Original Research Article

DIGITAL HEALTH

DIGITAL HEALTH
Volume 10: 1–15

DOI: 10.1177/20552076241239244
journals.sagepub.com/home/dhj

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A scenario-based web app to facilitate patient education in lung tumor patients undergoing video-assisted thoracoscopic surgery: Development and usability testing

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Abstract

Background: Patient education (PE) is essential for improving patients' knowledge, anxiety, and satisfaction, and supporting their postoperative recovery. However, the advantages of video-assisted thoracoscopic surgery (VATS)—smaller incisions and faster recovery—can result in shorter hospital stays, making PE more challenging to implement effectively. Multimedia PE can potentially enhance PE, but its effectiveness for patients undergoing VATS is unclear.

Objective: This study developed a scenario-based PE web app for lung tumor patients undergoing VATS (SPE-VATS) to facilitate the PE process and evaluated its usability through a clinical trial.

Methods: The SPE-VATS provided the experimental group (EG: 32 participants) with interactive scenario, query guidance, diagnostic analysis, experience sharing, and active reminder, while the control group (CG: 32 participants) used pamphlets and videos. The usability of SPE-VATS in terms of postoperative anxiety reduction and patient satisfaction with the app was evaluated using self-reported questionnaires based on the state-trait anxiety inventory, technology acceptance model, system usability scale, and task load index.

Results: There was no statistically significant difference in postoperative anxiety reduction between the EG and CG, possibly because 90% of the participants underwent a low-risk surgical type, and VATS is known to be advantageous in alleviating surgical anxiety. However, females and higher educated EG participants showed a non-significant but favorable reduction than their CG counterparts. Moreover, the EG was highly satisfied with the app (rated 4.2 to 4.4 out of 5.0), with no significant gender and education level difference. They particularly valued the interactive scenario, experience sharing, and diagnostic analysis features of SPE-VATS.

Conclusions: The SPE-VATS demonstrated its usability and high patient satisfaction, particularly for female and higher educated patients. Low-risk patient predominance and VATS's advantages may explain non-significant postoperative anxiety reduction, warranting further studies on high-risk patients to evaluate the impact of SPE-VATS on clinical practice.

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Keywords

Patient education, video-assisted thoracoscopic surgery, lung tumor, postoperative anxiety, patient satisfaction, web app, usability testing

Submission date: 6 November 2023; Acceptance date: 27 February 2024

Introduction

Video-assisted thoracoscopic surgery (VATS) is a minimally invasive surgical procedure used to treat chest conditions, such as lung tumor, using small incisions and a thoracoscope for visualization.[1] VATS has some advantages over open surgery, e.g. reduced pain and faster recovery. Nevertheless, patients' postoperative stress reactions and complications are still important factors that affect and limit their surgical efficacy, postoperative recovery, and quality of life. Effective nursing interventions have been shown to improve patient treatment outcomes and postoperative recovery.[2]

Research has shown that anxiety is common among surgical patients (60% to 92%)[3]; it is also one of the predictive factors for postoperative pain.[4] In addition to leading to poorer postoperative outcomes, longer hospital stays, and patient dissatisfaction,[5,6] it also decreases the retention of care information provided during education sessions.[7] Postoperative anxiety has implications for ongoing care and prognosis prediction in lung resection patients.[8–10] Therefore, it is critical to address operative anxiety experienced by patients undergoing surgery.

Patient education (PE) has been proven to successfully reduce anxiety in patients and their families, better prepare them for postoperative issues, improve their compliance with medical advice, reduce pain, increase self-efficacy, and support their activities during the postoperative recovery phase.[5,8–12]

Multimedia refers to the use of various types of media, including text, graphics, audio, video, and animation, in a digital environment to create interactive and engaging content. Multimedia patient education (MPE) has been demonstrated to help improve patient knowledge, reduce anxiety, and increase patient satisfaction with the surgery.[13–16] However, research has also found that MPE does not always show significant benefits compared to traditional education methods (e.g. leaflets or pamphlets).[17,18] Its effectiveness is related to the disease type, surgical type, age, ethnicity, education level, and health literacy of the patients.[19,20]

