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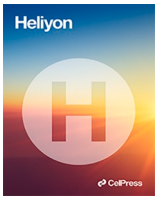

Virtual reality education program for women with uterine tumors treated by high-intensity focused ultrasound

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ABSTRACT

This study aimed to develop and determine the effects of a nursing education program using virtual reality (VR) for women with uterine tumors undergoing treatment with high-intensity focused ultrasound (HIFU). Various nursing education methods need to be developed alongside new treatment methods and their effects should be clinically verified. Nursing intervention using VR has recently been attempted. The study comprises a pre- and post-test design with a non-equivalent control group.

We assigned 54 women to experimental (n = 26) and control (n = 28) groups. The patients were diagnosed with benign uterine tumors and were treated with HIFU at two women's hospitals in D city. Data collected from these hospitals were analyzed using descriptive statistics, a pre-test of homogeneity, independent t-tests, and repeated measures analysis of variance. In the experimental group, uncertainty ($t = 4.26$, $p < 0.001$) and anxiety ($t = 4.09$, $p < 0.001$) were significantly lower compared to the control group. However, nursing satisfaction was significantly higher in the experimental group than in the control group ($t = -4.50$, $p < 0.001$). The VR education program is an educational nursing intervention that reduces uncertainty and anxiety and improves nursing satisfaction among women with uterine tumors treated by HIFU. We suggest that future nursing research integrates and converges disciplines according to progressive treatment methods and technological advancements for patients.

1. Introduction

The prevalence of benign uterine fibroids or adenomyosis due to various causes is 40%–50 % among women aged between 35 and 45 years [1]. Generally, the development and growth of a benign uterine tumor are closely associated with physiological changes in ovarian hormone concentrations in blood [2]. Most benign uterine tumors grow slowly, and 20%–50 % of them are asymptomatic, but severity varies according to their number, size, and location [3]. Some symptoms include heavy menstrual bleeding, atypical uterine bleeding, menstrual cramps, pelvic pain, late menstrual periods, infertility, frequent urination, and dyspareunia [4].

Symptoms and the condition associated with benign uterine tumors are treated through various treatment modalities, including surgically, medically with drugs, and non-invasively depending on the stage [1]. Specific non-invasive treatments such as uterine artery embolization and radiofrequency myolysis are presently used to preserve the uterus [5,6]. Moreover, liver cancer, prostate

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cancer, uterine fibroids, and adenomyosis can also be managed non-invasively with high-intensity focused ultrasound (HIFU) [7,8]. Typically, HIFU converts focused ultrasound mechanical energy generated by a transducer into heat energy to selectively cauterize affected areas [9].

Care before HIFU entails treating the abdominal skin through which ultrasound waves pass to penetrate the bladder and intestines, and care thereafter comprises monitoring urination, skin or abdominal pain in the treated area, and fever [10]. Furthermore, detailed information about the HIFU procedure, potential complications, possible discomfort, and post-treatment effects was provided in advance as part of psychological care. This approach aimed to address any anxiety and stress that patients might have experienced regarding the HIFU treatment [1].

The advantages of HIFU include non-invasiveness and no requirement for general anesthesia. However, anxiety and stress levels might escalate as patients can see, hear, and feel the entire procedure [3]. Patients might also experience a vague fear of the treatment and uncertainty about the results due to limited information available [11]. Hence, providing appropriate pre-procedural education helps to reduce patient uncertainty and anxiety while satisfying their desire to undergo the treatment [12].

Recent technological advances have resulted in innovative medical equipment and tools. Treatments and surgical processes involving robots or even virtual reality (VR) are being widely adopted worldwide [13]. Additionally, VR is an adaptation of an actual or imaginary environment in three-dimensional (3D) graphics emphasizing the concept of presence. Moreover, VR allows individuals to experience computer-generated reality using computer hardware and software systems through interactive technology [13,14,15].

