Patient Education and Counseling 129 (2024) 108394

Contents lists available at ScienceDirect

Patient Education and Counseling

journal homepage: www.journals.elsevier.com/patient-education-and-counseling

Use of virtual reality in preoperative education of cardiac surgery patients – A feasibility study

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ARTICLE INFO

Keywords:
Virtual reality
Cardiac surgery
Feasibility studies
Patient education

ABSTRACT

Objective: A Virtual Patient Tour (VPT) was developed to inform cardiac surgery patients about their hospitalization from the admission to their postoperative stay on the ward. The objective of our study was to assess the feasibility and acceptability of this VPT following the framework of the Virtual Reality Clinical Outcomes Research Experts Committee.

Methods: In this single-centre cross-sectional study, adult patients admitted to the hospital for elective cardiac surgery were included. Acceptability, usability, and tolerability were measured by the validated questionnaires Unified Theory of Acceptance and Use of Technology (acceptability), System Usability Scale (usability), and Virtual Reality Sickness Questionnaire (tolerability). Descriptive statistics were used for the analysis.

Results: Twenty-eight participants used the VPT. Results showed high acceptability (mean 16.7 ± 1.5), acceptable usability (mean 86.7 ± 9.3), and high tolerability (sickness score, median 7.1 % [0–17.1 %]).

Conclusion: The use of the VPT is a feasible and promising technique. The next step is to optimize the content and technique of the VPT based on the suggestions of the participants.

Practice implications: We recommend incorporating the VPT into preoperative patient education in addition to the routine information in cardiac surgery patients.

1. Introduction

Patients scheduled for cardiac surgery often experience preoperative anxiety [1]. Preoperative anxiety can be divided in feelings of uncertainty, fear associated with hospitalization itself, worries about the surgical process or its potential complications, the underlying disease and undefined [2,3]. Preoperative anxiety is researched in different studies and the level of preoperative anxiety varies from 28 % [4] up to 80 % in cardiac surgery patients [1]. Preoperative anxiety can increase postoperative complications, such as prolonged mechanical ventilation, hemodynamic imbalance, increased pain, increased anaesthetics and analgesics, and a higher readmission rate [2,4,5].

To reduce preoperative anxiety, extensive preoperative education could be helpful in the mental and psychological preparation of cardiac surgery in patients. An increasingly used and promising method of patient education is virtual reality (VR) [6]. VR is a technique in which a head-mounted display is used for visual engagement, complemented by handheld controllers for seamless navigation and interactive engagement within a virtual environment [7,8]. With VR, users often experience a sense of being mentally immersed or present in a virtual environment [9,10]. Patient education can be defined as a set of informational resources to increase a patient's understanding about their disease, treatment [8,11], and to positively influence health-promoting behaviour [8,10]. Education can help patients to understand what to expect in the preoperative, perioperative, and postoperative period [6]. In addition, VR can increase patients knowledge [8] and satisfaction [12], and may reduce preoperative anxiety levels [6,8,9].

In a previous study, the needs and preferences of information in

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https://doi.org/10.1016/j.pec.2024.108394
Received 10 October 2023; Received in revised form 15 April 2024; Accepted 8 August 2024
Available online 10 August 2024

cardiac surgery patients were explored [6]. That study showed the needs and preferences of patients for a realistic environment with facultative elements, a virtual tour of the hospital, and to create familiarity by seeing and experiencing what is to come in advance to hospital admission [6]. The results of that study were the basis for developing the 'Virtual Patient Tour' (VPT) for cardiac surgery patients. The VPT is a learning intervention that is developed from the patient's perception and takes the patient to the virtual admission wards during their hospital stay for cardiac surgery. The VPT is based on the learning principles of cognitive, affective, and multisensory learning and interactivity [13]. In the VPT, the participant is in control of the received information because participants can choose to read extra information about rooms or objects in the VPT or not.