For example, video-based MPE can increase the knowledge of Mohs micrographic surgery patients but does not mitigate their anxiety or improve their satisfaction with the surgery,[21] nor does it reduce anxiety in children during induction of anesthesia.[22] Animation-based MPE demonstrates more effective than video-based MPE in illustrating dynamic processes.[12] App-based MPE, e.g. integrating interactive anatomic diagrams, surgical videos, and radiology images, can improve the knowledge and satisfaction of patients with lung cancer[23] but may not reduce anxiety,[24] especially for adult patients.[18]

As patients undergoing VATS typically have a hospital stay of only about four days,[25,26] and most are admitted the day before surgery, they typically have little time for surgical PE or getting adjusted to the surgical process.[27] In addition, studies have found that patients with lower health literacy and education levels may have difficulty understanding the content of MPE.[19,20,28,29] In addition, female patients usually exhibit higher surgical anxiety than males.[30] Therefore, it is crucial to improve the effectiveness of PE so that it is comprehensible to patients.[18,31] However, research on postoperative anxiety in VATS patients is limited,[9] and previous studies[19,20,28,29] emphasized the importance of designing and developing an effective MPE system that is not affected by PE level, which is difficult to achieve with traditional MPE. As a result, the main concern of this study is to develop an effective method to facilitate surgical PE for VATS patients, with the aim of reducing their postoperative anxiety and ensuring their satisfaction with the PE process.

However, MPE's effectiveness in improving patient anxiety and satisfaction remains inconsistent.[32] Studies indicated that surgical patients' unfamiliarity with the surgical process and environment can lead to uncertainty, which contributes to anxiety.[27] Therefore, familiarizing patients with the surgical scenario, including procedures, hospitalization, and the environment, could reduce anxiety and improve satisfaction.[33,34] This aligns with the limitations of multimedia in providing authentic learning experiences.[35] Situated learning theory emphasizes the necessity of authentic learning contexts,[36] advocating for direct engagement in authentic or simulated scenarios to facilitate skill development. Scenario-based learning follows the principles of situated learning theory[37] and employs interactive scenarios to foster decision-making and problem-solving in a safe, technology-driven environment to motivate learners to take the initiative in learning and solve real-world problems.[38–40]

Therefore, based on scenario-based learning, this study developed a scenario-based PE web app for lung tumor patients undergoing VATS (SPE-VATS) to facilitate the PE process. The SPE-VATS enables patients to virtually

experience the VATS and understand the relevant knowledge effectively by using the app's various features: interactive scenario, query guidance, diagnostic analysis, experience sharing, and active reminder.

The objective of this study was to evaluate the usability of the SPE-VATS compared to traditional video-based MPE through a clinical trial. Self-reported questionnaires, including state-trait anxiety inventory (STAI), technology acceptance model (TAM), system usability scale (SUS), and task load index (NASA-TLX), were employed to evaluate its effectiveness in reducing postoperative anxiety in VATS patients and to understand their overall satisfaction with the app. Additionally, we also compare the app's effectiveness for PE among patients with different education levels and genders.

The research questions in this study are listed as follows:

1. Does SPE-VATS efficiently reduce postoperative anxiety in lung tumor patients undergoing VATS compared with the traditional method?
2. Does SPE-VATS achieve a high level of system satisfaction from patients' feedback?
3. Are there differences in system perception regarding SPE-VATS among patients with varying education levels and genders?

Methods

Study design

The present study was a single-center quasi-experiment design, in which the control group (CG) underwent the experimental procedures before the experimental group (EG) to prevent interference (Figure 1). In total, 64 participants were recruited. They were divided according to the order in which they were admitted to the hospital; the first 32 participants formed the CG, and the next 32 formed the EG. The EG used the SPE-VATS, and the CG received a video-based MPE supplemented with pamphlets. The pamphlets provided information on pre-operative precautions and principles of wound care after discharge. The video-based MPE, which described how to care for the chest drainage tube after surgery and demonstrated pulmonary rehabilitation exercises, was provided to patients on admission day to watch without face-to-face explanation from healthcare workers in the PE room. This study was approved by the Research Ethics Committee of a medical university hospital (A-ER-110-367).

