Manuscript Title: Virtual Reality for Proton Therapy - Child-life guided interactive tour for adolescents

Running Head: Virtual Reality tour of proton therapy facility

Article Category: Research Report

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What is already known?

Virtual reality applications have been described in medicine, specifically focusing on pain relief and cognitive behavior therapy.

What this article adds?

We describe a feasibility study of virtual reality in a radiation therapy setting to provide patient education about the facility and the radiation treatment sessions in a pediatric setting.

Abstract

Purpose

Proof-of-concept study to determine the feasibility of incorporating a virtual reality tour for children scheduled to receive radiation therapy. The secondary objective was to qualitatively describe each subject's virtual reality experience.

Methods

Children ages 13 or older scheduled to receive proton radiation therapy were included in the study. Subjects watched the virtual reality tour of the radiation therapy facility with a child life therapist experienced in coaching children receiving radiation therapy and completed a survey after the tour.

Results

Eight subjects consented for participation and 6 completed the virtual reality tour. All of the enrolled patients completed the virtual reality tour successfully. Two subjects did not complete the survey. Two subjects requested to pause the tour to ask questions about the facility. Five subjects said the virtual reality tour was helpful preparation before undergoing proton radiation therapy. Subjects stated that the tour was helpful because ‘it showed me what’s to come’ and it was helpful to see ‘what it’s like to lay in the machine.’ One subject said ‘it made me feel less nervous.’ Six subjects stated that they would like to see
this type of tour available for other areas of the hospital, such as diagnostic imaging rooms. None of the subjects experienced nausea or vomiting.

Conclusions

The virtual reality video tour allowed patients to explore the treatment facility in a comfortable environment. Participants expressed that the tour was beneficial and would appreciate seeing other parts of the hospital in this way.

MeSH Keywords:

- Radiotherapy
- Child Guidance
- Proton Therapy
- Virtual Reality Exposure Therapy
- Patient Simulation
Introduction

A course of radiation therapy consists of one simulation session followed by 10 to 35 daily radiation sessions. Each treatment session can last between 30 and 90 minutes depending on the treatment set up and delivery. Radiation therapy protocols are carefully designed to match the individual patient's condition.

Patients must be placed in the same position and remain perfectly still to ensure the radiation beam targeting achieves the highest accuracy. Many children require an immobilization device, usually an individually molded plastic shell that fits tightly over the face. For young or anxious children, sedation or general anesthesia is often required, while adolescents and older children may undergo radiation therapy without general anesthesia. (1-3) Individuals receiving radiation therapy without general anesthesia often work with child life specialists to learn about radiation therapy and what is involved, as well as to develop coping strategies. (4) One of the challenges patients face is learning about the radiation therapy facility. Visiting the facility may not be feasible due to conflicts with the radiation treatment schedules and the patient's availability. Many patients learn about the radiation therapy facility by watching videos or looking at photographs.

Virtual reality technology is becoming increasingly available to consumers for development and delivery of content. One of the leading developers for virtual reality consumer devices is Oculus, with the Oculus Rift. Oculus released the first consumer device in April of 2016. (5) Samsung also has introduced a virtual reality platform for mobile devices such as the Galaxy phones. Virtual reality technology will continue to evolve with new devices over the coming months and years.

Virtual reality applications in healthcare are flourishing. Applications have been developed and studied in evaluation and treatment of anxiety, pain and other conditions. (6-11) The consumer market for virtual reality technology is becoming increasingly accessible for both consumers and developers. Virtual reality is not without problems. One of the main limitations of virtual reality is that users may experience
dizziness, motion sickness, nausea or vomiting. Furthermore, virtual reality headsets consist of two eyepieces for binocular vision. The specific hardware configuration of a viewer may affect the end-user experience for individuals who cannot see through both eyepieces simultaneously, such as young children.

The primary objective of this study is to determine the feasibility of using a virtual reality headset, the Oculus Rift Development Kit, to deliver a tour of the radiation oncology facility to patients scheduled to receive proton radiation who are eligible for radiation therapy without general anesthesia. The secondary objective was to qualitatively describe the patients' impression of the virtual reality tour experience.

**Material and Methods**

This single-site study was conducted in full accordance with all applicable research policies and procedures at The Children's Hospital of Philadelphia. The study was approved by the Institutional Review Boards in The Children's Hospital of Philadelphia and the Hospital of the University of Pennsylvania. Study subjects and a parent or guardian provided informed consent and assent before enrollment. This proof-of-concept study evaluated the feasibility of delivering a tour of the Roberts Proton Therapy Center in the Perelman Center for Advanced Medicine (Philadelphia, PA) to pediatric patients with a virtual reality headset.

