JMIR Perioperative Medicine

Contents

Original Papers

Original Paper

An Interactive Virtual Reality Tour for Adolescents Receiving Proton Radiation Therapy: Proof-of-Concept Study

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Abstract

Background: Child life therapists provide patient education for children undergoing radiation therapy to assist in coping with and understanding their treatment.

Objective: This proof-of-concept study aimed to determine the feasibility of incorporating a 360-degree video tour via a virtual reality system for children scheduled to receive radiation therapy. The secondary objective was to qualitatively describe each subject's virtual reality experience.

Methods: Children aged ≥13 years scheduled to receive proton radiation therapy were included in the study. Subjects watched the 360-degree video of the radiation therapy facility in an immersive virtual reality environment with a child life therapist experienced in coaching children receiving radiation therapy and completed a survey after the tour.

Results: Eight subjects consented to participate in the study, and six subjects completed the 360-degree video tour and survey. All the enrolled patients completed the 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 tour was helpful preparation before undergoing proton radiation therapy. Subjects stated that the tour was helpful because "it showed [them] what's to come" and 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 360-degree video tour allowed patients to explore the treatment facility in a comfortable environment. Participants felt that the tour was beneficial and would appreciate seeing other parts of the hospital in this manner.

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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 setup and delivery. Radiation therapy protocols are carefully designed to match each 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, whereas 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 the steps 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 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 such as the Oculus Rift is Oculus (Irvine, CA). Oculus released the first consumer device in April 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 for the 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. However, virtual reality has its own set of problems. One of the main limitations of virtual reality is that users may experience dizziness, motion sickness, nausea, or vomiting [12]. 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 was to determine the feasibility of using a virtual reality headset—the Oculus Rift Development Kit—to deliver a 360-degree video 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 360-degree video tour through a virtual reality system.

Methods

Design

This single-site study was conducted in full accordance with all applicable research policies and procedures of the Children's Hospital of Philadelphia, Hospital of the University of Pennsylvania, and Oregon Health & Science University Institutional Research Boards. The study was approved by the Institutional Review Boards in The Children's Hospital of Philadelphia and the Hospital of the University of Pennsylvania. All patients and parents provided informed consent and assent to participate in the study.

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.

Subjects

After the tour, the subjects completed a questionnaire to describe their experience (Table 1). The inclusion criteria for subjects were as follows: proton beam radiation therapy scheduled for the patient, age ≥ 13 years, and English as the primary language. The exclusion criteria were presence of motion sickness, seizure disorder, developmental delay, claustrophobia, cranial incisions with surgical dressings, pain over the scalp or areas that may come in contact with the virtual reality headset, or radiation therapy scheduled to be delivered under general anesthesia. In addition, patients with visual impairment such as diplopia were excluded from enrollment. The virtual reality headset can work with corrective lenses; therefore, 20/20 vision was not a prerequisite. However, children undergoing radiation therapy may have neurologic and ophthalmic conditions that affect vision and may pose a challenge when using a virtual reality system. An interim analysis was performed after three patients completed the protocol, and the protocol was carried out to the conclusion of the study. The trial would have been stopped if two of three 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 successful completion of the 360-degree video tour using the virtual reality system and subsequently, the questionnaire.

The 360-Degree Video Tour and Virtual Reality System

A study member demonstrated the use of the equipment and headset to each subject. The subject then held the virtual reality headset over his/her eyes and experienced the 360-degree video 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 360-degree video playback from a laptop (MacBook Pro, Apple Inc, Cupertino, CA) that allowed pausing and replaying of specific portions of the video. The 360-degree video tour footage included the building entrance, elevators, waiting room, changing rooms, corridors, and proton treatment vault, and the tour was approximately 5-7 minutes in duration. Upon completion of the

360-degree video tour, the subject completed a questionnaire to describe his/her experience.

Equipment

The 360-degree video tour was projected using an Oculus Rift Development Kit 2 (Oculus) and a MacBook Pro (Apple Inc). The Oculus Rift viewer has foam face pads that pose an infection risk. Per the hospital's recommendations for 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-use lint-free cloths.

Table 1. The posttour questionnaire and answer choices. Subjects were approached to complete this questionnaire immediately after the virtual reality tour.

	Question	Answer choices
1	How many times did you pause or stop the video?	0/1/2/3 and why?
2	How many times did you rewind the video?	0/1/2/3 and why?
3	Did you complete the VRT[a]?	Yes/no. If no, why not?
4	Do you think the VRT might help you to prepare to go through proton therapy?	Yes/no/not sure
5	Was there any part of the VRT that was really helpful?	Yes/no. If yes, explain
6	Was there any part of the VRT that was not helpful?	Yes/no. If yes, explain
7	Did you have any other questions about the Proton Therapy Center after watching the VRT?	Yes/no. If yes, what are they?
8	Did you have any discomfort while watching the VRT?	Yes/no
8.1	If yes, what type of discomfort?	N/A[b]
8.2	If yes, did you continue watching?	Yes/no
8.3	What did you do to improve your comfort?	Nothing, adjust headset, pause and resume watching VRT, stopped, or other (_____)
9	Would you like to watch a VRT that is similar to this one for other areas or procedures in the hospital?	Yes/might/no/I don't know/other areas or procedures you would suggest (_____)
10	Would you recommend that others watch the VRT?	Yes/no/not sure

[a]VRT: virtual reality tour.

[b]N/A: Not applicable.

Figure 1. The virtual reality tour is delivered via 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 heads traps on the virtual reality headset were not used. Therefore, the subject had to hold on to the viewer throughout the tour. Subjects were allowed to remove the device if they experienced any discomfort.

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

The video tour was recorded using 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 using Final Cut Pro (Version 10.3.1, Apple Inc). The video was displayed using Kolor Eyes 360 Video Player for Mac, version 1.4.1 (Kolor, Francin, France) [13]. 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 eight subjects consented to participate in the study, and six subjects completed the 360-degree video tour through a virtual reality system (Table 2). Two subjects did not return the survey. Of these, one subject attempted to fill out the survey one day after the tour but had difficulty recalling the details of the tour. All patients who 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 subject paused the tour three times to ask additional questions. Five subjects stated that the 360-degree video tour via a virtual reality system was valuable preparation for proton radiation therapy. Subjects said that the tour was helpful because "it showed [them] 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.

Table 2. Survey results of the questionnaire. Eight subjects completed the 360-degree video 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 360-degree video tour and could not recall details of the tour. All subjects who completed the questionnaire said that they did not have additional questions about the facility after watching the 360-degree video in a virtual reality system. Two subjects experienced some discomfort described as "dizziness" or "eye discomfort" while watching the |tour; the discomfort was resolved by adjusting the headset, and these patients 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 for other areas of the hospital, such as magnetic resonance imaging rooms. None of the subjects experienced nausea or vomiting.

Question	Subject 1	Subject 2	Subject 3[a]	Subject 4	Subject 5	Subject 6	Subject 7[a,b]	Subject 8
1	0	0	LTF[c]	0	1 - to explain what was happening	3 - to talk and ask questions	Unevaluable	0
2	0	0	LTF	0	0	0	Unevaluable	0
3	Yes	Yes	LTF	Yes	Yes	Yes	Unevaluable	Yes
4	Yes	Yes	LTF	Yes	Not sure	Yes	Unevaluable	Yes
5	Yes, it was helpful because it showed me what's to come	Yes, seeing what it's like to lay in the machine	LTF	Yes, it made me less nervous	Yes, I didn't know how large it was	No	Unevaluable	Yes, laying down and seeing the gantry move
6	No	Yes, I saw rooms they showed me before in the actual tour	LTF	No	No	Yes, don't need to see the changing room	Unevaluable	No
7	No	No	LTF	No	No	No	Unevaluable	No
8	No	Yes	LTF	No	No	Yes	Unevaluable	No
8.1	The VRT[d] was not as clear as the computer	It made my eye feel some discomfort	LTF	__e	—	Some dizziness	Unevaluable	—
8.2	Yes	Yes	LTF	—	—	Yes	Unevaluable	—
8.3	Nothing	Adjust headset	LTF			Nothing	Unevaluable	Holding the headset was troublesome
9	Might	Yes	LTF	Might	Yes	Might, for younger patients	Unevaluable	Yes, especially for MRI[f]
10	Yes	Yes	LTF	Yes	Yes	Yes	Unevaluable	Yes

[a]These subjects did not complete the survey.

[b]This subject could not recall details of the tour 1 day after the tour.

[c]LTF: lost to follow-up.

[d]VRT: virtual reality tour.

[e]Not available.

[f]MRI: magnetic resonance imaging.