In the development of the VPT the methodological framework of the VR Clinical Outcomes Research Experts committee was followed, in which three phases of VR clinical study designs are distinguished: a VR1 study to develop the intervention with engagement of end-users, a VR2 trial to early assess the feasibility of the intervention in a representative clinical setting within the target population prior to a more definitive RCT trial, and a VR3 trial to evaluate the effectiveness of the intervention in (preferably) a randomized controlled trial [14]. The VR1 study is already executed [6]. In this study a VR2 trial is performed to investigate the feasibility within the target population. This step is important to determine whether the VPT can be successfully integrated within the flow of usual care and if cardiac surgery patients consider the VPT feasible in preoperative education. Therefore, our aim was to determine the acceptability, usability, and tolerability of the VPT intervention in the preoperative education of cardiac surgery patients.

2. Methods

2.1. Design and context

A single centered, cross-sectional study was conducted at the Cardiothoracic Surgery department. Recruitment and data collection were performed between February 2022 and June 2022. Data was reported according to the guideline Strengthening of the Reporting of Observational Studies in Epidemiology (STROBE) [15] and the Criteria for Reporting the Development and Evaluation of Complex Interventions in healthcare (CReDECI 2) [16]. Patients scheduled for elective cardiac surgery were eligible for inclusion. In addition, eligible patients must be aged $\geq$ 18 years, and able to give informed consent. Exclusion criteria were patients with 1) an inability to speak, read or write Dutch, 2) patients with a history of neurological diseases (i.e. epilepsy, cerebrovascular accident, Morbus Parkinson, and vertigo) since we were concerned that these patients were more vulnerable for disorientation or other VR-related adverse effects, 3) a personal or an implanted medical device (such as a pacemaker, cochlear implant, or hearing aids), since these devices may be affected by the VR device, and 4) uncorrected visual or hearing impairments since the VPT includes video and audio [17].

2.2. Sample size justification

For feasibility studies, different rules of thumb exist. One of them is that a sample size of at least twelve participants is needed [18]. However, a drop-out was expected due to VR sickness. Therefore, a larger sample is desirable. Another study describes for a feasibility study with two arms, 25 participants per arm are advised [19]. With only one arm in this study, the sample size was aimed between 12–25 participants, targeting the greatest sample.

2.3. Procedure

Written informed consent was obtained from eligible participants. On the day of admission, one day prior to surgery, the VPT was shown to the participant. The VPT was given in addition to routine care. A Pico Neo 3 Pro Eye headset (Pico Immersive Pte. Ltd.), with a hand motion controller, was used to watch the VPT. The VPT took the participant in approximately fifteen minutes through the hospital environment, virtually visiting the nursing ward, holding, operating theatre, intensive care, and medium care unit. Meanwhile, information is given by health care professionals or through a voice-over. In addition, hotspots were available in the VR environment, in which additional information is provided on various topics, such as medical devices in the room and frequently asked questions from patients. Participants could use the hand motion controller to activate the hotspots and read the information (see Fig. 1). A complete description of the VPT intervention was given according to the Template for Intervention Description and Replication (TIDieR) checklist [20] in the supplemental material. The participant used the VPT in a private room, on a chair with armrests. Before starting the VPT, demographic variables were collected by the researcher. After ending the VPT the participants were asked to complete the remaining questionnaire. Questionnaires were collected in an electronic data capture system (CASTORedc) [21].

2.4. Data collection

Demographic characteristics, type of surgery, and the level of preoperative anxiety were collected to describe the study population. Demographics were retrieved via a questionnaire and included gender, age, experience with VR, and education level, which was categorized in 'lower' (primary and lower secondary), 'intermediate' (upper secondary and post-secondary non-tertiary), and 'tertiary' (bachelor and master) education following the International Standard Classification of Education 2011 [22]. The type of surgery (heart valve, bypass, combined) was collected from the electronic patient file. In addition, recruitment rate was defined as the proportion of eligible participants who consented to participate during the recruitment period. Preoperative anxiety was measured by the Surgical Anxiety Questionnaire (SAQ), a reliable and valid 17-item questionnaire with six domains: concerns about health, recovery, procedures, pain and discomfort, being awake of conscious during surgery, and return to daily activity [3]. Answers were rated on a five-point Likert scale from "not at all" (0) to "extremely (4). Total scores range from 0–68, in which higher scores indicate more anxiety [3].