After the tour, the subjects completed a questionnaire to describe their experience (Table 1). Inclusion criteria consisted of 1) Patients scheduled to receive proton beam radiation therapy; 2) age greater than 13 years; and 3) primary English language. Exclusion criteria consisted of 1) motion sickness; 2) seizure disorder; 3) visual impairment (i.e. diplopia); 4) developmental delay; 5) claustrophobia; 6) cranial incisions with surgical dressings; 7) pain over scalp or areas that may come in contact with the virtual reality headset; or 8) plan to receive radiation therapy under general anesthesia. An interim analysis was performed when three patients completed the protocol, and the protocol was carried out to the conclusion of the study. The trial would have stopped if 2 out of 3 subjects experienced side-effects from the virtual reality tour, such as nausea, vomiting, dizziness or any other symptoms at the time of the
interim analysis. The primary endpoint was the successful completion of the virtual reality tour and subsequently the questionnaire.

**Virtual Reality Tour**

A study member demonstrated the equipment and headset to the subject. Then subject held the virtual reality headset over his or her eyes and experienced the tour of the radiation therapy facility in the presence of a child life therapist experienced in pediatric proton therapy (Figure 1). The child life therapist controlled the virtual reality tour from a laptop (MacBook Pro, Apple, Cupertino, CA) that allowed pausing and replaying specific portions of the video. The virtual reality tour footage included the building entrance, elevators, waiting room, changing rooms, corridors and proton treatment vault and was approximately 5 to 7 minutes in duration. Upon completion of the virtual reality tour, the subject completed a questionnaire to describe his or her experience.

**Equipment**

The virtual reality tour was shown on an Oculus Rift Development Kit 2 (Oculus, CA) and a MacBook Pro. The Oculus Rift viewer has foam face pads which pose an infection control risk. Per the recommendations of the hospital infection control, we fitted a nylon cover on the foam pads (Figure 2). Furthermore, the head straps were secured to prevent contact with the subject’s skin (Figure 2). The nylon cover and Oculus Rift were cleaned between use with hospital-grade disinfectant wipes. The lenses were cleaned with single-used lint free cloths.

The video tour was recorded with GoPro Hero 3 Silver Edition (GoPro, San Mateo, CA) and Kodak SP180 (Kodak, Rochester, NY) with guidance from a child life therapist who conducts the patient tours at the facility. Video editing was performed with Final Cut Pro (Version 10.3.1, Apple, Cupertino, CA). The video was displayed using Kolor Eyes 360 Video Player for Mac, version 1.4.1 (Kolor, Francin, France). The video player allowed the child life therapist to view the tour on the laptop while the subject was using the Oculus Rift.
Results

A total of 8 subjects consented for participation completed the virtual reality tour (Table 2). Two subjects did not return the survey. Of these, one subject was attempted to fill out the survey one day after the tour but had difficulty recalling the details of the tour.

All of the patients that started the tour were able to complete it successfully. Two subjects asked to pause the tour to spend more time exploring individual scenes and ask questions about the facility. One of the subjects paused the tour three times to ask additional questions. Five subjects stated that the virtual reality tour was valuable preparation for proton radiation therapy. Subjects said that the tour was helpful because ‘it showed me what’s to come’ and it was useful to see ‘what it’s like to lay in the machine.’ One subject said, ‘it made me feel less nervous.’ When asked if there were parts of the tour that were not helpful, four subjects answered ‘no.’ Two subjects said that the parts of the tour that were not helpful were the rooms that they were already familiar with such as the changing room.

All of the subjects that completed the questionnaire said that they did not have additional questions about the facility after watching the virtual reality tour. Two out of seven subjects experienced some discomfort described as ‘dizziness’ or ‘eye discomfort’ while watching the tour. The subjects that experienced discomfort resolved the discomfort by adjusting the headset and were able to complete the tour successfully. One subject had trouble holding the headset during the tour.

One subject commented that the image projection in the virtual reality headset was not as clear as the image on the computer. Six subjects stated that they would like to see this type of tour available for other areas of the hospital, such as magnetic resonance imaging rooms. None of the subjects experienced nausea or vomiting.

Discussion
We demonstrated that incorporating virtual reality into the patient orientation process to a proton therapy facility is feasible. The patients who experienced the tour described the experience positively. All of the patients enrolled were able to complete the virtual reality tour. The virtual reality tour also allowed the patients to experience what it is like to lay down in the proton therapy gantry and watch the machine move from the first person point of view. One patient expressed that ‘[the virtual reality tour] made me feel less nervous.’ Patients, particularly children and adolescents, undergoing radiation therapy may experience anxiety especially before the treatment begins. Virtual reality offers an opportunity to improve the patient’s experience. Child life therapists play an integral role in guiding patients through this process, which ultimately spares the patients from receiving general anesthesia for each radiation therapy session. We have successfully introduced virtual reality to the child life therapist’s education tools for this area, and are exploring other applications throughout the hospital.