Discussion

We demonstrated that incorporation of a 360-degree video tour via a virtual reality system into patient orientation to a pediatric proton therapy facility is feasible. The patients who experienced the tour described the experience positively. All patients enrolled were able to complete the 360-degree video tour and used the virtual reality system. The 360-degree video tour and virtual reality system allowed the patients to experience what it is like to lay down in the proton therapy gantry and watch the machine move from a first person's perspective. One patient expressed that "[the 360 degree video tour] made me feel less nervous." Patients, particularly children and adolescents, undergoing radiation therapy may experience anxiety, especially before the treatment begins.

Virtual reality experiences offer 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. One advantage of the configuration described is that the video footage is viewed simultaneously by the patient and the child life therapist. In this context, the child life therapist could coach the patient through the experience and answer questions as they come up. The child life therapist could also see what the child is looking at and answer questions accordingly as well as guide the child's attention to details that

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may have been missed otherwise. Furthermore, the child life therapist had the ability to pause, rewind, and resume the video to allow more time for discussion. In this study, we successfully introduced a 360-degree video tour delivered through a virtual reality system to the child life therapist's education tools in this field and are exploring other applications throughout the hospital.

The 360-degree video tour and virtual reality system provide a unique first-person perspective of the radiation therapy room in a neutral environment. In addition, the tour 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 360-degree video 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 also like to see other parts of the hospital in virtual reality. There are endless possibilities for patient-centered virtual reality-immersing experiences aimed at education, anxiolysis, or analgesia.

The 360-degree video tour was designed specifically for the Roberts Proton Therapy Center at the Perelman Center for Advanced Medicine. One of the limitations we encountered was specific to the device used for the tour. The Oculus Rift DK2 projects a low-resolution image, which appears pixelated. However, the video is not limited to virtual reality viewers, as it is compatible with mobile phones, tablets, and computers. The 360-degree video tour is compatible with most commercially available virtual reality viewers. In this study, we limited the virtual reality tour to patients aged ≥13 years according to the device's manufacturer recommendations. This age limitation is due to the fixed position of the eyepieces and limited range of 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 may potentially see double images. In fact, a group in Toronto has designed the "Childlife VR" application to introduce the operating room to patients and have successfully applied it with younger patients by using a generic Google cardboard viewer [14,15].

Virtual reality viewers such as the Oculus Rift are designed for personal use; thus, they may not translate well to clinical environments or may not meet hospital infectious disease-control specifications. The Oculus Rift DK2 has a foam pad, which 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 cleaning it with hospital-grade disinfectant wipes. Generic single-use devices such as disposable cardboard or paper viewers based on the Google Cardboard model can circumvent the cleaning problem [12]. However, viewers made of corrugated cardboard pose an infectious control risk and do not meet our hospital's requirements.

The device configuration described in this study is time consuming, requires a clean working surface to configure all the necessary equipment, and can take 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 is compatible with any commercially available virtual reality viewer, such as hand-held virtual reality viewers designed for mobile phones or hand-held devices. There are many options available in the market and more will become available. In the meantime, the 360-degree video tour can be delivered via a digital video player such as a computer or tablet in addition to any virtual reality device or 360-degree video player 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 health care, such as assisting health care providers in introducing patients to the hospital setting and therapy areas such as radiation therapy. Portable virtual reality technology is growing rapidly, and its role in healthcare is evolving quickly. This study provides an example of the feasibility of implementing virtual reality in a pediatric clinical setting to supplement child life efforts and dispel the fear of the unknown. Finally, the 360-degree video tour and virtual reality system provide access to a clinical area that is inaccessible to patients due to the high clinical demand and fast-paced schedules. As virtual reality technology continues to evolve, so will health care providers' ability to understand its application and improve the patient experience.

Acknowledgments

Conflicts of Interest

None declared.

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Abbreviations

LTF: lost to follow-up
MRI: magnetic resonance imaging
VRT: virtual reality tour

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Original Paper

Children's Use of and Experiences With a Web-Based Perioperative Preparation Program: Directed Content Analysis

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Abstract

Background: Web-based technology is useful as an alternative means of providing preparation programs to children in pediatric care. To take full advantage of Web-based technology, there is a need to understand how children use and learn from such programs.

Objective: The objective of this study was to analyze children's use of and experiences with a Web-based perioperative preparation program in relation to an educational framework of children's learning.

Methods: This study is the final part of a three-phase study in which all families with children aged 3 to 16 years (N=32) admitted for outpatient surgery over 1 week were asked to participate. Children were interviewed before (phase 1) and after (phase 2) anesthesia and surgery and 1 month after hospitalization (phase 3). The data in this study (phase 3) relate to six children (5 to 13 years) who participated in the follow-up interviews in their homes a month after hospitalization. The study used a directed qualitative interpretative approach. The interviews were conducted in a semistructured manner as the children—without guidance or influence from the interviewer—visited and navigated the actual website. The data were analyzed based on a combination of the transcribed interviews and field notes, and were subjected to a previous theoretical investigation based on children's learning on a website in pediatric care.

Results: Six children, five boys (5-12 years) and one girl (13 years), participated in the follow-up study in their homes a month after hospitalization. The children were selected from the 22 initially interviewed (in phases 1 and 2) to represent a variation of ages and perioperative experiences. The children's use of and experiences with the website could be explained by the predetermined educational themes (in charge of my learning, discover and play, recognize and identify, and getting feedback), but additional aspects associated with children's need for identification, recognition, and feedback were also revealed. The children used the website to get feedback on their own experiences and to interact with and learn from other children.

Conclusions: This analysis of children's use of and experiences with a Web-based preparation program emphasizes the importance of including a theoretical educational framework of children's learning in the development and design of websites in pediatric care. Creating opportunities for Web-based communication with others facing similar experiences and possibilities for receiving feedback from adults are important factors for future consideration.

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Introduction

Background

Millions of children around the world are hospitalized every year for anesthesia and surgery. Many experience preoperative anxiety that negatively affects the individual experience, medical outcome, and relations with health care services in both the short and long term [1-5]. Understanding the perioperative procedures and continuous information and interaction with health care providers decreases distress, increases compliance with medical procedures, improves cooperation with health care providers, and reduces postoperative trauma [6-8]. Despite strong evidence that preparation of children for anesthesia and surgery reduces fear and anxiety [7,9,10], the content, design, and availability of preparation programs vary greatly [10,11]. Many children continue to report a lack of information and are forced to experience the perioperative processes unprepared [12,13]. Web-based technology represents a rapidly expanding alternative with almost unlimited opportunities for development and distribution of preparation programs for children in pediatric care [14-16]. Websites should not just provide information but must also incorporate features that allow for children's need to process information appropriately to understand the content [17-19].

Learning Concepts

The use of Web-based technology as a tool for children's preparation and comprehension of perioperative procedures requires knowledge of how children of different ages learn.

In this study, the learning processes are active construction processes in which the individual's lifeworld forms the basis for their understanding, thinking, and actions [17,19]. Learning involves the whole person using different kinds of information and interactions with people, artifacts, and the environment [19,20]. No one can passively receive understanding and skills from others. Learning is a multifaceted phenomenon that requires processing of information cognitively, emotionally, and socially through testing and practical actions [21,22]. The learning concepts of preunderstanding, motivation, learning processes, and learning outcomes, which were previously used in a theoretical analysis of a Web-based preparation program for children [18], are used in this study to analyze and describe children's approach to a website consisting of a comprehensive, interactive, age-differentiated multimedia Web-based portal aimed to prepare and educate children and their families before pediatric perioperative care (see Multimedia Appendix 1 for further explanation of central learning concepts).

A new learning situation is understood and interpreted based on the learner's preunderstanding, knowledge, experiences, attitudes, and behaviors that the individual has internalized over time. Preunderstanding supports understanding of new things but can also become a hindrance to learning [19,21,23]. Misunderstandings and reactions to something that seems odd, different, or frightening can obstruct the will to consider and learn about the unknown [17]. Motivation is vital to stimulate the start and maintenance of a learning process [17,23-25] and can be triggered by curiosity and experiences of something being fun [26]. Another driving force is when previous

approaches are not working, and new questions that need to be answered and investigated arise [17,23-25]. Motivation is stimulated both by the challenge to master something, as well as by the feeling of succeeding [27]. The essence of the learning process constitutes the individual's processing of information by noticing different data through all senses: by listening, watching, touching, smelling, and tasting. A learner not only receives information, but also reflects, tries out, and relates to previous knowledge and thereby constructs new understanding and abilities [21,22]. Learning processes are meant to result in learning outcomes such as understanding, ability to perform skills, and possibly changed attitudes and behavior depending on the learning situation [17,19,28]. In this case, the learning outcomes are related to children and parents being prepared for hospitalization and, specifically, for anesthesia and surgery. The aim is for the child to understand what is going to happen and be able to cope with the situation. Moreover, it is important that both children and parents experience safety and confidence. Feedback on the learning achievements is important to support the learner's confidence that the message has been understood correctly or to show that the information should be repeated to improve understanding [29,30]. (See Multimedia Appendix 1 for further explanation of central learning concepts.)