2.4.1. Acceptability

Acceptance of technology was operationalized using the Unified Theory of Acceptance and Use of Technology (UTAUT) [23]. This theory assumes that behavioral intention towards the acceptance of information technology is predicted by performance expectancy, effort expectancy, social influence, and facilitating conditions. The UTAUT is a 15-item questionnaire and is rated on a five-point Likert scale from "strongly disagree" (1) to "strongly agree" (5). The total score for behavioral intention ranges from 4–20, performance expectancy ranges from 4–20, effort expectancy ranges from 3–15, and social influence has a range from 4–20. Higher scores indicate more behavioral intention, performance expectancy, effort expectancy, social influence, and facilitating conditions. In this study the constructs behavioral intention, performance expectancy, effort expectancy, and social influence are being researched [24].

2.4.2. Usability

To evaluate the usability of the VPT, the system usability scale (SUS) was used. This is a 10-item questionnaire, and answers are rated on a five-point Likert scale from "strongly disagree" (1) to "strongly agree" (5) [25]. The total score is not a percentage but a total score out of 100, wherein 100 is the best imaginable score and a score below 25 is seen as the worst imaginable score. The average SUS score is 68 and is indicated as an OK to good score [26].

In addition, usability was measured by barriers and satisfaction. Barriers in usability were defined as anything that prevented the completion of the VPT without disturbances. A two-item questionnaire

