meeting. No ethics approval was required for this project.

Materials

VRthrscoy™ technology was used on stage by five orthopaedic surgeons for an iVR knee arthroscopy demonstration. The iVR technology allowed the demonstrators to exist and move in a simulated operating room and perform a knee arthroscopy and ACL reconstruction procedure. (Figure 1) The demonstrating 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

Questionnaire development was based on previous questionnaires in the literature to establish initial validity for the use of iVR for education and clinical practice. The final questionnaire contained 19 items. 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) (Figure 1).

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’. The questions were grouped by domains with means and standard deviations 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.

Results

A total of 43 practicing orthopedic 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.
### 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 only</td>
<td>15 (35%)</td>
</tr>
<tr>
<td>Both academic and community</td>
<td>11 (26%)</td>
</tr>
</tbody>
</table>

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 observed value for all 13 questions. (Figure 2).
Figure 2. Likert responses percentages on a seven-point scale for the 13 questions on the value of iVR in teaching and learning, clinical practice, and distance education and mentoring.

All three domains demonstrated mean Likert scores above five indicating that orthopaedic surgeons and Fellows perceive iVR as having value in training and learning, clinical practice, and distance education and mentoring. (Table 2) The respondents who felt that iVR had value (score of 5 or greater) ranged from 78-98% for the teaching and learning domain, 66-97% for the clinical practice domain, and 88-100% for the distance education and mentoring domain.
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>

The individual questions with the highest value 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 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”.

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 demonstrated that a cohort of surgeons and Fellows perceived that iVR technology has value for teaching and learning, clinical practice, and distance education and mentoring. The highest value scores were observed in the teaching and learning domain with 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 methods for medical training. 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 (https://precisionostech-20727313.hs-sites.com/vr-curriculum). 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, 30-33] 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, using iVRs 3D feature, remove the bone from the ‘body’ provides immediate feedback as to the placement of the pin and the surrounding structures. [6]

Immersive virtual reality 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. [34] 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, 35, 36]

**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, in this study surgeons and Fellows reported potential value of iVR, for reducing surgical complications and improving clinical outcomes. Immersive virtual reality 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] Immersive virtual reality 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 is 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, surgeons and Fellows in study reported 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 significant potential in creating 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 orthopedic 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 that a group of Canadian sport medicine orthopedic surgeons and Fellows had favourable attitudes and perceived that iVR has value 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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References


Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ 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. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.