Web-Based Technology in Pediatric Care

The age at which children start using the internet is notably earlier nowadays (67% of 2-year-olds) and the proportion who use it daily increases with age (32% at age 2 years, 50% at age 6 years, 75% at age 10 years, and 96% of teenagers) [31]. Web-based information opens up opportunities for reaching children in their natural venues, from their perspectives, and engaging them as part of their own care. Compared to "traditional education materials" Web-based technology can expand the range of things that children can create and in doing so enable them to encounter ideas that were previously not accessible to them [32]. Web-based technology also enables contact with experts and others facing similar health challenges. As a learning tool, Web-based technology allows tailoring of information for individual needs, a private learning environment, and an immediate reinforcement of the learning that has occurred [32-36]. To take advantage of Web-based technology as a learning resource for children in pediatric care, there is a need to understand how children use and learn from Web-based preparation programs. A previous theoretical analysis of a Web-based preparation program related to the central learning concepts of preunderstanding, motivation, learning processes, and learning outcome resulted in four themes (in charge of my learning, discover and play, recognize and identify, and getting feedback) important for children's learning with Web-based technology prior to contact with pediatric care [18].

Objective

The objective of this study was to analyze children's use of and experiences with a Web-based perioperative preparation program in relation to an educational framework of children's learning.

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Methods

Research Approach

A directed qualitative content analysis primarily guided by Hsieh and Shannon [37] was applied to illuminate and explain children's use of and experiences with a Web-based perioperative preparation program. The chosen approach of content analysis applies predetermined variables or concepts to interpret data and is used when existing theoretical and/or empirical knowledge about a subject is judged to enhance the understanding of a certain research question. The aim is to describe common themes characterizing the object being studied. The directed content analysis approach in this study builds on a previous investigation [18] that provided a theoretical basis of children's learning on a website. This approach is judged to be appropriate since the analysis is operationalized based on previous knowledge that would benefit from further refinement or development. To further enhance the understanding of how children learn on a website, the themes from the previous study [18] formed the basis for the directed analysis [18,37,38] in this study. This study comprises descriptions of the manifest, concrete content focused on the visible, obvious components and what the children expressed, as well as interpretations of the meaning of what was said, the latent messages, yet still close to the children's experiences [39,40].

Data Collection

This study is the final part of a three-phase study in which all families with children aged 3 to 16 years (N=32) admitted for outpatient surgery at Astrid Lindgren Children's Hospital in Stockholm, Sweden, during 5 days in February 2015, were asked to participate in interviews on their arrival to the hospital. The request was followed by age-differentiated verbal and written information. The families had visited the preoperative assessment clinic, received information from an anesthesiologist, and were advised to use both written brochure information and the Anaesthesia-Web, the website investigated in this study, a month before admittance. Children were interviewed before (phase 1) and after (phase 2) anesthesia and surgery and again at home 1 month after hospitalization (phase 3).

Both children and parents were informed that consent was negotiable, that it was possible to withdraw at any point, and they were guaranteed that their participation would not affect their care or treatment in any way. Prior to the interviews in the third phase, children and parents received additional verbal and written information and renewed consent was obtained by using forms designed and adapted for children with different cognitive abilities. The first author (GL), who is a nurse specialized in anesthesia and pediatrics with extensive experience with talking with children in the health care context, performed the interviews in all different phases. The study was approved by the Regional Ethical Review Board in Stockholm (2014/309-31/3).

The data in this part of the study (phase 3) relates to six children (ages 5 to 13 years) who participated in the follow-up study in their homes a month after hospitalization. The children were selected from the 22 originally interviewed (in phases 1 and 2)

to represent a variation of ages and perioperative experiences (Figure 1).

To establish a relaxed atmosphere, the meeting in the child's home began with play or an informal conversation about the child's interests and daily activities. The interviews were performed, without any parent present, in a room chosen by the child. The interviews were conducted in a semistructured manner when children visited the website. The children maneuvered the website without guidance or influence from the interviewer. Field notes of the children's actions were taken. The conversation was adapted to the individual child's existing cognitive developmental stage.

To explore the children's experiences and comprehension of perioperative processes in relation to their use of the Web-based preparation program, they were asked to show the interviewer around the website. Children were encouraged to explain the reason for the route chosen in navigating the website, describe the content and context, as well as their positive and negative experiences in relation to what they encountered on the website.

To encourage children to expand on their experiences, they were asked "If you were to tell a friend about hospitalization, anesthesia, and surgery, how would you describe it?" (for children aged 3-6 years), "If one of your friends was about to be operated on, how would you explain about anesthesia and surgery?" (for children aged 7-11 years), or "What was your experience of hospitalization, anesthesia, and surgery?" (for children aged 12 years and older) [41]. The interviews were recorded and transcribed verbatim. Nonverbal communication, such as silences, looks, laughter, posture, and gestures, were also transcribed because these may influence the underlying meaning of responses [42].

Data Analysis

The data were analyzed based on a combination of the transcribed interviews and field notes, which were subjected to directed qualitative content analysis. To ensure trustworthiness [40,43], the analysis of the text was performed in several steps by a research team consisting of three members with extensive knowledge within the areas of pediatrics, anesthesia, medical education, preparation of children for medical procedures, and of designing Web-based information in medical context.

In the first stage of the analysis, the recordings were listened to and the transcripts were read several times by one of the authors (GL) to ensure familiarity with the data and to get a sense of the whole. In the second stage, those parts of the text that appeared to be related to the predetermined themes were highlighted. In the third stage, the predetermined concepts for the children's learning processes on the website were analyzed related to the children's expressions, experiences, and use of the website during the interviews. Data that could not be related primarily to the predetermined themes were identified and saved. The data were interpreted to elucidate additional dimensions of children's experiences and usage of the website. The interpretations were compared with the predetermined themes and described as a new theme. To ensure confirmability, each theme was linked to the data by quotations from children. The research team continuously reviewed the data to ensure that the

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analysis accurately reflected the children's statements and performance on the website and to validate the predetermined themes reconciling any differences using the theoretical framework.

Predetermined Themes

The predetermined themes applied in the directed content analysis were derived from the theoretical educational analysis of a Web-based preparation program, the Anaesthesia-Web [18]. The Anaesthesia-Web represents a comprehensive, interactive, age-differentiated multimedia Web-based portal that prepares and educates children and their families before pediatric perioperative care. The analysis related to central concepts for children's learning processes on the Anaesthesia-Web resulted in the following themes: (1) in charge of my learning, (2) discover and play, (3) recognize and identify, and (4) getting feedback [18]. The correspondence between the concepts and the themes is presented in Figure 2.

Figure 1. Overview of the participants and interviews conducted in the three-phase study.
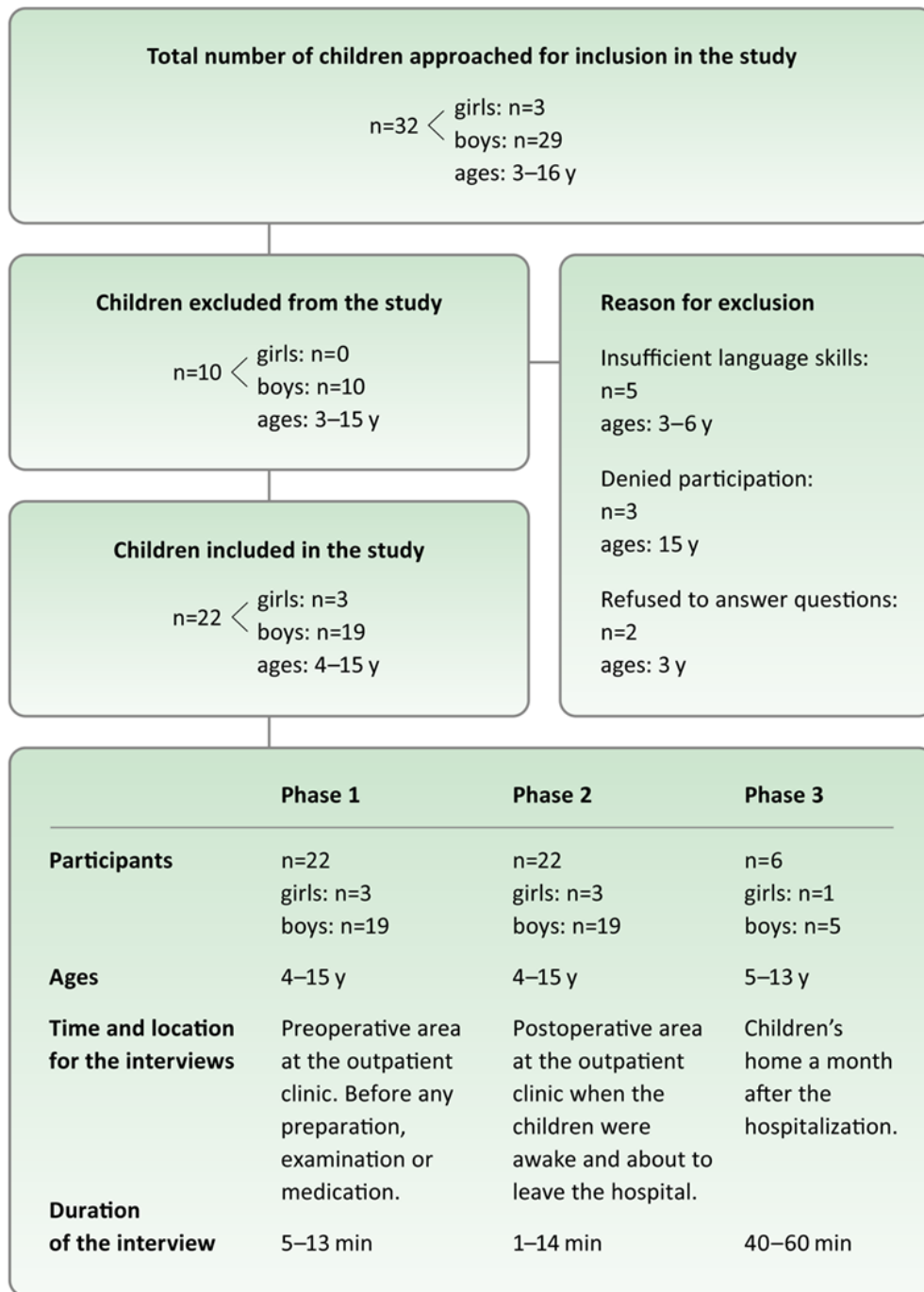
Figure 2. Predetermined themes related to children's learning processes on the Anaesthesia-Web applied in the directed content analysis [18].