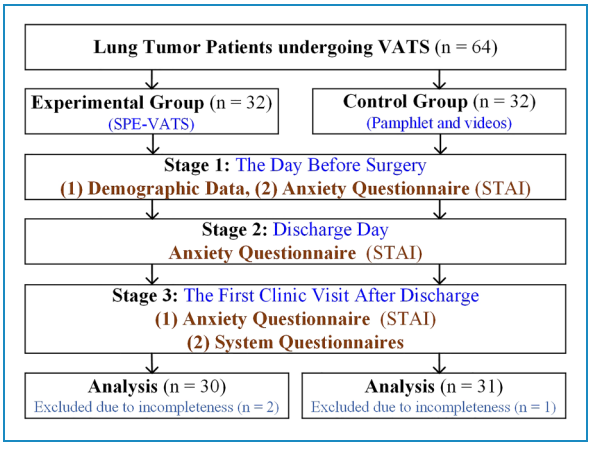

Figure 1. Experimental procedure.

Data collection

Data collection was conducted in three stages. Stage 1 was the day before the surgery. Stage 2 was the day of discharge. Stage 3 was the first clinic visit after the discharge. The patients were administered the same anxiety questionnaire in all three stages with their consent. In addition, patients in the EG completed system questionnaires to provide feedback on their experience and opinions of using the SPE-VATS. Demographic data, including age, gender, level of education, length of hospitalization, and basic surgery information, were also collected (see Table 2).

Patients typically completed the anxiety questionnaire before they received their final pathological diagnosis at their first clinic visit after discharge (Stage 3). Patients with suspected malignant tumors who underwent prior biopsy confirmation (hereafter referred to as "biopsy-confirmed patients") were an exception, as they had already received their final pathological diagnosis before completing the anxiety questionnaire.

Participants and clinical trial setting

Patients were eligible for inclusion if they were scheduled to undergo any VATS for wedge, segmentectomy, lobectomy, or pneumonectomy. All patients scheduled for VATS were screened for inclusion based on purposeful sampling. The inclusion criteria were (a) consent to participate, (b) first-time undergoing routine lung resection surgery, (c) aged 18 years or older, (d) alert and able to read and understand Chinese, and (e) owned a personal mobile phone or a family member's phone that can download healthcare education materials and use the SPE-VATS. The exclusion criteria were (a) refusal to participate, (b) significant visual or auditory impairments, and (c) inability to operate a mobile phone or unavailability of any family member or caregiver who can assist. The recruitment was conducted in the hospital ward and the outpatient area.

Scenario and features of the SPE-VATS

Research found that illness-related information, self-management skills, and psychosocial support are essential for effective PE interventions,[41] and interactive technology