Moreover, VR technology has been integrated into various therapeutic approaches, such as cognitive-behavioral therapy (CBT) for attention deficit hyperactivity disorder, anger management utilizing VR-based CBT (VR-CBT), risk reduction for falls in older individuals with diabetes, enhancements in the quality of life (QOL), and heart rate variability for patients undergoing hemodialysis [13, 15–17]. In clinical patients, VR relaxation meditation programs enhance pain regulation [16–18,19] and can control anxiety and depression in patients with bipolar disorder [20]. VR technology can serve as an educational or treatment tool by recomposing the knowledge or cognitive structure of an individual through interactions with the environment [13]. Additionally, the sense of reality provided by education through VR technology, captures the interests and motivation of patients, thus improving their concentration and treatment effects [21].

Women are generally more anxious about diseases of the uterus than of any other organs because of the significance of the reproductive role associated with the uterus [22,23]. Most patients become anxious due to the unfamiliar environment and uncertainty of treatment ahead of surgical procedures. Anxiety and uncertainty can manifest as physical symptoms including pain and require intervention [3,11,22]. They are also associated with postoperative pain and health problems after discharge. Intervention that can reduce pre-treatment anxiety and uncertainty is clinically meaningful.

Therefore, we developed an educational nursing program using VR technology for women with uterine tumors undergoing HIFU.

1.1. Purpose of this study

We aimed to develop, implement, and evaluate the effects of a nursing educational program using VR technology for women with benign uterine tumors undergoing HIFU.

2. Methods

2.1. Study design

This quasi-experimental study used pre-test and post-test designs with a nonequivalent control group.

2.2. Setting and sample

The sample size was determined based on a previous study that had educated patients before undergoing hysterectomy [12]. We calculated the sample size using G* Power 3.1.9.2, (Heinrich-Heine-University, Düsseldorf, Germany) based on a significance level of 0.05, power 0.80, and effect size of 0.50 [24]. The appropriate sample size for both the experimental and control groups was determined to be 25, based on previous findings [12,24]. Thus, each group comprised 28 participants considering a dropout rate of 10 %.

Women (n = 54) with benign uterine tumors treated by HIFU at two hospitals and who met the inclusion criteria participated in the study via convenience sampling. The control (n = 28) and experimental (n = 28) groups comprised patients from the M-medi and Hyosung Women's hospitals respectively. The author distributed questionnaires to the participants before and after HIFU. All participants completed the questionnaire before HIFU, but two in the experimental group who refused to complete the questionnaire thereafter were excluded from the final analysis. Therefore, we analyzed data from 54 (control, n = 28; experimental, n = 26) participants.

2.3. Ethical considerations

The Institution Review Board (IRB) at Keimyung University approved this study (IRB No. 40525-201710-HR-62-01). After receiving an explanation of the purpose, methods, intervention details, and the survey content, the women voluntarily provided written informed consent before participating in the study. Confidentiality was guaranteed and the participants could withdraw from the study at any time without negative consequences. We advised sufficient rest and withdrawal from the VR training program if any of

the participants experienced discomfort or dizziness during the intervention.

2.4. Measurements

The study utilized a structured questionnaire survey consisting of general and obstetric characteristics, uncertainty, anxiety, pain, and satisfaction with nursing care.

2.5. Uncertainty

Uncertainty was measured using the Mishel Uncertainty Illness Scale [25] translated into Korean [26]. The survey consisted of 33 questions on a 5-point Likert scale, where the total score ranged from 33 to 165. High scores indicated increased uncertainty. Mishel [25] and Jeong [26] identified Cronbach's α values of 0.93 and 0.85, respectively, whereas this value was 0.91 in the present study.

2.6. Anxiety

Anxiety was measured using the State-Trait Anxiety Inventory (STAI) [27] translated into Korean [28]. The STAI consists of 20 questions on a 4-point Likert scale ranging from 1 (not at all) to 4 (very high). The total score range was 20–80, with high scores indicating significant anxiety. The reliability of the STAI [28] (Cronbach's α) and the present study was 0.86 and 0.90, respectively.