In charge of my own learning	Discover and play	To recognize and identify	Feedback
Preunderstanding	Motivation	Preunderstanding	Motivation
Motivation	Learning process	Motivation	Learning outcome
		Learning process	

Theme 1: In Charge of My Learning

The diversity and design of the website offer the visitors individual choice of how to enter and use the program. Children are in control and can use the website based on their varied backgrounds, abilities, and what they think is interesting and meaningful. This is important for motivation and each child's individual preunderstanding.

Theme 2: Discover and Play

The content on the website is mediated by playful interactive elements to stimulate the children's natural curiosity, creativity, knowledge seeking, and motivation—factors which are crucial to initiate and maintain the learning process. Through discovery and play, children can receive, process, and apply information cognitively, emotionally, and by active participation. Interactive parts of the website enable children to explore the hospital environment, prepare for upcoming events, and process any previous experiences.

By providing children with tools to help them understand and manage procedures, they may be able to relate simulated performances on the website with their perioperative expectations and experiences.

Theme 3: Recognize and Identify

On the website, children can recognize situations and feelings, interact with a diversity of characters, and find someone with whom to identify. They can also recognize and identify themselves as a person needing to learn and prepare before hospitalization. Recognition and identification are important factors to experience the visit as meaningful and to maintain the motivation to learn.

Theme 4: Getting Feedback

The website offers children opportunities to get feedback, which is crucial for keeping up the motivation to learn and is necessary to judge the learning achievements, confirm understanding, and the need for repetition. On the website, children get immediate feedback on their performance and progress with acknowledgment for achievements and performances. This increases motivation and concentration and stimulates the learning process.

Results

Overview

These results are from the last part of the three-phase study. Six children were selected from the 22 originally interviewed in phases 1 and 2, five boys (5-12 years) and one girl (13 years), and they were interviewed in their homes 1 month after hospitalization.

Children's use of the website could be described through the predetermined educational themes on which the analysis was based. The analysis also clearly revealed a new theme: interaction with other children. This theme describes a dimension of recognition and feedback in which children's interactions with other visitors on the notice boards came to the fore as important.

Theme 1: In Charge of My Learning

Children's entrance into the multimedia on the Anaesthesia-Web was based on individual choices characterized by a nonsystematic search to get an overview of the structure and content. Without instructions, the children surfed around the website. Independent of routes and choices taken on the website, they finally made individual choices and returned to parts they wanted to explore further. Characteristic of the children's visits was an expressed desire to understand and cope with experiences from the hospitalization. The timeframe in which children stayed at the respective sections of the website differed depending on interest and experience. Parts of the website that caught the children's interest were characterized by both long and recurring visits, triggering them to challenge their experienced fear, find answers to questions, and test their existing knowledge: "I want to go back to the film showing the bowels from the inside. Maybe I can find out why I have been in such pain when I understand how it looks inside me" (boy, 10 years). It was also obvious that the children choose different approaches for understanding the same problem: "First I learned about the intravenous needle by watching the film but since I want to find out more I also want to read about it and try doing it myself" (boy, 12 years).

In their individual choices of how to receive the information, the children used the open access of the website: "I am actually 12 years old but I think 13+ is best for me since I have been hospitalized before" (boy, 12 years). The children's interest was captured by colors, sounds, and movement. The interactive parts of the website were described as fun, curious, and triggered the children's motivation for exploration: "I am sure you can learn a lot on the reading part, but the interactive parts seem more fun since you can do things yourself there" (boy, 9 years). The children's choices also reflected how their actual cognitive stage was affected by the situation: "Normally, I remember and learn best by reading, but in this special situation I think it's better

for me to receive information aimed for younger children" (girl, 13 years).

The children's choices on the website reflected their desire to take command of decisions and actions. In the interactive operating room, the children recognized and discussed the frightening environment, furnishing, and technical equipment: "I wish I had my own operating room where I could decide and do what I want" (boy, 10 years). Based on individual choices and desires, they created their own operating room and suggested arrangements on how to decrease fears and make these surroundings suit children better. In the role play, the children took command over the selection of characters and roles: "I want to operate on the doctor. If he gets scared and starts to cry, I will just continue and say: you have to lie still, we have to do this, and this is not so dangerous?" (boy 5 years). The children's choices of characters for the patient's roles were similar to themselves in regard to age, diagnosis, procedures, and surgical interventions: "I want to play with a child with problems and pain from the same part of the body as mine" (boy, 9 years). The nurses and doctors for the role play were selected based on personalities "I think it is important that all nurses are happy and friendly" (boy, 5 years) and capabilities "Because there is a risk that older people may be a bit shaky in the hands, it is safest to choose a young surgeon" (boy, 10 years).

As the children were interacting on the website, they discussed and confirmed their own positive and negative experiences and proposed changes for the perioperative processes. Based on their own preunderstanding and the available content on the website, the children also expressed how and what parts of the website could be resources for other children's preparation for perioperative processes: "The Anaesthesia-Web resembles the reality and you can decide yourself what to do. All children should visit the website to decrease their fears before admission to the hospital" (boy 12 years).

Theme 2: Discover and Play

The interactive parts of the website were popular and the most visited by all children. With the interactive elements, the children explored the hospital environment and perioperative processes and compared them to what they had understood and remembered from their own visit. With great enthusiasm, they discovered the playful interactive parts simultaneously as they described what they were doing and the reason for their actions. It was also obvious that the playful and interactive parts of the website were important for the children's processing of events and a useful tool in their description and explanation to others about procedures. The children created personal patches and bandages and decorated and furnished the interactive operating room to their own desire and taste. Based on their impressions of the hospital environment as cold, rigid, and with boring furnishing, they created their "dream hospital" (boy, 9 years). They painted the walls and floors in the operating room with strong and bright colors because "it would be less frightening for children going in to the operating room if the surroundings were more colorful" (girl, 13 years), and with a camouflaged pattern because "in films there are always blood on the walls and floors in the operating room" (boy, 10 years). When the

children played, they chose a comfortable and soft operating table and a less hospital-like operating lamp, which both could be maneuvered by them.

The children's play was permeated by practical applications of their own experiences of undergoing treatments and procedures. They drew many and long marks on the patients to be operated on. They also argued the need for several intravenous accesses, which would need innumerable attempts for insertion. They confirmed the need for procedures and convinced themselves it would be less painful and frightening than expected. During the practical exercises, they identified events and put words on concepts and objects: "It's so much easier to understand how things work when you've tested yourself" (boy, 9 years).

When the children were playing on the website, their need to understand the procedures surrounding the insertion and use of the intravenous needle was prominent: "The use of the local anesthetic cream will make it less painful and, look carefully, I remove the needle and throw it away, it is only a small plastic hose remaining which does not hurt at all" (boy, 11 years).

