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Virtual Reality and Surgical Simulation Training for Orthopaedic Surgery Residents

A Qualitative Assessment of Trainee Perspectives

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Background: The demonstrated benefits of virtual reality (VR) in orthopaedic surgical training are numerous. However, it is relatively unknown how best to implement VR into an already established orthopaedic resident education curriculum and how trainees will engage and use these technologies longitudinally.

Methods: This was an exploratory, qualitative research study performed in accordance with Consolidated Criteria for Reporting Qualitative Research guidelines. Orthopaedic surgery residents at a single institution were recruited during the 2022 to 2023 academic year. Semistructured interviews were conducted. Data were analyzed through grounded theory methodology, beginning with open coding, followed by axial coding, and concluding with selective coding that describes orthopaedic surgery residents' current perceptions of VR as a training tool.

Results: Six residents participated in interviews before thematic saturation was achieved. Average interview length was 13:27 (±2:59) minutes. Residents felt that currently, VR is most useful for interns and junior residents as an educational adjunct for learning anatomy, surgical exposures, and the steps of a procedure in a risk- and judgment-free arena. There seems to be a "ceiling effect" with VR given current technological limitations, and residents remarked that there is an associated "opportunity cost" with using VR technology. Some residents may find it more time-efficient to study texts, videos, or surgical guides rather than use VR. Cost (limited number of headsets) and technological barriers (i.e., hardware, software, and Wi-Fi issues) were some of the described barriers to VR utilization. Residents felt that there needs to be dedicated technological support to help with these issues. At this time, given these limitations of VR, many preferred VR as an optional educational adjunct rather than as a required curricular tool or assessment of surgical competency.

Conclusions: There is current utility for VR in orthopaedic surgical training. Future technological advances may make VR more central to resident education. This study describes resident perceptions about the technology and best use practices for the technology.

Level of Evidence: Qualitative Study, Level V Evidence

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A607).

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Introduction

Virtual reality (VR) has potential for significant utility within orthopaedic surgical training[1]. Typically, a VR user wears a headset display and holds onto handheld devices, allowing for the manipulation of objects within a simulated, interactive, three-dimensional environment such as a virtual operating room. The primary benefit of VR within surgical training is that it allows users to learn, rehearse, and review the steps of a surgical procedure independently and relatively risk-free because many of the developed software modules include built-in instructional guides and real-time feedback[2,3]. Although the demonstrated benefits for VR in orthopaedic surgical training are numerous, including skill acquisition and improved operative performance, many of these studies have not focused on end-user perceptions of the technology[4-28]. It is relatively unknown how best to implement VR into an already established orthopaedic resident education curriculum and, further, how trainees will engage and use these technologies longitudinally. In 2020, 1 study polled trauma and orthopaedic specialty trainees in the United Kingdom and found that many believed that current VR systems were not widely available or realistic enough to be useful and most preferred online videos and operative technique guides for case preparation[29]. The purpose of the current study is to better understand orthopaedic surgery trainee's current perceptions about VR and how it can best be implemented within their own training.

Methods

Study Design

This is an exploratory qualitative research study design for which Institutional Review Board approval was granted (IRB #202208165). The study was performed in accordance with Consolidated Criteria for Reporting Qualitative Research (COREQ) guidelines[30]. The COREQ guidelines include a 32-item checklist that aims to promote complete and transparent reporting among researchers and indirectly improve the rigor, comprehensiveness, and credibility of interview and focus-group studies[30].

Setting and Participants

All orthopaedic surgery residents at a single institution, Washington University in St. Louis, were recruited during the 2022 to 2023 academic year. The program is a diverse academic program, with 40 residents total, 8 per year, and composed of 50% women. Residents were sent an email describing the goals of the study and welcoming their participation. A purposive sampling strategy was devised to include a diverse group of residents regarding their use of, exposure to, and perceptions of VR. Purposive sampling, as opposed to random sampling, is a sampling technique often preferred in qualitative research because deliberately choosing interviewees because of the qualities they possess often yields richer data than would be achieved through random sampling[31]. Recruitment and data collection continued until thematic saturation was reached. Thematic saturation is defined as the point when no new information is gleaned from the interviews and no new codes occur in the data. It should be noted that a few months before the initiation of this study, the department acquired 5 Facebook VR Oculus Quest 2 (Meta; Menlo Park, CA) with PrecisionOS (Precision OS; Vancouver, BC) headsets. All residents were given a 1-hour "Introduction to Virtual Reality" didactic session and were also given the opportunity to demo the software after and create personal logins.