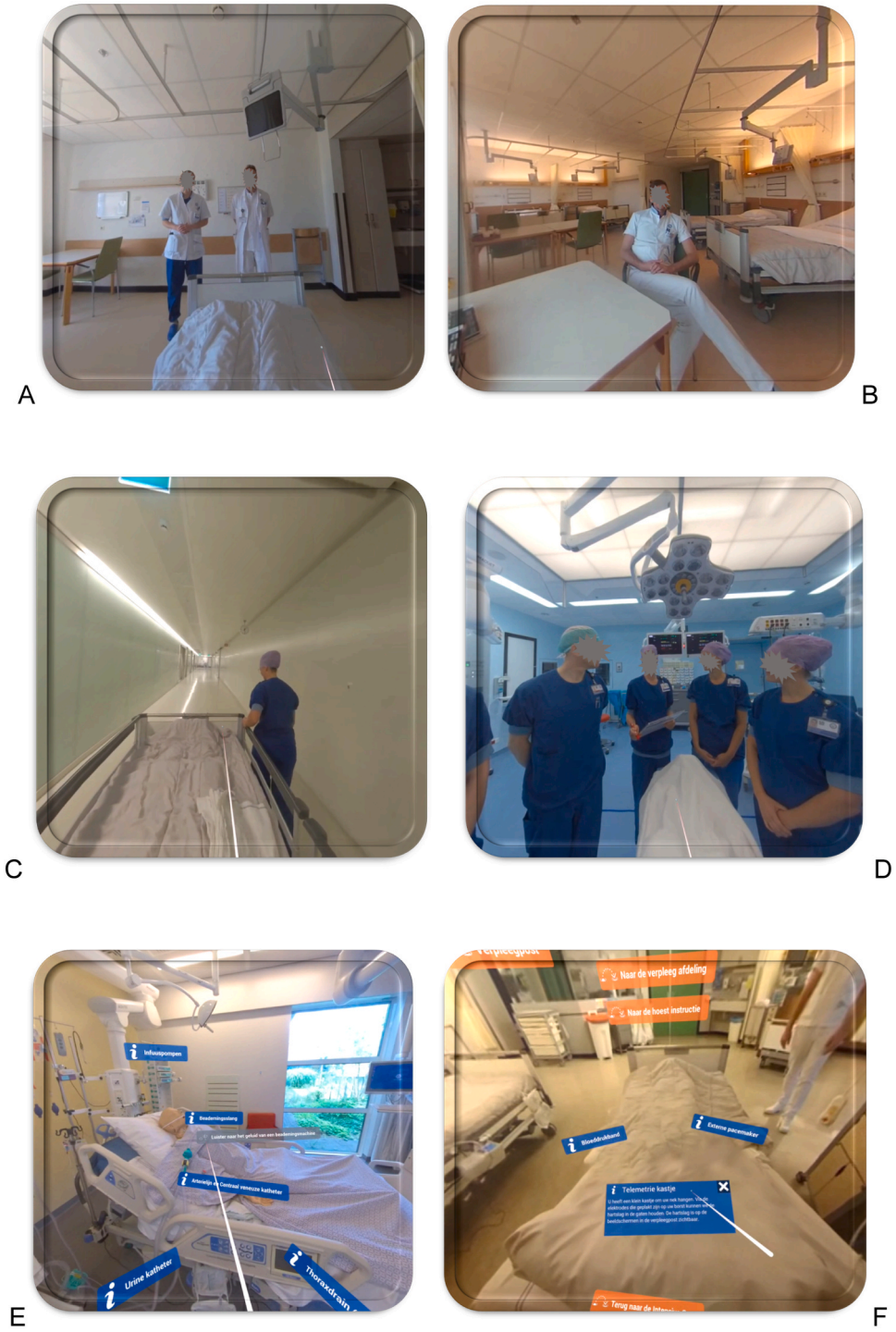

Fig. 1. Screenshots of images of the Virtual Patient Tour (copyright: UMC Utrecht, The Netherlands). This figure demonstrates the various caregivers giving explanations to the patient, the different wards the patient visits during admission, and the hotspots where the patient can virtually click on to receive additional information about certain topics. A: The thoracic surgeon and physician assistant explaining the doctor's visit, recovery and discharge to the patient in one of the patient rooms. B: The thoracic surgery nurse explaining the course of admission in the admission room. C: The route the patient takes to the operating room. D: The surgical team introducing themselves when the patient enters the operating room. E: The intensive care unit. F: The medium care unit. Both with different hotspots that the patient can virtually click on to get more info about the medical device or orther issues relevant to that area. Hotspots are available in every room in the VPT.

was developed by the research team to ask whether the VPT was completed, interrupted, or ended prematurely, and the reason why the VPT was interrupted of prematurely ended.

Satisfaction was defined as meeting the expectations and needs of the participants. A three-item, open-ended questionnaire was developed by the research team to ask for keywords to describe participant's experiences with the VPT, the hotspots, and suggestions to improve the VPT.

2.4.3. Tolerability

Tolerability was defined as whether participants experience VR sickness. Tolerability was measured using the Virtual Reality Sickness Questionnaire (VRSQ), a 9-item questionnaire. The questionnaire has two constructs measuring oculomotor and disorientation. Each construct contains items that correspond with symptoms for virtual reality sickness. The oculomotor construct contains the items 1) general

discomfort, 2) fatigue, 3) eyestrain, and 4) difficulty focusing. The construct disorientation contains the items 5) headache, 6) fullness of head, 7) blurred vision, 8) dizzy (eyes closed), and 9) vertigo. Answers were rated on a four-point Likert scale from "non" (0) to "severe" (3). Higher scores indicate more severe VR sickness. Both constructs of the VRSQ showed good reliability (oculomotor $\alpha = 0.847$, disorientation $\alpha = 0.886$) [27]. Nausea, is not measured with the VRSQ, but could be considered as a symptom of VR sickness [28,29]. Therefore, one question was added by the research team asking to what degree nausea was experienced during the VPT. Answers were rated on a four-point Likert scale (range from (0) none to (3) severe).

2.5. Statistical analysis

Baseline demographics were analyzed using descriptive statistics. Continuous variables were checked for normal distribution through histograms and described as mean ± standard deviation (SD) for normal distributed data, or as median [Quartile Range (QR)] for non-normal distributed data. Categorical variables were presented as frequencies and percentages. Scores of the SAQ were determined by summing questions per construct, while summing all questions resulted in a total score. No cut-off values were available for the SAQ. Analyses were performed using the Statistical Package for the Social Sciences (version 26).

Scores of the UTAUT were determined per factor by summing related questions. The acceptance of technology was categorized as low (score 4 to 9), moderate (score 10 to 15), and high (score 16 to 20) [30].