When playing with the anesthesia machine and the monitors, the children related the anatomical and physiological conditions to the measurement values and suggested a possible need for action: "You'd better take deep breaths to get more oxygen in the lungs when the saturation is low" (boy, 11 years). The children's curiosity about body functions and how body parts and organs are related to one another were also prominent when they were playing games on the website. Without any signs of being bored, the children used puzzles and games on the website to try to find out about the body, illness, and treatments.

Theme 3: Recognize and Identify

After the children's initial tour around the website, their individual choices focused in on what they could identify and recognize from their own hospitalization. The children recognized the hospital environment, technical equipment, and procedures: "The website is very similar to the hospital and everything that happens there. Yes, it is almost as the reality" (boy, 9 years). Confirmed was also the website's reliability: "The website tells you how it will be at the hospital. You will get to know if it will be as painful as expected and be assured that everything will work out well" (boy, 12 years). It was also obvious that orders of procedures were noticed and that these were important for the children's identification and recognition: "Everything that happened to the children on the website also happened to me, exactly in the same order" (girl, 13 years). Adjustments to processes were another factor children recognized and expressed as important: "My mother was also allowed to be with me when I was anesthetized, but she had to wait for me outside during the operation, that's the rules" (boy, 9 years).

The children identified and recognized preoperative orders "The clown is not allowed to eat any breakfast on the day of surgery, but maybe she can drink some clear liquid" (boy, 9 years) and frightening and painful procedures "It will hurt very, very much for the clown to get an intravenous access, I can see how scared she is" (boy, 5 years). The children identified their own symptoms, discussed possible investigations and treatments,

and compared these to the medical conditions of the characters on the website: "I can exactly recognize the sour taste coming in the throat from the stomach. Maybe there is a need of an examination and some medication for this child" (boy, 10 years). They also identified their own medical condition and experiences in relation to the health care providers: "Think if the doctor had a problem with peeing, had to get a urine catheter and maybe operated on" (boy, 5 years). With help of the website's key feature, Hilding Vilding, the children were able to recognize and identify fears and worries simultaneously as reflecting their experiences to someone always doing worse: "Hilding Vilding is doing what you are not allowed to at the hospital and he is afraid of needles as me" (boy, 5 years).

Theme 4: Getting Feedback

The different opportunities for the children to receive feedback on the website were expressed as the most important to confirm their experiences and understanding, and expand and judge their learning. By receiving feedback, the children were given opportunities to apply ideas, correct and learn from errors, improve performance, and achieve goals. The children appreciated the help from the website's main feature, Doctor Safeweb, to receive feedback on quizzes, games, and frequently asked questions, but they also sometimes found his personality disturbing: "Lucky you can choose to turn off his voice in the background when he gets too nagging" (boy, 10 years). They also highlighted the importance of having different levels of the challenges and frequent opportunities to apply their ideas: "It is fun when I can test how much I understand and have learned in different ways on the website" (boy, 11 years). When the children were testing their knowledge in games and quizzes, they were triggered and motivated to continue when they received immediate answers, and their progress was visible in any way. The children showed impatience and continued to other parts of the website when the content and layout did not catch their attention or when the feedback was slow: "I like the short films when you quickly get to know how it goes and do not have to wait for the answer" (boy, 10 years).

Theme 5: Interaction With Other Children

The children's identification with others in the same situation was prominent when they were visiting the notice board. Children appreciated being able to chat, ask questions, and receive answers from others: "It feels good to know how and what others felt, thought, and wondered" (boy, 11 years). They confirmed that many of the children writing on the notice board shared their own experience of being uninformed, having many questions, and being afraid of what to expect at the hospital. They highlighted the importance for these children to receive information before their admission because it had been crucial for their own preparation. When the children were reading other children's notes, they were concerned that many questions remained unanswered: "It must be such a terrible feeling to be afraid and not having their fears addressed" (girl, 13 years). Prominent in the children's identification with other visitors was also their recognition of how previous medical experience did not protect them from being afraid. On the contrary, it often meant the opposite: "I know exactly how they feel. To know

what to expect also makes me even more nervous" (boy, 12 years).

The children used all opportunities for feedback on the website: they not only received feedback but they were also giving feedback on the notice board to other children's questions and concerns. Advice on how best to relate to events and procedures was frequently exchanged with other visitors. Based on identification and recognition of their own experienced fear, the children wrote advice in the notes as they verbally expressed how to best prepare for and handle events to reduce stress and anxiety during the hospitalization: "It is normal and legitimate to be afraid for being hospitalized, but believe me you don't have to be frightened, they have total control" (boy, 11 years). The children also identified with and replied to commonly asked questions from children on the notice board function of the website. Of special concern was the fear of the intravenous access "The local anesthetic cream works very well so it will not be painful at all to get the intravenous access" (boy, 12 years) and for anesthesia and painful procedures "You will fall asleep very fast and not experience any pain at all during the surgery since the nerves will be anesthetized by the sleeping medication" (girl, 13 years). The children also identified and replied to questions associated with the postoperative procedures: "It is normal to have pain after surgery, but you don't have to be afraid. Just relax and take some painkillers, it will help" (boy, 11 years).

Discussion

The goal of this study was to provide theoretical and empirical knowledge as a basis for the design and development of websites for children's learning in pediatric care. Such websites should not just provide information, but should also stimulate learning. This analysis shows how this could be achieved.

The themes derived from a previous theoretical analysis of a website [18] were recognized in the children's use of the website in this study. In particular, the themes "in charge of my learning" and "discover and play" corresponded well with the theoretical educational assumptions of the design and the children's use and behavior. Correspondence was also found with the predetermined themes "recognize and identify" and "getting feedback." In addition to these themes, aspects which appeared as significant for children's needs and interest in processing experiences and information related to the perioperative processes came to the fore. To capture these aspects of learning and to highlight the importance of children's needs for interaction with others facing similar experiences, the additional theme "interaction with other children" highlights an important part for consideration in the development of websites in pediatric care.

The interpretations of the children's statements and actions when using the website revealed how they took advantage of all available opportunities in making their own choices to manage their experiences from the hospitalization. This is consistent with results from previous studies about children's engagement on websites with open content and possibilities for choices [33]. The different possibilities for them to be in charge of their own learning were shown as important driving forces

both to start and proceed with their search for learning. To consider assumptions about the significance of preunderstanding and motivation in children's learning processes thus seem to be important factors in the design of websites in pediatric care. Preunderstanding is significant for learning as it constitutes the base for interpretations, thoughts, and understanding of new experiences [19,21]. The development of Web-based learning opportunities for children in pediatric care thus should be designed including prerequisites for individual interactions by using complementary multimedia and sensorial features to offer children a choice of interfaces. In addition, the child should be offered control to stimulate triggers for their learning activities. This can be achieved by offering free access to the diversity of multimedia to choose when, how, and what information to receive [18].

A large proportion of the time the children spent on the website was related to play and discovery both to confirm and process experiences and to stimulate their curiosity to find out and learn new things related to their body, perioperative processes, and the hospital environment. By playing the different roles of the professionals, in a virtual reality, children were exposed to and learned about the setting itself as they played and interacted. As the children were playing, they verbally expressed and explained what they were doing and the reasons for their actions.

Creating possibilities for play and interactive participation is known to be of key importance in the development of Web-based learning opportunities for children [18,33,35]. This was confirmed in this study where it was obvious that children virtually can prepare for and process experiences by practicing skills and procedures. With the help of Web-based technology, children can be exposed to and learn about the surroundings and procedures that would otherwise be inaccessible for them [32].

Opportunities for choices and creativity are known to be important for children's learning [33]. Thus, we would highlight the importance of combining possibilities for children to discover and play with possibilities to be in charge of their learning. To stimulate and maintain motivation through children's curiosity and knowledge seeking, the content and design of websites in pediatric care should be developed to be filled with fun and excitement to explore [33]. With the use of creative tools involving all senses, children can be given opportunities for interactive imaginative expressions to increase interest and engagement as a base for their learning processes [21].

Children's need for identification and recognition were prominent when they were using the website. They interacted with the diversity of characters and perioperative procedures on the website and displayed ability and a need to express, engage in, and compare to their own experiences. It seems these interactions helped them challenge their fears and legitimize their own worries and need for help as well as to keep up their motivation to understand and learn more. To optimize children's prerequisites for identification and recognition, they should have the ability on websites in pediatric care to interact both with common procedures and with a diversity of characters. It is also important to include opportunities for children to recognize the emotional aspects they may experience in hospital [14,15].