Data Collection

Semistructured interviews were conducted by the first author (A.W.K.). Semistructured interviews were chosen over structured interviews because this format makes better use of the knowledge-producing potentials of dialog by allowing more leeway for following up on whatever angles are deemed important by the interviewee, increasing the richness of data[32]. He and other study team members have had past experience conducting qualitative research[33-35]. At the time of the study initiation, he was a current orthopaedic surgery resident (Post-Graduate Year [PGY]-3) within the program. He also served as a member of the department's program education committee. He had no vested or financial interest in any virtual reality software or hardware at the time of the study. Semistructured interview questions were developed, primarily focusing on previous experience with and perceptions of VR as an educational tool in orthopaedic surgical residency training with attention to usefulness, barriers to use, and best practices for implementation. The questions were agreed on by all authors (Table I).

Participants chose the most convenient location for their interview. No other individuals were in the room during the interview, and all interviews were conducted either virtually or

TABLE I Semistructured Interview Questions and Prompts

Questions	Prompts
-Have you had any previous experience with virtual reality (for gaming, etc), and if so, what was your experience?	-Can you describe/explain further?
-What are your perceptions about the utility/usefulness of virtual reality during orthopaedic residency training?	-What do you mean specifically?
-Do you anticipate any barriers to using virtual reality during your orthopaedic residency training?	-When you said ___ how did you mean?
-How can we best implement virtual reality training in the already established orthopaedic residency didactic curriculum?	-What did you think about that?

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in-person over a single session. All interviews were audio recorded and transcribed verbatim to convert the audio recordings to text in Microsoft Word (Redmond). These transcriptions were made available to the participants on request. The transcripts' accuracy was verified, and any identifying information (such as peer names, attending physician names, and mentor names) was removed. The deidentified data were uploaded into the software program Dedoose Version 9.0.107 for data analysis[34,36,37].

Data Analysis

We used grounded theory methodology to conceptualize a theoretical model of orthopaedic residents' perceptions of VR as a surgical training tool[34,38]. Grounded theory is an approach to interpreting qualitative data that allows for a comprehensive understanding of individual perspectives through the process of (1) coding raw data, (2) categorizing and combining codes into themes, and (3) forming a conceptual (theoretical) model based on the themes[39,40]. Data were analyzed through this three-step process, beginning with open coding (identifying small ideas that signify meaning), followed by axial coding (defining themes from the generated codes), and concluding with selective coding (forming a conceptual model based on the themes that emerged)[40-42]. Two authors (A.W.K. and J.K.Y.) independently read and coded all transcripts. All authors discussed coding discrepancies until consensus was reached. Frequent communication through memo writing allowed the investigators to continually refine their theory, challenge emerging assumptions, and raise insights while also highlighting 1 another's own subjectivities. Open coding produced a codebook with 41 codes. Through the process of axial coding, these codes were consolidated into themes that will be discussed in detail below, and through selective coding, ultimately resulted in a conceptual model that describes orthopaedic surgery residents' current perceptions of VR as a training tool. Quotes presented in-text and within the tables were selected to be representative examples of the theoretical concepts in our study.

Results

Participants

Six residents participated in interviews before thematic saturation was reached. None of the participants who agreed to be interviewed dropped out. There was an equal distribution of men and women. Orthopaedic residents in varying postgraduate year of training and of different orthopaedic subspecialty interests were included. The average interview length was 13:27 (±2:59) minutes (Table II).

TABLE II Orthopaedic Resident Interviewee Characteristics*

Characteristic	n (%), Mean (±SD)
Gender	
Male	3 (50.0)
Female	3 (50.0)
Year in residency	
PGY-1	0 (0.0)
PGY-2	1 (16.7)
PGY-3	1 (16.7)
PGY-4	2 (33.3)
PGY-5	2 (33.3)
Intended orthopaedic subspecialty training	
Adult reconstruction	1 (16.7)
Hand	1 (16.7)
Oncology	1 (16.7)
Sports	1 (16.7)
Trauma	1 (16.7)
Undecided	1 (16.7)
Average length of interview (Min)	13:27 (±2:59)

*PGY = Post-Graduate Year.