The virtual reality tour provides a unique first-person perspective of the radiation therapy room in a neutral environment. The tour furthermore allowed patients to experience laying down on the proton therapy machine and watch the machine operate. Five patients highlighted this as the most valuable part of the tour. The virtual reality tour also offers access to the proton therapy room without interrupting the scheduled treatment sessions. The proton therapy rooms are always in high clinical demand and patients have limited opportunities to visit the room before their treatment starts. We are exploring options to expand virtual reality tour access to adult patients in the proton therapy center as well as other parts of the hospital. The patients in our study cohort commented that they would like to see other parts of the hospital in virtual reality. There are endless possibilities for patient-centered virtual reality immersive experiences aimed at education, anxiolysis or analgesia.

The virtual reality tour was designed specifically for the Roberts Proton Therapy Center at the Perelman Center for Advanced Medicine (Philadelphia, PA). One of the limitations of we encountered was specific to the device used for the tour. The Oculus Rift DK2 projects a low-resolution image which does appear pixelated. However, the video is not limited to virtual reality viewers, as it is compatible with smartphones, tablets, and computers. The virtual reality is compatible with most commercially available
virtual reality viewer. We limited the virtual reality tour to patients 13 years or older according to the
device’s manufacturer recommendations. This age limitation is due to the fixed position of the eyepieces
and limited range for interpupillary distance for adults. It is possible for younger children to use the device.
However they may not be able to experience the binocular view, or potentially see double-images. In fact,
a group in Toronto have designed the ‘Childlife VR’ application to introduce the operating room to patients,
and have successfully used it with younger patients using a generic Google cardboard viewer.(14, 15)

Virtual reality viewers such as the Oculus Rift are designed for personal use, thus may not
translate well to clinical environments. As such, they may not meet hospital infectious disease control
specifications. The Oculus Rift DK2 has a foam pad that contacts the face around the eyes, and two
elastic head straps which cannot be easily cleaned or disinfected according to our hospital’s
specifications. Hospital infectious disease specialists recommended placing a waterproof cover over the
foam pad and cleaned with hospital-grade disinfectant wipes. Single use devices such as disposable
Google cardboard viewers circumvent the cleaning problem. However, viewers made of corrugated
cardboard pose an infectious control risk and do not meet requirements in our hospital.

The device configuration described in this study is time-consuming and requires a clean working
surface to configure all the necessary equipment and can take from 5 to 15 minutes to set up. Portable
virtual reality technology is evolving rapidly, and new devices are constantly entering the market. The
virtual reality tour is available as a digital video file and can is compatible with any commercially available
virtual reality viewer, such as hand-held virtual reality viewers designed for smartphone or hand-held
device. There are many options available in the market and more will become available. Ultimately, virtual
reality viewers are available as smartphone apps or dedicated devices and compatible with various multi-
media formats. In the meantime, the virtual reality tour produced can be viewed with a digital video player
such as a computer or tablet in addition to any virtual reality device in the market.

Health care providers are constantly evaluating emerging technologies to improve patient care
and the patient experience. Virtual reality technology is becoming widely available for consumer use. This
technology has great potential for various applications in healthcare, such as assisting healthcare
providers in introducing patients to the hospital setting and therapy areas such as radiation therapy as described. Portable virtual reality technology is growing rapidly, and its role in healthcare is evolving quickly. This study provides an example of a feasibility of implementation of virtual reality in a pediatric clinical setting to supplement child life efforts, dispel the fear of the unknown. Finally, the virtual reality tour provides access to a clinical area that is inaccessible to patients due to high clinical demand and fast paced schedule. As virtual reality technology continues to evolve, so will health care provider’s ability to understand how to apply it and improve the patient experience.

Acknowledgments

The project would not have been possible without the support from the clinical staff at the Roberts Proton Therapy Center. Radiation therapists volunteered their time to operate the proton gantry to make the video tour a reality. I continue to be amazed with their collegiality and support.

Disclosures

Ethics

This study was conducted in accordance with the research policies of the Children’s Hospital of Philadelphia, Hospital of the University of Pennsylvania and Oregon Health & Science University Institutional Research Boards. All patients and parents provided informed consent and assent to participate in the study.

Funding

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Conflict of interest

The authors do not have any conflicts of interest to report.