To calculate the SUS score, the score contributions from each item are summed. Each item's score contribution range from 0 to 4. For the uneven items, the score contribution is the scale position minus 1. For the even items, the contribution is 5 minus the scale position. The sum of the scores is multiplied by 2.5 to obtain the overall value of SUS. Scores range from 0 to 100 [25]. Barriers in usability were calculated as sum scores. Open-ended questions were analysed within the research team (MvR, JW, SW) and clustered based on the content.

To calculate the VRSQ score, each construct is summed, divided by the maximum score per construct, and multiplied with 100. A total VRSQ score was calculated by summing both construct scores and divided with two [27].

2.6. Ethical issues

The study was conducted according to the principles of the Declaration of Helsinki and Dutch regulations. The Medical Research Ethics Committee of the University Medical Centre Utrecht concluded that Medical Research Involving Human Subjects Act does not apply to this study; therefore, no approval was needed. Written informed consent was obtained from all participants. Data were only used for research purposes.

3. Results

3.1. Participants

Patients planned for elective cardiac surgery were screened for eligibility by a research nurse from February 2022 to June 2022 (N = 54) After obtaining informed consent by telephone (N = 44), nine patients were excluded because they were found not to meet the inclusion criteria after all (N = 5), and (N = 4) patients ended up not wanting to participate in the study after all. A total of 35 patients agreed to be contacted again at admission. On the day of admission, two patients refused to participate due to being too anxious (N = 2), too tired (N = 1) or due to other personal reasons (N = 2). The researcher was unable to contact two patients (N = 2) since the surgery was rescheduled. A total of 28 patients participated in the study. A recruitment rate of 57.1 % was reached, since 28 out of 49 eligible patients participated in this study.

3.1.1. Demographic characteristics

Of the included participants, 79 % were male (N = 22) with a mean age of 60.7 years. Nearly 40 % of the participants were intermediate educated, and 50 % were scheduled for bypass surgery. The majority of the participants (75 %) had no previous experience with VR (Table 1). The SAQ median total score was relatively low with a score of 7.5 [2.3–16.0], mostly due to concerns about pain of discomfort after the surgery, and concerns about the length of time returning to daily activities (Table 2).

3.1.2. Acceptability

Behavioural intention and performance expectancy had a mean score of 16.7 indicating high acceptance level of the VR intervention (Table 3). Effort expectancy (median score 15) and social influence (median score 14.5) showed a high acceptance level of the VPT.

3.1.3. Usability

The mean SUS score in participants was 86.7 which is indicated as an excellent score. The SUS score of 86.7 indicates that the usability of the VPT was assessed as acceptable by cardiac surgery patients. (Table 4).

All participants completed the VPT without any disturbances. In addition, participants found the VPT to be very informative, educational, and interesting. The experiences with the hotspots were valued as clear and educational. One participant stated there were too many objects to read, and one participant that there was medical jargon in the hotspots. Suggestions for improvement included to sharpen the vision (N = 5), since some participants experienced a blurred vision, and to change the position of the speakers in the VPT (N = 8). Further experiences are described in Table 5.

3.1.4. Tolerability

Table 6 shows the results of the VRSQ. The total VRSQ median score was 7.1 %, which was relatively low. The oculomotor construct contributed the most. Blurry vision (N = 15) and difficulty focusing (N = 12) were most reported by participants. Considering the results of the VRSQ, the VPT has a high tolerability in participants. Nausea was described as slightly present by only one participant; all the other participants reported no nausea.

4. Discussion and conclusion

4.1. Discussion

In this VR2 trial, the feasibility of the VPT in preoperative education of elective cardiac surgery patients was assessed. This study showed that the VPT has high acceptability, acceptable usability, and high tolerability in participants.

To the best of our knowledge our study is the first study which used a self-developed tour in the cardiac surgery environment. Our results are

Table 1
Demographic variables of participants in feasibility study.

Variable	n (%)	Mean (SD)
Gender		
Male	22 (78.6)	
Age, *years*		60.7 (11.6)
Education		
Lower education	8 (28.6)	
Intermediate education	11 (39.3)	
Tertiary education	9 (32.1)	
Type of surgery		
Bypass surgery	14 (50.0)	
Heart valve surgery	8 (28.6)	
Combined surgery	6 (21.4)	
Experience with VR		
No	21 (75)	

Abbreviations: VR = Virtual Reality, SD = standard deviation

Table 2
Surgical Anxiety Questionnaire, to measure the preoperative anxiety level in the study population.