Themes and Representative Quotes

Orthopaedic Residents Had Some Knowledge of and Experience with VR Before Starting Residency

Two (n = 2) of the orthopaedic residents interviewed had no hands-on experience with VR before starting residency. The others had used VR, albeit limited, mostly in regard to gaming: "*…I have had pretty limited prior experience with VR…I have used…the Oculus headset for gaming when Oculus first came out and it was probably a total of two hours of exposure.*" All participants knew of its existence, but most never imagined VR would be used for surgical education or training at that time: "*I knew that theoretically, or in an abstract form, (it) would have a lot of…applications in a lot of sectors in the future, but I never specifically envisioned at that time that this (would) make a great surgical training (tool).*"

There Currently Exists Barriers to Using VR

Cost (including limited number of headsets) and technological problems such as hardware, software, and Wi-Fi issues were some of the described barriers to VR use: "*I had trouble just simply wearing glasses and putting on the goggles,*" and "*one of the things that's been challenging (in getting) ours set up is interfacing with the Wi-Fi at our institution.*" One resident suggested holding a session at the beginning of the academic year that would allow trainees to become familiar with the hardware and software. Moreover, most felt that there needed to be dedicated technological support to help with these issues and that the onus should not fall on residents to troubleshoot, given that VR programs are often licensed annually for a fee: "*Ideally it should be…reps from the VR company that could help us troubleshoot…I don't think we should put anything else on residents.*"

There Is an Opportunity Cost Associated with Using VR

Each resident learns differently and "*…sometimes it feels like just another thing you're able to do…*" With what limited time they have, some may find more value in studying texts, videos, or surgical guides rather than using VR, especially if the

perceived benefit is only marginal: "*When you commit to spending 2 hours doing virtual training…you have to be mindful of the opportunity cost associated—that might be two hours looking through surgical technique guides that you've made or looking through Hoppenfeld's surgical exposures or such.*" Residents did hypothesize that if they were able to bring the headsets home, it may become more time-efficient learning for them. Currently, as it stands, 1 felt that "*I'd be eating up an hour of my precious time to get a marginal gain…it's a long run for a short slide.*"

At This Time, VR Would Benefit Orthopaedic Interns and Junior Residents Most, Given Current Technological Limitations Leading to a "Ceiling Effect" for Others

VR may be better suited for interns and junior residents because 1 resident remarked that "*it has the most value for junior residents, PGY-1 and PGY-2, and the reason why is the content is good.*" In addition, "*…it essentially takes away all of the fear… you're not going to hurt (anyone), you don't have circulators and the scrubs looking at you….*" Most felt it would best used as an educational adjunct for learning anatomy, surgical exposures, and the steps of a procedure before seeing it for the first time in a risk- and judgment-free arena: "*I think it would make a good supplement to the anatomy lab (and) skills week for interns…and (before) going into a specific rotation—doing the cases associated with that rotation…just to get an idea.. of what those cases may look like.*" There seems to be a ceiling effect, given the current limitations in technological capability of VR including lack of fine detail/minutiae, inability to provide more freedom to make more mistakes, and the absence of true motor feedback (e.g., tactile feedback): "*I think it's a really good introduction to different surgical procedures…it's very informative if you do not have much experience doing those surgeries, but I think once you become more facile…as a more upper-level resident, the utility tends to drop off.*" Another resident said that "*… it falls short in terms of actual tactile feedback…different factors for each patient…this is an optimized setup where everything goes perfect.*" Furthermore, "*it just seemed like we go step by step with one surgery…if you could grab different (instruments) instead of it automatically saying "grab the guide pin"…(where) there's only one option for me to grab… I'm not really learning.*" As technology improves, it may prove more useful to senior level residents, fellows, or even attendings: "*If they were really able to integrate finer details, and somehow improve the (tactile/motor) feedback throughout their modules, it definitely could be applicable to senior residents, attendings…*" For instance, if the software were able to upload patient-specific imaging, it could help with planning for complex cases: "*If the technology improves, and we can get patient-specific challenging cases represented in VR, that would be great too.*"

VR Should Not Be a Required Educational Tool and Should Not Be a Measure of Surgical Competency at This Time