References
<table>
<thead>
<tr>
<th>QUESTION #</th>
<th>QUESTION TEXT</th>
<th>ANSWER CHOICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>How many times did you pause/stop the video?</td>
<td>0,1,2,3,WHY?</td>
</tr>
<tr>
<td>Q2</td>
<td>How many times did you re-wind the video?</td>
<td>0 / 1 / 2 / 3</td>
</tr>
<tr>
<td>Q3</td>
<td>Did you complete the VRT?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q4</td>
<td>Do you think the VRT might help you to prepare to go through proton therapy?</td>
<td>Yes / No / Not sure</td>
</tr>
<tr>
<td>Q5</td>
<td>Was there any part of the virtual reality tour that was really helpful?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q6</td>
<td>Was there any part of the virtual reality tour that was not helpful?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q7</td>
<td>Did you have any other questions about the Proton Therapy center after watching the VRT?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q8</td>
<td>Did you have any discomfort while watching the VRT?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q8.1</td>
<td>If yes, what type of discomfort?</td>
<td></td>
</tr>
<tr>
<td>Q8.2</td>
<td>If Yes, did you continue watching?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>Q8.3</td>
<td>What did you do to improve your comfort?</td>
<td>Nothing / Adjust headset / pause and resume watching VRT / Stopped / ________</td>
</tr>
<tr>
<td>Q9</td>
<td>Would you like to watch a VRT that is similar to this one for other areas or procedures in the hospital?</td>
<td>Yes / Might / No / I don’t know / Other areas or procedures you would suggest: ________</td>
</tr>
<tr>
<td>Q10</td>
<td>Would you recommend that others watch the VRT?</td>
<td>Yes / Not sure / No</td>
</tr>
</tbody>
</table>

Table 1 Caption: The post tour questionnaire and answer choices as asked of the participants in the study. Subjects were approached to complete this questionnaire immediately following the virtual reality tour.
<table>
<thead>
<tr>
<th>Question</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>0</td>
<td>0</td>
<td>LT</td>
<td>F</td>
<td>0</td>
<td>1 - to explain what was happening</td>
<td>3 - time to talk and ask question</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q2</td>
<td>0</td>
<td>0</td>
<td>LT</td>
<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q3</td>
<td>Yes</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td>Yes</td>
<td>Yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Q4</td>
<td>Yes</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td>Yes</td>
<td>Not Sure</td>
<td>Yes</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q5</td>
<td>Yes - it was helpful because it showed me what's to come</td>
<td>Yes - Seeing what it's like to lay in the machine</td>
<td>LT</td>
<td>F</td>
<td>Yes - it made me less nervous</td>
<td>Yes - I didn't know how large it was</td>
<td>No</td>
<td>inevaluable</td>
</tr>
<tr>
<td></td>
<td>Yes - it was helpful because it showed me what's to come</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>yes - laying down and seeing the gantry move.</td>
<td></td>
</tr>
<tr>
<td>Q6</td>
<td>No</td>
<td>Yes - I saw rooms they showed me before in the actual tour</td>
<td>LT</td>
<td>F</td>
<td>No</td>
<td>No</td>
<td>Yes - don't need to see the changing room</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q7</td>
<td>No</td>
<td>No</td>
<td>LT</td>
<td>F</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q8</td>
<td>No</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q8.1</td>
<td>The VRT was not as clear as the computer</td>
<td>It made my eye feel some discomfort</td>
<td>LT</td>
<td>F</td>
<td></td>
<td></td>
<td>Some dizziness</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q8.2</td>
<td>Yes</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td></td>
<td></td>
<td>Yes</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q8.3</td>
<td>Nothing</td>
<td>Adjust headset</td>
<td>LT</td>
<td>F</td>
<td></td>
<td></td>
<td>Nothing</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q9</td>
<td>Might</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td>Might</td>
<td>Yes</td>
<td>Might - for younger patients</td>
<td>inevaluable</td>
</tr>
<tr>
<td>Q10</td>
<td>Yes</td>
<td>Yes</td>
<td>LT</td>
<td>F</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>inevaluable</td>
</tr>
</tbody>
</table>
Table 2 Caption – The survey results based on the questions shown in Table 1. Eight subjects completed the tour but only six patients completed the survey. Subjects 3 and 7 did not complete the survey. Subject 7 was approached one day after completing the virtual reality tour and could not recall details of the tour.
The virtual reality tour is delivered with a laptop and headset in a pediatric consultation room. The child life therapist can control video playback from the laptop. The user can virtually look around the room using the headset. The child life therapist describes each scene as the subject experiences them with the headset. The elastic headstraps on the virtual reality headset were not used, thus requiring that the subject held onto the viewer throughout the tour. Subjects were allowed to remove the device if they experienced any discomfort.

Figure 2 caption: The Oculus Rift DK2 headset with a custom nylon cover over the foam face pads. The device was modified by installing a water-proof cover to facilitate cleaning with alcohol solutions. Furthermore, the elastic straps were secured over the front of the device to allow users to wear the device without using the straps.