The website's different opportunities for feedback on the processes and performances emerged as central to help the children understand what was going to happen and to experience safety and confidence. The children used the available chances to correct, learn from errors, and improve performances. By using different levels of challenges and frequent opportunities to apply ideas, they strived to receive feedback on actions taken on the website. Therefore, feedback received on the website constituted an important factor in confirming the children's experiences and learning outcomes and in keeping up their focus and motivation [29,30,34]. Yet, the feedback the children received on the website was mainly related to their understanding of the perioperative processes, and not individual feedback on their experience and emotions. The additional theme connected to the children's need for identification, recognition, and feedback that appeared in the analysis is connected to this need for individual feedback. The notice board, which gave the children access to other children's experiences, resulted in deep concerns and engagement. The children's usage of the website to not only receive feedback on their own experiences but to also interact and give feedback on other visitor's questions and concerns emerged as very important. It was obvious that the children had a need for access to a platform where they could identify, interact, and learn from other children's perspectives. In turn, that led to increased motivation to reflect on and learn about their own situation.

The results from this study showed that children's use of and experiences with a website such as this can be explained through the educational themes defined in a previous theoretical analysis [18]. The study also reveals new aspects that need to be taken into consideration and further developed when designing Web-based learning opportunities in pediatric care. The children used the different opportunities for receiving feedback on the website, but it was obvious that this area constitutes a vulnerable and challenging part in the configuration of websites in pediatric care. Careful consideration has to be taken when the learning aims for the child are to be prepared for situations filled with unfamiliar and emotional components. In addition, this learning process mostly takes place at home where the possibility of correction of misunderstandings and inaccuracies cannot be taken for granted. The results of the children's learning outcome will not be obvious until the day of admission at the hospital.

During the children's performances and use of the website, it was evident that their processing of experiences and gathering of information included both interactive actions and verbal reasoning about feelings and experiences. The opportunity for children to reflect on their experiences to an adult constituted an important component in their processing of experiences and continuation of learning processes on the website. In this case, the researcher represented the adult connection. Without controlling or affecting their children's ability to be in charge of their own learning, parents should visit the website together with their child sometimes. In addition, we would suggest future development of websites within pediatric care to consider possibilities for children to chat and receive feedback on questions and concerns direct from medical professionals.

This analysis of children's use and experiences of a Web-based perioperative preparation program emphasizes the importance of including the central learning concepts of preunderstanding, motivation, learning processes, and learning outcome in the development and design of websites in pediatric care [18]. Creating opportunities for Web-based communication with others facing similar experiences and possibilities for receiving feedback from adults constitute additional inclusive factors for consideration.

Although this study was aimed to be carefully prepared and accomplished, some methodological limitations need to be highlighted and discussed. The choice of learning theories and the assumptions about learning they mirror will influence the analysis and the result. The theoretical educational framework directs the attention of the researchers in the analysis process and also permeates the interpretations. To ensure trustworthiness, the theoretical educational framework are described in detail (see Multimedia Appendix 1) and applied systematically [43] by an experienced multidisciplinary group. The research process and context have been thoroughly described to enable researchers and other readers to transfer the results to other contexts. One limitation in this study was that the children were recruited from the same health care setting, were relatively healthy, and undergoing routine surgeries.

Another limitation was the imbalance of gender, which is explained by the type of surgeries performed during the week of data collection. Although the number of participants was small, the configuration of the study provided continuity of children's experiences which, in combination with the qualitative approach, provided deep insights into the children's perspectives.

This analysis of children's use of and experiences with a Web-based perioperative preparation program shows the significance of including a theoretical educational framework of children's learning in the development and design of websites in pediatric care. In this study, the central learning concepts of preunderstanding, motivation, learning processes, and learning outcome represented a useful general educational level of inquiring into children's learning using a website. The most important characteristics supporting children's learning were found to be in charge of my learning, discover and play, recognize and identify, getting feedback, and to be in interaction with other children. The last theme emphasizes that creating opportunities for Web-based communication with others facing similar experiences and possibilities for receiving feedback from adults have to be carefully considered in the future development of websites preparing children for perioperative care.

Conflicts of Interest

The first author (GL) is the developer of the Anaesthesia-Web and is currently the owner of the nonprofit website. The other authors have no conflicts to declare.

Multimedia Appendix 1
Learning concepts.
[PDF File (Adobe PDF File), 203KB - periop_v2i1e13565_app1.pdf]

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Original Paper

The Trendelenburg Position and Cognitive Decline: A Case-Control Interventional Study Involving Healthy Volunteers

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Abstract

Background: Postoperative cognitive decline (POCD) is defined as a new cognitive impairment arising after a surgical intervention. Aspects of cognitive function can be assessed using various validated cognitive function tests including the N-back task, the Stroop task, and the lexical decision-making task (LDT). There is some concern that prolonged Trendelenburg positioning during laparoscopic colorectal surgery may cause POCD.

Objective: The objective of this study was to assess the effect of time spent in the Trendelenburg position on cognitive function.

Methods: Volunteers were placed in the Trendelenburg position for 3 hours and, then, supine for 30 minutes. Validated cognitive function tests including 1-, 2-, and 3-back tasks, Stroop test, and LDT were performed at baseline and every 30 minutes after Trendelenburg positioning. Cognitive decline was defined per the International Study of Postoperative Cognitive Dysfunction trial: a decrease in accuracy from the volunteers' baseline or an increase in response time from the volunteers' baseline by >2 control group SDs.

Results: We recruited 15 healthy volunteers (8 males, 7 females) with an average age of 69 years (range 57-81) and average body mass index of 27.7 kg/m^2 (range 20.9-33). Accuracy remained within 2 SDs at all time points. An increase in response time did occur, and of 15 participants, 3 (20%) showed cognitive decline in the Trendelenburg position after 30 minutes, 4 (27%) after 1 hour, 5 (33%) after 90 minutes, 4 (27%) after 120 and 150 minutes, and 6 (40%) after 180 minutes. On moving to a supine position, 33% (5/15) participants showed cognitive decline.

Conclusions: The results of this study indicate that Trendelenburg positioning leads to cognitive decline. This may have implications for patients undergoing prolonged Trendelenburg positioning during laparoscopic colorectal surgery.

Introduction

Impairment of cognitive function following surgery has been recognized since the 1950s. Postoperative cognitive decline (POCD) is defined as a new cognitive impairment arising after a surgical intervention [1]. It is a subtle disorder of thought processes, which may influence isolated domains of cognition such as verbal memory, visual memory, language comprehension, visuospatial abstraction, attention, or concentration [2]. POCD can lead to increased hospital stay,

higher readmission rates, impairment of daily functioning, delayed return to work or normal level of functioning, and dependency on government economic assistance post discharge from hospital [3]. It can affect patients at any age but was shown to have a longer and more significant effect on daily life activities and return to work in patients aged >60 years.

Trendelenburg positioning is commonly used during laparoscopic colorectal surgery to allow the use of gravity to move the small bowel out of the pelvis and provide the surgeon with adequate view. The degree of tilt and time spent in these

positions vary depending on the type of resection and complexity of the case. The gravitational effect of the Trendelenburg position is thought to divert blood away from lower extremities and increase central blood volume [4]. This increases cerebral blood flow and intracranial pressure by impairing venous outflow from the brain, increasing hydrostatic pressure within the cerebral vasculature and pushing fluid into the extracellular spaces. After being in a steep Trendelenburg position for a prolonged period, significant cerebral perivascular edema can develop. All of these can cause impaired cerebral perfusion and cerebral edema [5]. If significant cerebral perivascular edema develops, the effective cerebral perfusion may get significantly reduced [6], resulting in impaired tissue oxygenation and leading to cognitive decline [7]. This effect is likely to be exacerbated if a pneumoperitoneum is used, which would further increase central venous pressure.

The N-back task is used as a measure of working memory and executive function [8]. It is favored because the ability to change the value of "N" gives researchers a reliable way of altering the processing load of the task [9]. The Stroop test provides a paradigm case of attention and inhibition. The Stroop effect is recognized as the inclination to say the word presented rather than the color that it appears in. A delay in response is usually seen when the color of the word does not match the meaning of the word (an "incongruent stimulus") [10-12]. Lexical decision-making task (LDT) primarily tests the language aspect of cognitive function. Executive functions (decision making) are also tested in this task because a quick decision must be made as to whether the letters form a word or not [13]. The aim of this study was to assess the effect of the amount of time spent in the Trendelenburg position on cognitive function.

Methods

Ethics Approval

This case-controlled interventional study involving healthy volunteers was reviewed and approved by the University of Nottingham Research Ethics Committee (reference #: N14082014 SoM GI Surgery NDDC).

Recruitment

We recruited healthy volunteers aged >18 years. Volunteers with pre-existing cognitive impairment (either a pre-existing diagnosis of dementia or poor performance in baseline tests), smokers, those unable to read or understand English, those with visual impairment, or those who refused to give written informed consent were excluded from our study.

After practicing each test 3 times (to allow for the learning effect of repeated tests), a baseline performance for each cognitive function task was recorded while sitting for 1-back, 2-back, and 3-back task; Stroop test; and LDT.