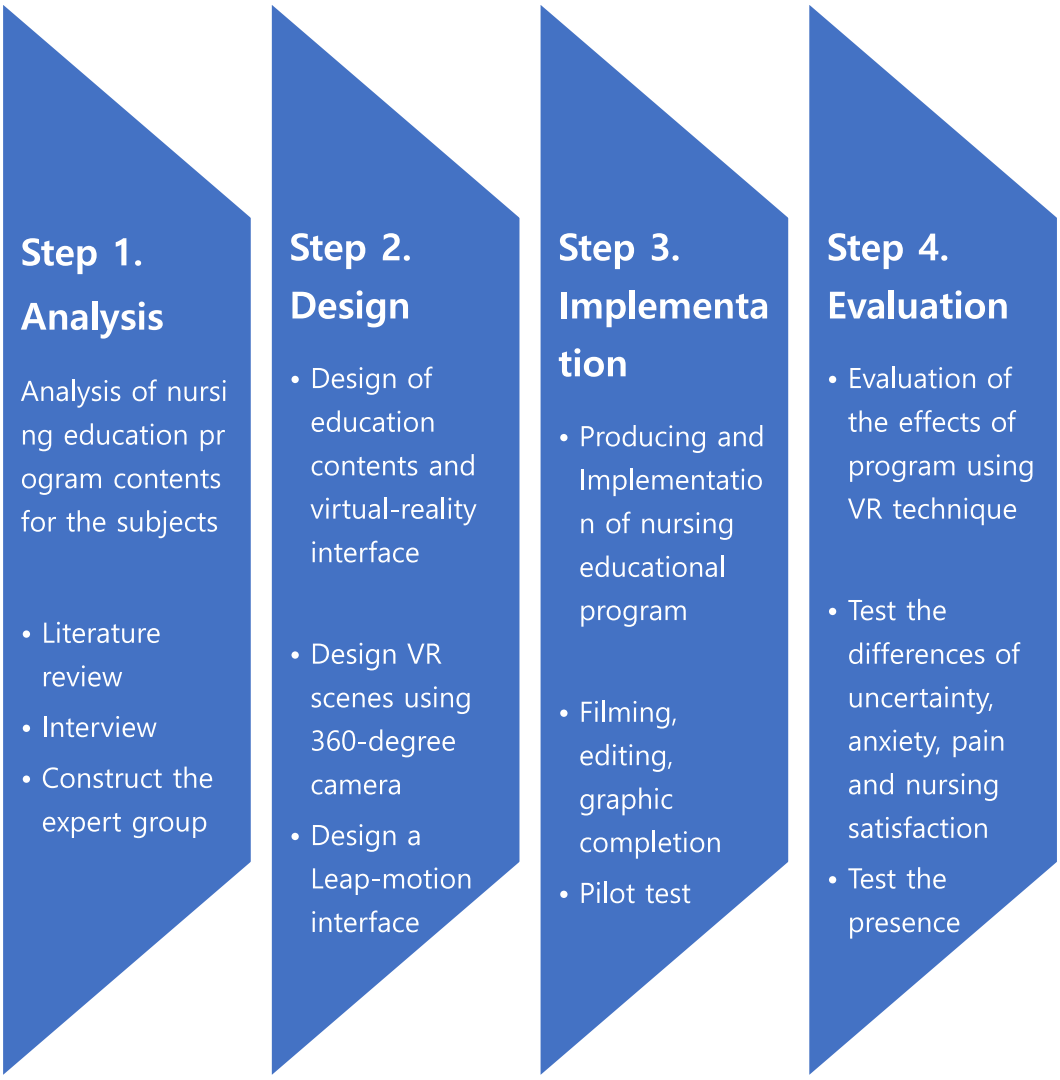

Fig. 1. The development Process of the program.