Given the limitations and reasons denoted above, most agreed that VR should not be a measure of surgical competency until the technology improves: "*I can see…some departments trying to implement VR in terms of…structured landmarks for surgical experience that you have to pass…measures of competency, length of your training…I don't know if that's a great path…I think it's just not a totally accurate representation of real surgery…competency should hopefully come from faculty or others who can evaluate surgical skills in real time….*" Some discussed the topic of having structured rotation requirements (i.e., completing a set number of virtual total hip arthroplasties before starting the adult reconstruction rotation); however, "opportunity cost" was a major deterring factor: "*…If you're going on to Adult Reconstruction, can you get through a total hip 10 times before you start of service?…I don't think (it) should be like 'you can't scrub in' type of thing…but I think it would be (helpful) as you're going onto the service preparing for it in that way…but you have to balance it with an understanding that we only have so many hours in the day.*" Others believed that making VR a required curricular component would be less preferred over it serving as an educational adjunct: "*It grades your performance, but the performance…doesn't reflect reality—it's short of how good you are at virtual surgery…rather than actual competency and how you're doing*" and "*I don't think that having it built into the curriculum as formal training…is a good approach…especially for more senior residents.*"

Overall Model Framework

These themes were coalesced and synthesized, which resulted in a conceptual model describing orthopaedic residents' current perceptions about VR and surgical simulation training (Fig. 1).

Discussion

Interest in VR was exponentiated recently in the context of the COVID-19 pandemic, where traditional educational avenues for orthopaedic trainees such as in-person cadaver laboratory test results and didactics were stopped concomitantly with a decrease in elective surgical volume[43]. As a result, there was an urgent need to fill the void of lost education and surgical experience for orthopaedic surgery residents. VR companies have since partnered with several orthopaedic societies and industry to create VR training modules and curricula for residents and fellows because VR has been hypothesized to be promising avenue for orthopaedic surgical training.

In the spine literature, VR has been shown to improve anatomic knowledge and has purported utility regarding preoperative planning among trainees[4]. Those who train with VR for placing pedicle screws have been shown to outperform those who receive only didactic teaching and verbal instruction on cadaveric and sawbones models[5-7]. Most of the VR literature within the domain of sports medicine has focused on arthroscopy. A few studies report on the validation of arthroscopic virtual reality training systems[8-11]. However, most have examined the benefits of VR training regarding arthroscopic skill acquisition particularly for inexperienced surgeons, medical students, and residents[12-21]. Within adult reconstruction, VR training for total hip arthroplasty among surgical residents

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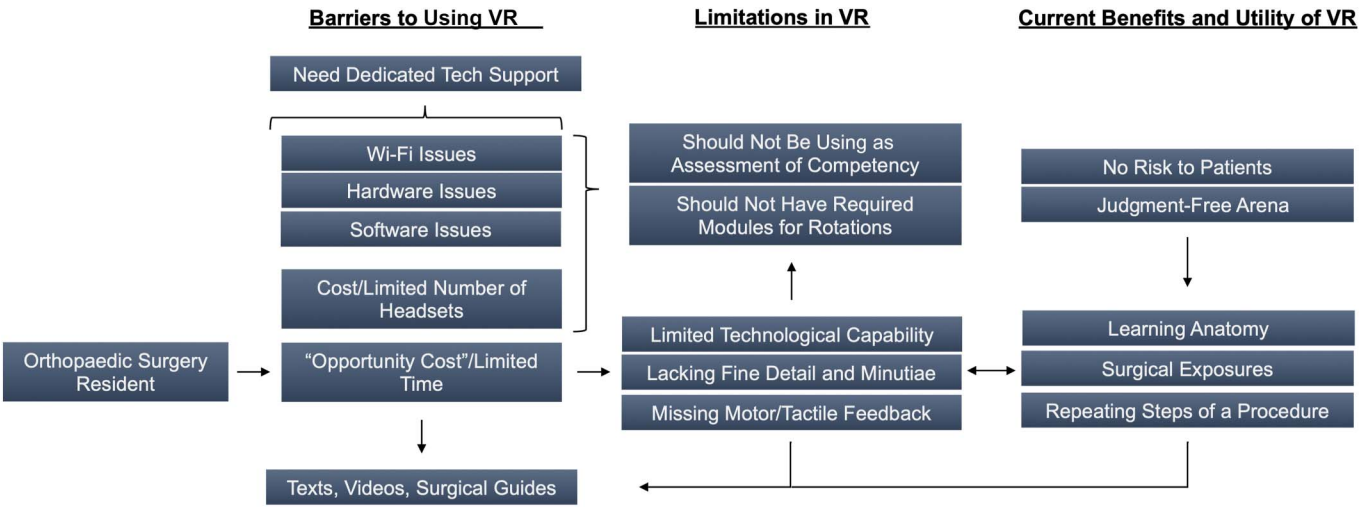