The volunteers were then placed in the Trendelenburg position at 17° head-down for 3 hours, moved to supine position for 1 hour, and then asked to sit up. The above tests were then repeated after 30 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours (volunteers were moved to supine position after 3 hours, so these tests were performed immediately after volunteers moved to supine position), 3.5 hours, and 4 hours (after 4 hours, the volunteers were asked to sit up in a chair, and the tests were performed immediately after they sat up; Figure 1). Between 90 minutes and 2 hours, 5 of the volunteers took a "toilet break." The duration of toilet breaks ranged between 2.5 minutes and 4.8 minutes including walking to and from the toilet. This break was unavoidable because our volunteers were awake.

Figure 1. Flow diagram of position changes during the study. LDT: lexical decision-making task.
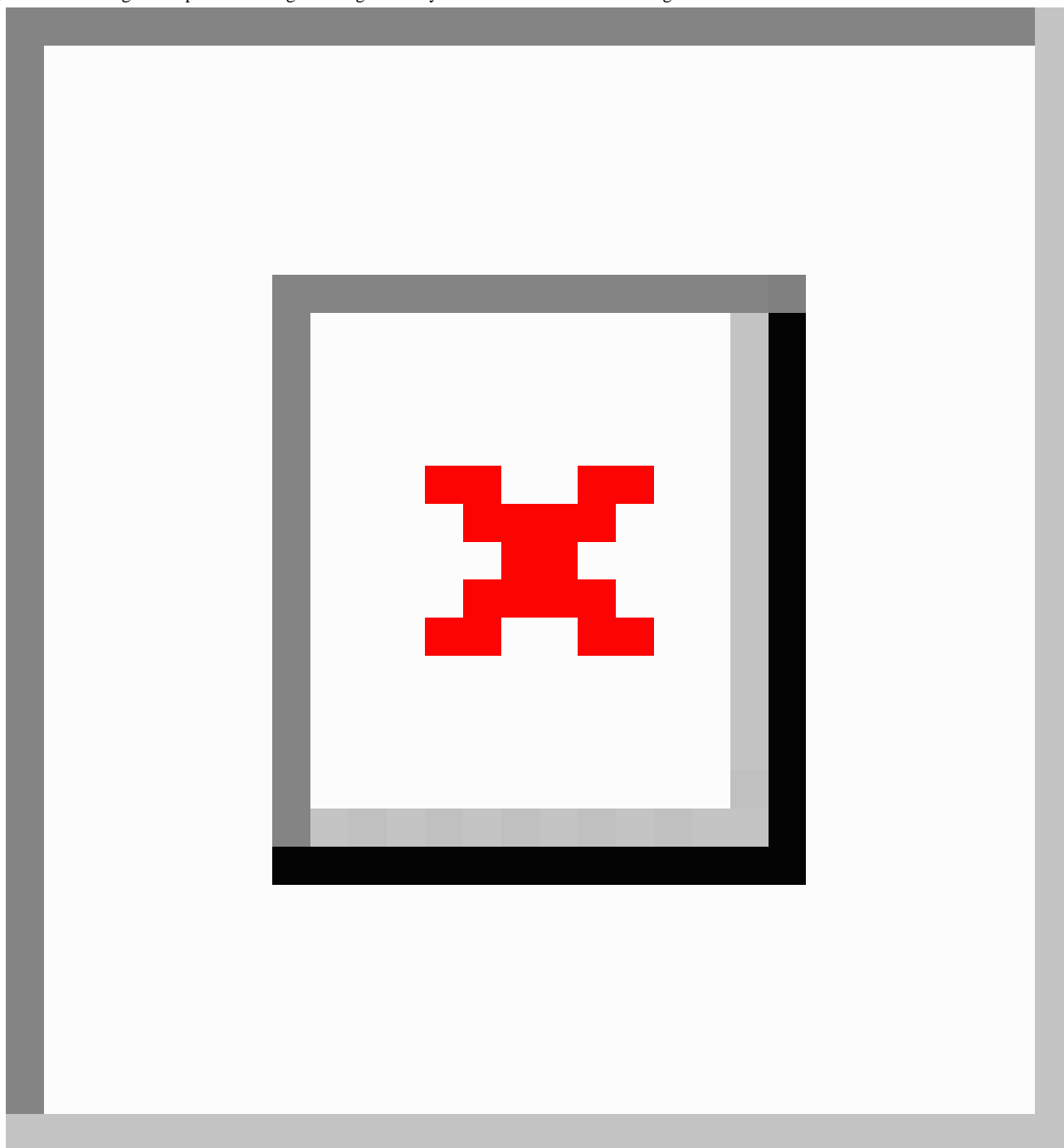
Control Data

To allow for the continued learning effect that may mask the cognitive decline, a control group was recruited to provide control data for analysis. Accordingly, 5 volunteers repeated each test 4 times. Each test was analyzed individually, and the mean and SD values were calculated for a change in both accuracy and response time (RT) between the third and fourth attempt of the tests. The mean change was taken to represent the learning effect for the tests, which is known to occur when the same tasks are repeated multiple times.

Statistical Analysis

Power

A statistical power analysis was performed for sample size estimation based on data from Brookes et al who compared the effect of increased task difficulty on magnetoencephalography activity. They detected a mean accuracy of 98% (SD 2%) for the 1-back task and 91% (SD 8%) for the 2-back test. With an alpha of .05 and power of 0.80, the projected sample size needed with this effect size (STATA 14.0) was n=10 [14]. We, therefore, chose to recruit 15 volunteers to our study.

A repeated measures analysis was performed to compare the change in accuracy and RT at each time point. For each volunteer, the accuracy and RT at each time point was subtracted

from their own baseline results. A repeated measures test was then performed using STATA.

To assess the percentage of volunteers who suffered cognitive decline from their own baseline performance, the International Study of Postoperative Cognitive Dysfunction (ISPOCD) definition was used [15]. The baseline for the volunteers was subtracted from their own results at each time point; furthermore, the learning effect was also subtracted from this change in "test score". This result was then divided by the SD of the control group to give a Z score. A large positive Z score (z>1.96) showed a deterioration in cognitive function from baseline for accuracy, and a large negative Z score (z<−1.96) showed the same for RT [16]. This, therefore, allowed each time point to be compared directly to the volunteer's own baseline performance. Therefore, any decline in performance indicated a decline from the volunteer's own baseline performance.

Results

A total of 15 healthy volunteers (8 males and 7 females) completed the study. The average age of the participants was 69 (SD 6.98) years and average body mass index was 27.7 (SD 3.4) kg/m^2. Tables 1 and 2 show the results of repeated measures analysis of the change in accuracy and RT from the volunteers' own baseline, respectively. The percentage of volunteers with cognitive decline from their baseline was analyzed (Table 3).

Figure 2 shows the overall percentage of volunteers who demonstrated cognitive decline at each time point compared to those who did not show a significant change in their cognitive function from baseline in the tests as per the ISPOCD trial definition of cognitive decline.

Table 1. Repeated measures analysis of change in accuracy from volunteer's baseline for each time point.

| Time point	Event	Accuracy, mean change from baseline (95% CI)	P value
2	30 minutes after Trendelenburg positioning	−0.04 (−0.072 to 0.001)	.06
3	60 minutes after Trendelenburg positioning	-0.01 (−0.05 to 0.03)	.66
4	90 minutes after Trendelenburg positioning	0.01 (−0.03 to 0.05)	.67
5	120 minutes after Trendelenburg positioning	0.02 (−0.02 to 0.05)	.44
6	150 minutes after Trendelenburg positioning	0.002 (−0.35 to 0.04)	.91
7	Supine (after 180 minutes in the Trendelenburg position)	0.02 (−0.01 to 0.06)	.20
8	30 minutes after supine positioning	0.01 (−0.03 to 0.04)	.82
9	Sitting up (60 minutes after supine positioning)	0.02 (−0.02, 0.06)	.29

Table 2. Repeated measures analysis of the change in response time from baseline for each time point.

Time point	Event	Accuracy, mean change from baseline (95% CI)	P value
2	30 minutes after Trendelenburg positioning	−0.04 (−0.11 to 0.04)	.34
3	60 minutes after Trendelenburg positioning	−0.08 (−0.16 to 0.01)	.03
4	90 minutes after Trendelenburg positioning	−0.11 (−0.18 to −0.03)	.004
5	120 minutes after Trendelenburg positioning	−0.15 (−0.22 to −0.07)	<.001
6	150 minutes after Trendelenburg positioning	−0.14 (−0.22 to −0.07)	<.001
7	Supine (after 180 minutes in the Trendelenburg position)	−0.19 (−0.26 to −0.11)	<.001
8	30 minutes after supine positioning	−0.15 (−0.22 to −0.7)	<.001
9	Sitting up (60 minutes after supine positioning)	−0.16 (−0.23 to −0.08)	<.001

Table 3. Average response time to tests at each time point with the percentage of volunteers with cognitive decline from their own baseline (N=15).