Construct	Score	Range
Concerns about health, *median* ***[QR]***	2.5 [1.0 −5.0]	0 −10.0a
Concerns about recovery, *median* ***[QR]***	1.0 [0 −2.0]	0 −8.0b
Concerns about procedures, *median* ***[QR]***	1.5 [0 −4.0]	0 −9.0b
Worries about being awake or conscious during surgery, *median* ***[QR]***	0 [0]	0 −4.0c
Worries about length of time returning to daily activity, *median* ***[QR]***	1.0 [0 −2.0]	0 −3.0c
Worries about pain or discomfort, *median* ***[QR]***	1.0 [0 −2.0]	0 −4.0c
Total score, *median* ***[QR]***	7.5 [2.3 −16.0]	0 −27.0d

Abbreviations: QR = Quartile Range.[a] Reference range 0-24, [b] reference range 0-16, [c] reference range 0-4, [d] reference range 0-68.

Table 3
Unified Theory of Acceptance and Use of Technology, to evaluate the acceptance of the 'Virtual Patient Tour'.

Factor	Score	Range
Behavioural Intention, *mean ± SD*	16.7 ± 1.5	14 −20a
Performance expectancy, *mean ± SD*	16.7 ± 1.8	12 −20a
Effort Expectancy, *median* ***[QR]***	15	[14.0 −15.0]b
Social Influence, *median* ***[QR]***	14.5	[12.0 −16.0]a

Abbreviations: SD = standard deviation, QR= Quartile Range. [a] Reference range 4-20, [b] reference range 3-15.

Table 4
System Usability Scale, to evaluate the usability of the 'Virtual Patient Tour'.

	Mean	SD
SUS score	86.7	9.3

Abbreviations: SUS= system usability scale; SD= standard deviation

Table 5
Satisfaction of participants using the 'Virtual Patient Tour'.

Questions	Responses
Can you describe your experiences with the VPT (keywords)?	Informative, educational, clarifying, complementary, interesting, pleasant, clear, calming, helpful, added value, worth recommending, nothing disturbing to see
Can you describe your experiences with the hotspots (keywords)?	Clear, adequate, educational, valuable, sufficient, nice addition, too many objects, self-explanatory, medical jargon
Do you have suggestions for improvement?	Sharpen vision, improve perspective, include more information, change position of hotspots, indicate the route through the VPT more clearly, avoid medical jargon, use of swivel chair, post-synchronization

Abbreviations: VPT = Virtual Patient Tour

Table 6
Virtual Reality Sickness Questionnaire, to evaluate the tolerability of the 'Virtual Patient Tour'.

Construct	Score	Range
Oculomotor, median **[QR]**	8.3 % [0 −16.7 %]	0 −67 %
Disorientation, median **[QR]**	6.7 % [0 −13.3 %]	0 −40 %
Total score, median **[QR]**	7.1 % [0 −17.1 %]	0 −50 %

Abbreviations: **QR= Quartile Range;** VRSQ: Virtual Reality Sickness Questionnaire