Fig. 1

Conceptual framework of orthopaedic resident's perceptions about VR and surgical simulation training. VR = virtual reality.

has been shown to improve technical skills including completion, component accuracy, and speed when transferred to cadaveric specimen[22,23]. In shoulder and elbow surgery, senior residents who trained on VR for reverse total shoulder arthroplasty demonstrated superior learning efficiency, knowledge, and skill transfer in "real-world performance" compared with a control group who did not train with VR[24]. In the orthopaedic trauma literature, medical students training with VR demonstrated greater procedural accuracy and completion of inserting an intramedullary tibial nail in a saw bones model compared with those who only read technique guides[25,26]. Similar results were reported for a dynamic hip screw module, where those who trained on VR had improved performance metrics, and reported that they enjoyed using the simulator and recognized the need for the simulator in formal training[27]. In pediatrics, for slipped capital femoral epiphysis, training with VR was also subjectively rated higher in value compared with reading/video materials[28]. Although the benefits of VR are numerous, the previous studies were conducted at a single point in time. There are less data on end-user perceptions, how trainees will use the technology longitudinally, and how best to implement VR into an already established curriculum.

Our study used qualitative techniques to help address these knowledge gaps in VR research. Interviews with a diverse group of residents from our program resulted in a conceptual model that describes their current perceptions about VR and surgical simulation training. They believed that VR, as it currently stands, may be more useful for interns and junior residents as an educational adjunct for learning anatomy, surgical exposures, and the steps of a procedure before seeing it for the first time, in a risk- and judgement-free arena. There seems to be a ceiling effect, currently, with learning on VR, given the current limitations in technological capability including incorporating fine detail/minutiae and providing motor feedback (e.g., tactile feedback) that simulates reality in the operating room.

However, as technology improves, it may prove more useful for senior-level residents, fellows, or even attendings. Many reported that there is an associated current "opportunity cost" with VR technology, given lack of overall time. Some residents may find it more time-efficient to study texts, videos, or surgical guides rather than use VR. Cost (limited number of headsets) and technological barriers including hardware, software, and Wi-Fi issues were some of the described barriers to VR use. Residents felt that there needs to be dedicated technological support to help with issues and that the onus should not fall on residents to troubleshoot software issues, given that these VR programs are typically licensed annually for a fee from different companies. At this time, the interviewees recommended VR being used as an education adjunct over any specific curricular or rotation-specific requirements. In addition, given the limitations of VR, most felt strongly that it should not be used to assess surgical competency.

These data help define end-user perceptions about how best to implement VR in an already established curriculum. Addressable action items include (1) holding an information session at the beginning of the year to acclimate residents with the hardware/software; (2) identifying and addressing barriers to use, including having dedicated technological support available both on the software and institutional sides; (3) finding ways to implement the software/modules into an already established curriculum as an educational adjunct—primarily regarding anatomy/surgical exposures, and additionally providing a document about what modules or procedures are available for what rotations/services; and (4) obtaining more headsets and providing the ability to lease or take the headsets home. Notably, future implementation of a required VR curriculum would need senior resident and faculty champions who could provide real-time feedback to early trainees during VR modules. As the technology continues to improve, VR may become more central to resident education and become more useful for senior-level residents, fellows, and even attendings,

but until then, it lacks the ability to accurately and completely assess surgical competency.

This study is not without limitations. This was a qualitative, Level V evidence study made up of resident opinion. The residents in this study have had minimal exposure to VR, only using 1 type of headset and engaging with a single software company. A recent systematic review found that most qualitative studies reach thematic saturation between 9 and 17 interviews, where in the current study, thematic saturation was achieved after 6, which we hypothesize is likely due to the homogeneity of respondents perspectives[44]. Varying or different opinions may have been missed. These data are unique to residents at a single institution and may not be generalizable to other orthopaedic surgical residency programs. Future study should aim to assess the perceptions of VR in orthopaedic surgical training at different programs.

Conclusion

This study describes orthopaedic surgical resident perceptions about VR, as well as best use practices for the technology as it currently stands. There is current utility for VR in orthopaedic surgical training primarily as an educational adjunct. Barriers to use must be identified and addressed because there is a significant opportunity cost, given time constraints placed on orthopaedic residents. Future technological advances may make VR more central to orthopaedic surgical resident education. ■

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