Time point	Event	Volunteers with normal cognitive function, n (%)	Volunteers with cognitive decline, n (%)
2	30 minutes after Trendelenburg positioning	12 (80)	3 (20)
3	60 minutes after Trendelenburg positioning	11 (73)	4 (27)
4	90 minutes after Trendelenburg positioning	10 (67)	5 (33)
5	120 minutes after Trendelenburg positioning	11 (73)	4 (27)
6	150 minutes after Trendelenburg positioning	11 (73)	4 (27)
7	Supine (after 180 minutes in the Trendelenburg position)	9 (60)	6 (40)
8	30 minutes after supine positioning	10 (67)	5 (33)
9	Sitting up (60 minutes after supine positioning)	9 (60)	6 (40)

Figure 2. Percentage of volunteers with cognitive decline at each time point. 1: Trendelenburg 30 minutes; 2: Trendelenburg 60 minutes; 3: Trendelenburg 90 minutes; 4: Trendelenburg 120 minutes; 5: Trendelenburg 150 minutes; 6: Trendelenburg 180 minutes or supine 0 minutes; 7: Supine 30 minutes; 8: Supine 60 minutes or volunteer sat up. CD: cognitive decline.
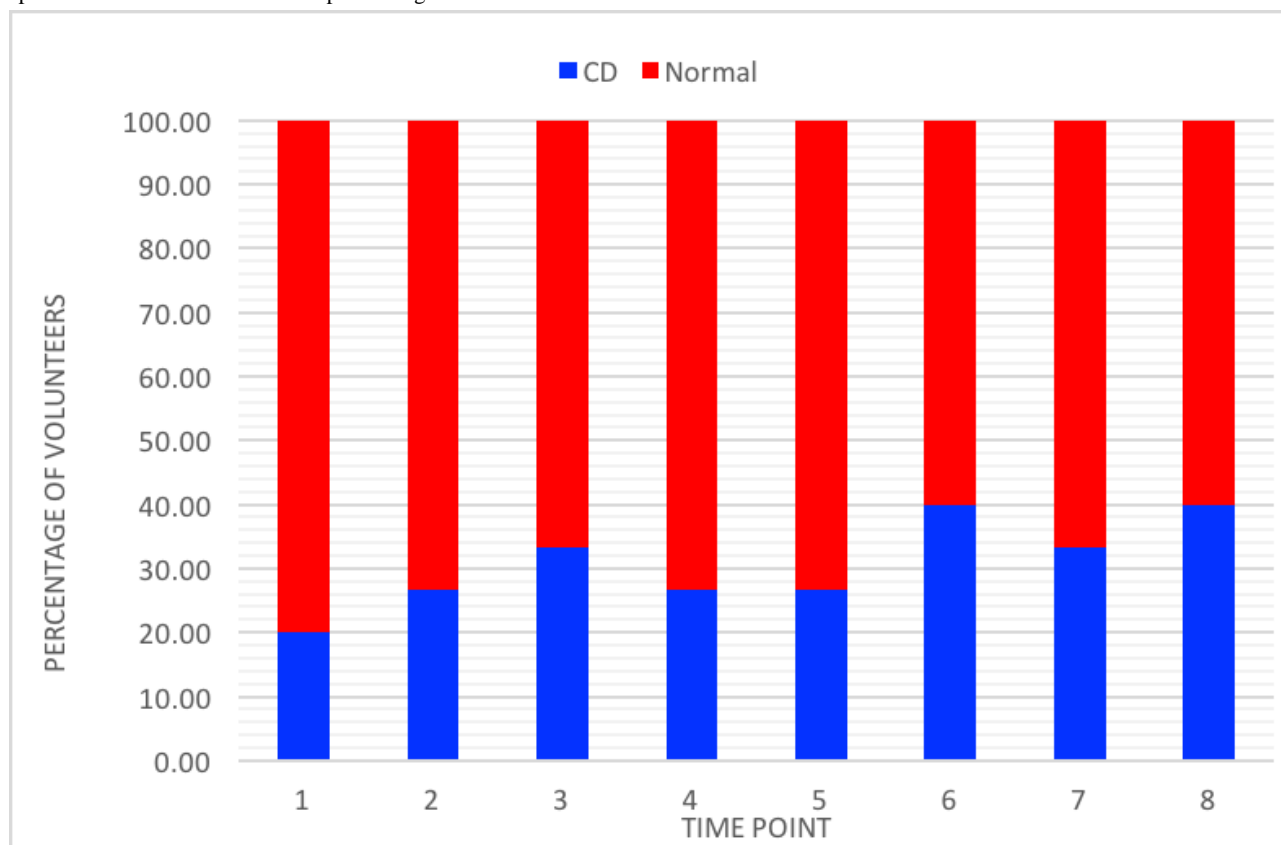
Discussion

Principal Findings

Our study showed a decline in the cognitive function of participants following Trendelenburg positioning. Each volunteer's cognitive function was assessed at various time points against his or her own baseline cognitive performance. The overall percentage of volunteers with cognitive decline increased to 40% (6/15) after 3 hours in the Trendelenburg position. After 1.5 hours, 33% (5/15) had cognitive decline, but this reduced to 27% (4/15) after 2 hours. This could be due to adaptation to being placed in the Trendelenburg position as per the Monroe-Kellie doctrine or possibly due to 5 of the 15 volunteers requiring a toilet break between 90 minutes and 2 hours into the test [17].

Once the participant sat up (after 3 hours in the Trendelenburg position and 1 hour in supine position), the initial tests revealed another slight increase in the number of participants with overall cognitive decline from 33% (5/15) to 40% (6/15). Many physiological changes initially occur in an individual when sitting from a supine position. Deegan et al recruited 19 healthy volunteers and induced transient hypotension while in both the seated and supine positions and measured mean arterial pressure and cerebral blood flow in the middle and anterior cerebral arteries along with cerebral autoregulation response. They found that autoregulatory responses were worse in the seated position

in both the anterior and middle cerebral arteries, which was thought to be due to the hydrostatic gradient that occurs when in a seated position [18]. Previous studies have shown that cerebral autoregulation is dependent on vascular tone [19]. Deegan et al found that a drop in cerebral perfusion pressure leads to dilatation of the cerebral vessels, which results in reduced cerebral vascular resistance. They also looked at the theory of reduced cerebral perfusion pressure resulting from a shift in the autoregulatory curve to the right. However, the subjects included in their study did respond with an increased heart rate, suggesting a sympathetic response that should result in vasoconstriction and, therefore, an increase in cerebral vascular resistance [18]. This could explain the increase in the percentage of volunteers with cognitive decline that occurred at time point 8.

A break was taken by some volunteers between time points 3 and 4, which lasted for a maximum of 5 minutes. The volunteers then returned to the Trendelenburg position. This break could explain the reduction in the percentage of volunteers with cognitive decline at time point 4. The resulting reduction in cognitive decline that may have occurred following a short period in the upright position was comparable to the worsened cognitive decline that occurred when in the sitting position, which further supports the reduced cerebral perfusion pressure that has been shown to occur when in the seated position versus the standing position. Patients undergoing left-sided laparoscopic resections are often placed in either a modified lithotomy position (with the legs slightly flexed) or the Lloyd-Davis position. Further studies to reassess the response of a standing or head-up tilt position on recovery of cognitive function would be of clinical benefit.

There were limitations to this study, which included a bathroom break that may have affected the results achieved at time point 4. Test fatigue could also be a contributing factor, with repetitive tests being conducted in such a short time period. A repeat set of tests 24 hours after the end of the study would possibly have been beneficial for assessing the clinical impact.

A further limitation is the lack of a clear definition for POCD. ISPOCD is the largest study in this area so far, but it treats POCD as a binary definition. The clinical implications and impact on daily life of these definitions need to be further evaluated and defined along with standard tests that should be used. The high percentage of cognitive decline could be due to the sensitivity and number of the cognitive tests that were used in our study.

Conclusion

The results of our study indicate that Trendelenburg positioning leads to cognitive decline. A finding of potential clinical significance was that when the volunteers sat up from supine position, there was an increase in the number of volunteers with cognitive decline. This suggests that in a clinical setting, simply reducing the tilt of the table when the patient is in the modified lithotomy or Lloyd-Davis position may not be beneficial as this would most likely mimic the physiology of sitting and could further impair cognitive function due to reduced cerebral vascular resistance [18]. Further studies to assess the effect of a "break from the Trendelenburg position" while in the modified lithotomy or Lloyd-Davis position versus supine position would be clinically relevant.

Conflicts of Interest

None declared.

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Abbreviations

ISPOCD: International Study of Postoperative Cognitive Dysfunction
LDT: lexical decision-making task
POCD: postoperative cognitive decline
RT: response time

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