2.7. Pain

Pain was measured using the Numeric Rating Scale [29]. The measurement modality is a 10 cm long horizontal scale divided into 10 equal parts, from 0 (no pain at all) at one end and 10 (worst possible pain) at the other.

2.8. Satisfaction with nursing care

This self-report questionnaire addresses satisfaction with nursing care education [30], which was measured using a modified tool based on 15 items [31]. Validity was verified by consulting six experts, and satisfaction with nursing was determined from responses to 13 questions including issues related to patient preparation, treatment preparation and duration, pain control, method of anesthesia, post-treatment, discharge, and complications related to the procedure. Responses are scored on a Likert scale from 1 (very dissatisfied) to 4 (very satisfied) and the total score range is 13–52. The Cronbach's α in the present study was 0.89 compared with 0.92 in a previous study [31].

2.9. Development of the program

The education program was developed in the order of analysis, design, implementation, and evaluation based on the System Development Life Cycle for a nursing educational program using VR for women with benign uterine tumors (Fig. 1).

The analysis step comprised a literature review and interviews with women diagnosed with benign uterine tumors. The education step comprised understanding reproductive disorders of women, treatment and nursing management, symptoms and health management, and discharge education, comprising three subject areas and 15 detailed items (Table 1). During the design step, a scenario, flowchart, and scene design were created based on the education content that was validated by a group of experts consisting of gynecologists, clinical nurses, and a nursing professor. The scenes and pictures were used to enhance understanding of the procedure and maintain consistency in illustration methods. A leap-motion interface was used to maximize interaction in VR by recognizing the movement of fingers [31]. This allows immediate nursing intervention for anxiety and pain that participants with a uterine myoma may experience during HIFU. During implementation, an educational program using VR was produced according to the stages of planning, filming, editing, and graphic completion. In VR, a 360° camera was used for filming, where each scene was edited to form a 3D space (Fig. 2). In the editing and production process, the captured 360° video was used in an editing program [Fig. 2(a)]. The overlapping portions of the captured 360° images were synthesized using a stitching technique [Fig. 2(b)]. The screen configuration, brightness, and direction were edited for each scene [Fig. 2(c)], and checked before and after editing [Fig. 2(d)]. Finally, it was completed through rendering to implement 3D video using a video display device (HMD) [Fig. 2(e)]. The educational programs using VR were developed to enable training using a head-mounted display (HMD). Additionally, the educational VR program titled, "The Effects of an Educational Program for HIFU Using Virtual-Reality" is about 10 min long. During the evaluation step, we utilized a presence tool [32] that was modified [33] to evaluate the sense of reality (presence) of HIFU treatment using VR. Experts, participants, and program users evaluated the presence of this program. The presence scores for both the experts and participants were 187.60 ± 2.88, and 188.00 ± 0.58 out of 190, respectively. The scores indicated that the sense of presence in the VR program was high.

2.10. Data collection

Data were collected before and after HIFU by a self-reporting face-to-face method. The pre-and post-treatment questionnaires

Table 1
Educational content for high-intensity focused ultrasound.

Domain	Items	Methods	Contents
Preparation for procedure	• Disease characteristics • HIFU procedure	• Description using PPT	• Understanding of female reproductive organs and diseases • High-intensity ultrasound therapy (HIFU) definition and indications • Pre-procedure examination • Preparation for hospitalization • Overall procedure and method of HIFU • Guidance on bowel preparation and bladder preparation during the procedure.
Procedure process	• Environmental characteristics • Physical symptoms • Communication	• Education programs using VR	• Information on the procedure ward and procedure environment • Guidance on position (supine) during the procedure • How to take breaths • How to communicate with medical staff during the procedure • Management of anxiety and pain during the procedure
Follow-up management	• Discharge Nursing care • Daily living management • Physical symptoms after discharge	• Description using PPT	• Description of possible discomfort after the procedure • Precautions after discharge • Return to daily life • Hospital visit circumstances