in line with another recently published pilot study. In a study of Aardoom et al., a VR application was developed for cardiac patients undergoing catheterization and assessed as feasible, and tolerable [31]. In that application, patients could experience the hospital process from the moment of admission, heart catheterization, postprocedural stay, and discharge [31]. Their participants (N = 8) were satisfied, felt better informed, and were better prepared for the cardiac catheterization process [31]. Other studies have researched VR as an intervention in distracting or calming patients, such as using VR to calm intensive care unit patients with elements of nature VR content [32], to distract patients during chemotherapy with VR games [33], or distract young adults in the emergency department with pre-loaded apps such as TV-shows, mindfulness or games [34]. Although these VR interventions were not developed for patient education, these studies show that the use of VR as a intervention is promising: participants were positive about the intervention, accepted the intervention, and experienced only minimal adverse effects. Lastly, there are two recently published randomized controlled trials researching the effects of VR. One study, a study by Grab et al., researched different methods for patient education and their effect on patient understanding and preoperative anxiety. Methods used were 3D-VR models, 3D-printed models, and conventional paper-based methods. Their study showed that the utilization of 3D models was well-received by patients, who expressed overall satisfaction. In particular, they appreciated the immersive visual encounter provided by VR for better comprehension of procedures. After using VR as patient education, anxiety decreased [35]. The study of Kwon et al. investigated in a RCT the effect of preoperative education using VR on preoperative anxiety and information desire. In their study, the VR group had significantly lower preoperative anxiety and information desire scores after preoperative patient education than the control group. There was no statistical difference in patient satisfaction [36]. The quartile range of the VRSQ shows potential heterogeneity, suggesting variations among patients in susceptibility to virtual sickness. While this observation does not undermine the quality of the VPT per se, it implies practical implications wherein some patients may experience heightened levels of virtual sickness compared to others. In case of symptoms of VR sickness, participants have the option to immediately end their virtual experience by taking off the VR glasses. The VPT serves to supplement conventional sources of information; thus, in cases where VR sickness prevents the use of the VPT, participants are still provided with all relevant preoperative information, but without the accompanying VR experience. Although we used state of the art VR hardware, some participants described blurred vision as a negative outcome. This is in line with some other studies researching VR [33,34]. This may have caused some participants to be distracted as a result and have had therefore a different kind of VR-experience. VR is booming on patient education and interventions in healthcare. Considering these developments in VR, our study contributes to the further development of this very promising technique in health care.

To appreciate the findings of this study, some aspects require further consideration. Although the study revealed that the VPT is accepted, usable and tolerated, the study has some limitations. First, we have not explored whether the tool enhances learning and understanding. This prohibits conclusions on enhancing preoperative education. Second, the VPT is developed for a specific hospital because the VPT is filmed on the actual departments that patients visit during admission with actual hospital personnel. The VPT can therefore be used in more departments in our hospital. However, developing the VPT took relatively little time, developing a VPT in another setting or hospital is certainly easy achievable. Third, by excluding patients with a history of neurological diseases and hearing aids we do not know if this patient population is indeed more vulnerable for adverse effects and if the VPT is of added value in this specific population. Fourth, this study population included relatively low preoperative anxiety in the baseline data. The added value of VPT to reduce preoperative anxiety in patients with high levels of anxiety has to be determined.

A strength of this study is that in the context of intervention development we've followed the methodological framework of the VR Clinical Outcomes Research Experts committee. Before we implement the VPT in clinical care we have conducted a feasibility study, this ensures a rigorous, reliable, and credible approach to intervention development and contributes to the advancement of knowledge in the field [14]. In a larger research context, the content of this VPT will need to be adapted in response to the patient feedback, however, the tool itself is shown to be acceptable, usable and tolerable.

5. Conclusion

The results of this study imply that the use of the VPT is feasible in preoperative education of cardiac surgery patients. The VPT is shown to be acceptable, usable, and tolerable in cardiac surgery patients. In addition, participants were satisfied with the VPT and indicated the VPT as educative, informative, and pleasant. The VPT is a promising tool and the next step in the development of the VPT is to optimize the content and technique, based on the suggestions given by participants and to research the VPT further in a VR3 RCT trial.

Practice implications

This study has shown that the use of the VPT is accepted, usable and well tolerated. Our recommendation is to use the VPT in preoperative information provision in addition to the routine information patients receive in preparation for cardiac surgery.

CRediT authorship contribution statement

Michelle M van Rijn: Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Jenny Nieuwenhuis-Wendt:** Writing – review & editing, Writing – original draft, Project administration, Formal analysis, Conceptualization. **Linda M de Heer:** Writing – review & editing, Supervision, Resources, Conceptualization. **Heleen Westland:** Writing – review & editing. **Lars van der Plank:** Writing – review & editing, Software. **Saskia Weldam:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Eveline G.E. Moolenaar:** Writing – review & editing, Project administration. **Niels P van der Kaaij:** Writing – review & editing, Resources. **Daan Halle van der Ham:** Writing – review & editing, Software.

Declaration of Competing Interest

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

Acknowledgements

The authors would like to thank Fiona Slond for her technical support, assistance and advice in the development of the VPT.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.pec.2024.108394.

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