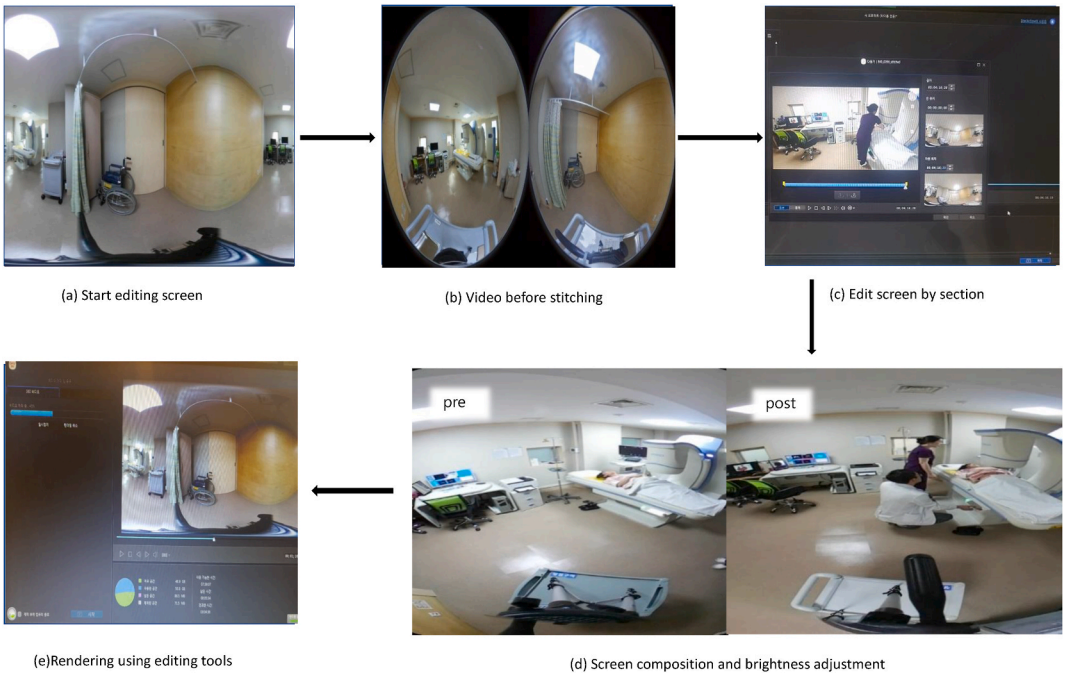

Fig. 2. Virtual reality education program editing and production proc.

Table 2
Homogeneity of the characteristics of the two groups ($N = 54$).

Characteristics	Category	Exp.(n = 26) N (%) or M±SD	Cont.(n = 28) N (%) or M±SD	t or x^2	p
Age(years)		44.00 ± 4.95	43.82 ± 5.29	0.12	.899
State of marriage	Married	24(92.4)	22(78.6)	2.34[a]	.598
	Single	1(3.8)	3(10.7)		
	Divorced	1(3.8)	3(10.7)		
Level of education	High school	14(53.8)	7(25.0)	4.72	.058
	College	12(46.2)	21(75.0)		
Occupation	Yes	12(46.2)	16(57.1)	0.65	.419
	No	14(53.8)	12(42.9)		
Type of residence	Alone	1(3.8)	2(7.1)	1.61[a]	1.000
	With spouse	2(7.7)	2(7.1)		
	With children	22(84.7)	21(75.0)		
	With parents	1(3.8)	3(10.8)		
Experience of delivery	Yes	22(84.6)	22(78.6)	0.32[a]	.414
	No	4(15.4)	6(21.4)		
Method of delivery[b]	Normal	18(81.8)	16(72.7)	1.22	.541
	C-section	4(18.2)	6(27.3)		
Times of delivery[b]	1	7(31.8)	6(27.3)	0.11[a]	1.000
	2	14(63.7)	15(68.2)		
	3	1(4.5)	1(4.5)		
Experience of abortion	Yes	18(69.2)	14(50.0)	2.06	.151
	No	8(30.8)	14(50.0)		
Type of abortion[c]	Artificial	13(72.2)	9(64.3)	0.23	.631
	Miscarriage	5(27.8)	5(35.7)		
Times of abortion[c]	1	13(72.2)	6(42.9)	2.95[a]	.400
	2	3(16.6)	5(35.7)		
	≥3	2(11.2)	3(21.4)		
Uncertainty		77.80 ± 17.23	69.96 ± 13.00	1.89	811
Anxiety		49.88 ± 10.47	45.71 ± 11.77	1.37	176
Pain		0.88 ± 0.76	0.71 ± 0.89	0.74	458

C-section: Cesarean section, M: Mean, SD: Standard deviation.
[a] Fisher exact test.
[b] 44 respondents with delivery experience.
[c] 32 respondents with abortion experience.

required ~20 min to complete and included questions about the general characteristics of participants, uncertainty, anxiety, pain, and satisfaction with nursing care.

2.11. Data analysis

All data were analyzed using SPSS 22 (IBM Corp., Armonk, NY, USA). Values with $p < 0.05$ were considered statistically significant. General and obstetric characteristics are demonstrated as ratios (%) and mean with standard deviation were analyzed using χ^2 and Fisher exact tests. The homogeneity of the experimental and control groups was analyzed using independent t-tests. The effects of uncertainty, anxiety, and satisfaction with nursing care were assessed using independent t-tests, and repeated measures analysis of variance.

3. Results

3.1. Characteristics of the participants

General characteristics, obstetric characteristics, and dependent variables did not significantly differ between the experimental and control groups, indicating their homogeneity (Table 2).

3.2. Effects of the program

The uncertainty and anxiety scores after treatment using VR were significantly lower in the experimental group than in the control group ($t = 4.26$ and $t = 4.09$, $p < 0.001$ for both). Compared to the control group, satisfaction with nursing care scored significantly higher for the experimental group ($t = -4.50$, $p < 0.001$; Table 3). However, pain scores did not significantly differ between the groups ($F = 1.82$, $p = 0.172$; Table 4).

4. Discussion

We developed and verified the effects of a nursing educational program using VR based on the System Development Life Cycle, for women with benign uterine tumors treated using HIFU. The program was developed through analysis, design, implementation, and evaluation.

In the analysis step for constructing educational program contents, we decided on the goals for the VR program, the arrangement of the expert group, and the educational needs required for the program to target women with benign uterine tumors treated using HIFU. The participants reported that they wanted to understand the specific method, procedure, and details of the treatment [34]. Based on the responses of participants during interviews to determine their educational needs for nursing and literature reviews, we classified their educational needs based on procedure preparation, actual procedure, and follow-up care. Details on procedure preparation and follow-up care were explained to the participants via handouts. The participants wanted to know the environment of the procedure room and understand the treatment process in detail. Patients preparing for colorectal surgery express significant educational needs, seeking comprehensive information from healthcare professionals. They seek details on the overall treatment procedure, environment, and pain management to reduce uncertainty and anxiety [35]. Therefore, nurses must ensure that patients understand the situation clearly and recognize their educational needs accordingly. Ultimately, the educational content needed to include a description of the procedure environment, position during the procedure, breathing method, communication with healthcare professionals during the procedure, and anxiety and pain management during the procedure. The validity of the content of the nursing educational program for this study was verified by a group of experts.

In the second step of program development, the overall educational contents were designed based on the analysis step. During the development of the educational program using VR, we drafted an educational content scenario, and VR scenes were composed and designed. To help participants receiving the HIFU treatment obtain the information efficiently, a leap motion interface program using hand movements was designed. Additionally, educational contents were arranged with consistency based on the analysis to facilitate the ability of the participants to understand the program.

During the implementation step, the program was revised and supplemented by experts to ensure that the educational program using VR could be applied in actual clinical settings. Fig. 2 displays the following details: images filmed with the 360° camera are stitched, combined, edited, and rendered to create a 360° video. To make the educational video realistic, the actual voice of an

Table 3
Differences of uncertainty, anxiety and satisfaction of nursing after treatment among the two groups ($N = 54$).

Variables	Exp. (n=26)	Cont. (n=28)	t	*p*
	M±SD	M±SD		
Uncertainty	56.61 ± 9.45	69.64 ± 12.63	4.26	<.001
Anxiety	45.71 ± 11.77	37.03 ± 7.54	4.09	<.001
Satisfaction of nursing	49.00 ± 3.42	42.03 ± 7.16	−4.50	.001

M: Mean, SD: Standard deviation.

Table 4
Pain level after VR nursing educational intervention among the two groups ($N = 54$).

Time	Exp. (n = 26)	Cont. (n = 28)	F(p)
	M±SD	M±SD	
Admission	0.88 ± 0.76	0.71 ± 0.89	Group 2.66(.014)
Pre-test	0.76 ± 0.76	0.82 ± 0.98	Time 38.75(.001)
Post-test	2.61 ± 1.47	2.75 ± 1.73	Group × time 1.82(.172)

M: Mean, SD: Standard deviation.

investigator (who is also a nurse) during a training session was recorded, and subtle background music was incorporated. We inserted captions at the bottom of the screen to facilitate understanding and emphasize important content in the video. Including footage of nurses providing care to patients in the video served to alleviate apprehension among viewers. The final video can be viewed with an HMD that can display 360° video clips. The leap motion interface using hand movements can be applied interactively without having to remember the gestures of the participants.

In the evaluation step of program development, we compared the level of uncertainty, anxiety, pain, and satisfaction with nursing care among 26 and 28 participants in the experimental and control groups, respectively. We used pre-and post-tests and assessed the effects of our nursing educational program using VR. The experimental group that received the educational program using VR had lower scores for uncertainty and anxiety, and significantly higher scores for satisfaction with nursing care, compared to those of the control group.

The impact of anxiety, uncertainty, and pain on women with benign tumors undergoing HIFU has not been investigated using VR. However, women with uterine tumors who plan to be treated using HIFU might be concerned due to an uncertain prognosis and insufficient information about the treatment [34].

When HIFU treatment proceeded without anesthesia, patients were anxious about the pain caused by the ultrasound and were uncertain about being unable to complete the treatment. This result was in line with the finding that uncertainty decreased when patients were provided with a video education program before initiating HIFU treatment [36]. Although treatment methods and interventions differed from the present focus, preoperative education delivered using video to patients scheduled for hysterectomy effectively reduced their uncertainty [12]. The utilization of videos as part of preoperative preparation for spinal surgery has demonstrated effectiveness in reducing anxiety among patients [37]. The present results concurred with the finding that providing video education to patients about their treatment reduced uncertainty. Our findings also partially concurred with the fact that using PowerPoint presentations or brochures reassured older patients undergoing total knee replacement by reducing uncertainty [38]. The aforementioned results indicate that visual educational materials with easily comprehensible content, pictures, and illustrations comprise effective interventions for nurses.

One of the key responsibilities of nurses is to appropriately educate patients; thus, appropriate media must be developed and different structural methods must be identified in the actual work environment to create the most effective education modality [31]. The educational needs of patients and 3D content should be investigated to increase effectiveness [13,21].

As a result of this study, the needs of nursing education for women with benign uterine tumors were identified in advance through literature reviews and interviews. The educational content was divided into procedural preparation, procedure, and post-procedural follow-up. We developed an educational program using VR that provided improved conformity with experience [39] and significantly reduced levels of uncertainty among patients.

For patients scheduled to receive treatment, the prospect of an unexpected situation, an unfamiliar hospital environment, and concerns about complications can cause anxiety. The educational program using VR provided a good sense of reality through various simulations, enabling patients to face frightening situations more vividly. In other words, the level of anxiety decreases when patients realize that situations where they may feel troubled or anxious do not occur [15–18]. Our patients directly experienced the surgical procedure in advance through VR, which was effective. Therefore, direct interviews and educational programs using VR worked as interventions for physical, emotional, and educational support, and helped to reduce anxiety among the participants.

Patients undergoing laparoscopic hysterectomy have been presented with a mock-up, educational video, and leaflets to guide them regarding post-procedural pain management. Thereafter, the experimental and control groups did not significantly differ in terms of pain [37–39]. The ineffectiveness of the educational program for pain management can be attributed to several factors, including the timing of pain evaluation, insufficient educational content, and a lack of consideration for the participants' characteristics. Thus, pain levels need to be measured at various points during treatment, as the timing of the measurement can influence the outcome. The level of pain ($p = 0.001$) experienced by the participants in this study significantly decreased over time. However, the interaction between the group and time ($F = 1.82$, $p = 0.172$) did not reach significance. This might be because patients with uterine leiomyoma who received non-invasive HIFU were discharged on the same day, so the average pain score was ≤ 5 [10]. Patients with benign uterine tumors who undergo HIFU treatment without anesthesia experience anxiety and fear before the procedure, which may negatively affect the pain they briefly experience during the procedure. The educational program using videos before undergoing surgery [40] resulted in a significant difference in satisfaction with post-procedural nursing care in the experimental group. These results indicate that providing necessary information to patients as a part of nursing intervention increases their level of knowledge and can positively affect their satisfaction with nursing care.

Therefore, experiencing the procedure through a VR educational program increased satisfaction with nursing care. Tailoring education content to address the specific information needs of patients and incorporating experimental measures, including 3D content,

are also effective methods of intervention [14,21,34].

Uncertainty and anxiety in patients with benign uterine tumors treated by HIFU might affect post-procedural pain and health status after discharge. Hence, nursing interventions to reduce uncertainty, anxiety, and pain are required in the clinical environment [34]. Therefore, we used an educational program using VR as a nursing intervention. This helped patients to be less terrified by exposing them to appropriate situations in advance. This verified the positive impact of the program on levels of uncertainty, anxiety, and satisfaction with nursing care.

This study had a few limitations. The results cannot be generalized because this study proceeded in two hospitals and the participants comprised a convenient sample of women diagnosed with benign uterine tumors. Therefore, different contexts and groups should be studied in the future to replicate our results.

Blinding was not possible and this might have led to bias in the results. Nevertheless, investigators were careful to be fair in terms of providing interventions during the study. We determined *a priori* whether the two hospitals and participants were homogeneous. The average age of our participants was >40 years and they had never experienced VR.

Despite these limitations, we reduced anxiety and uncertainty in women with benign tumors before undergoing HIFU treatment. The technology of VR is expanding across disciplines. Therefore, our findings might contribute to clinical interventions in various fields.

5. Conclusions

This is the first educational program for HIFU treatment using VR applied to patients with benign uterine tumors. This intervention reduced uncertainty and anxiety and increased satisfaction with nursing care.

Our findings might contribute to the development of new treatment strategies and serve as basic data to advance related treatment protocols.

The necessity and importance of converged multi-disciplinary investigations are now widely acknowledged due to the advancement of science and technology. Among these, VR technology will have substantial effects and relevance in the future. This study is meaningful in that it developed an educational program by adopting VR technology for hospitalized patients. We propose nursing research with integrated disciplines according to advanced treatment methods and technological development in the future.

6. Ethics approval and consent to participate

This research was approved by The Institution Review Board (IRB) at Keimyung University in South Korea (IRB No. 40525-201710-HR-62-01).

7. Availability of data and materials

Data will be made available on request.

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CRediT authorship contribution statement

Seo A. Park: Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jumi Lee:** Writing - review & editing, Validation. **Hye Young Kim:** Writing - original draft, Visualization, Supervision, Software, Resources, Project administration.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e23759.

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