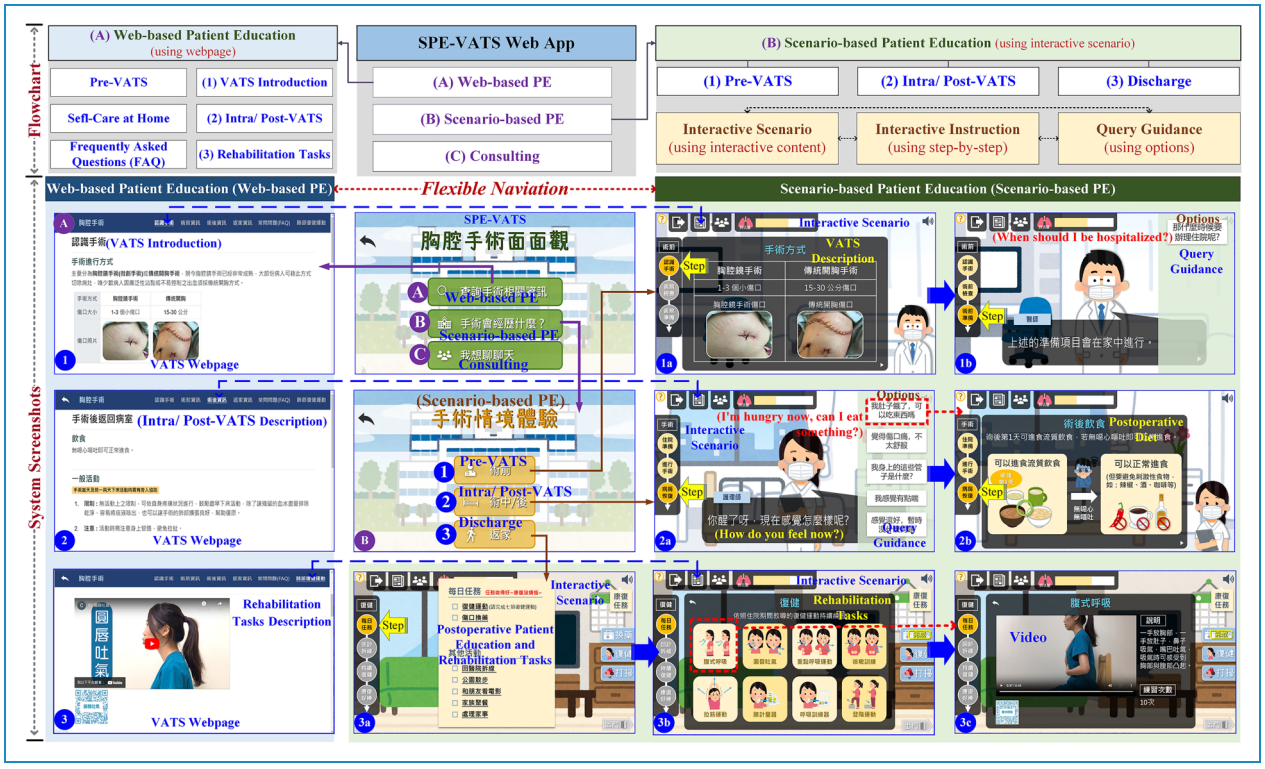

Figure 2. Screenshots of the features in the SPE-VATS.

may be more effective than passive technology in PE.[18] Therefore, the SPE-VATS was developed based on these essential elements. Figure 2 shows the scenario and features of the SPE-VATS. The app offers traditional web-based PE for detailed information (Figure 2A) and scenario-based PE for interactive scenario (Figure 2B). The scenario-based PE feature provides pre-, intra-, and post-VATS scenarios to allow patients to experience the surgery virtually and understand the necessary information effectively. They can understand the VATS scenarios and information step-by-step in each stage through the interactive scenario (Figure 2B.1a – Figure 2B.3c). In the process, the app offers different options through Query Guidance to guide the patients to understand VATS information systematically, such as when to be hospitalized (Figure 2B.1b), whether to eat after surgery (Figure 2B.2a) and what the postoperative rehabilitation tasks are (Figure 2B.3a-3c). The app also provides Flexible Navigation to allow patients to switch freely between web-based PE and scenario-based PE, which can improve the query efficiency, for example, pre-VATS (Figure 2B.1a and Figure 2A.1), intra/ post-VATS (Figure 2B.2a and Figure 2A.2), and discharge (Figure 2B.3b and Figure 2A.3).

Scenario-based Questions are provided during the interactive scenario to assess patients' understanding of the content of VATS PE (Figure 3A-3B). SPE-VATS offers patients a Diagnostic Report to assist their reflection and error correction (Figure 3C). Based on their browsing and query behavior, Active Reminder provides queried items and relevant items not yet queried (Figure 3D) to quickly access web-based PE for review and reference (Figure 3E). The app also offers Consulting with Different People feature to facilitate topic-based virtual professional consultations with medical personnel (Figure 4A) and other recovering patients for experience sharing (Figure 4B). Query Guidance is also used to assist patients in understanding the content of VATS PE. Patients can also use the Additional Questions feature to inquire about other concerns (Figure 4A.1.a-c).

Measurement instruments

Postoperative anxiety questionnaire. The postoperative anxiety of the participants was evaluated by the STAI, which is a widely used self-report questionnaire designed to assess the state and trait aspects of anxiety. State anxiety refers to a temporary emotional state characterized by feelings of nervousness and uncertainty in response to a specific situation or event. Trait anxiety refers to a more stable and persistent tendency to experience anxiety across a variety of scenarios. The STAI consists of 20 items for each type of anxiety; the final score ranges from 20 to 80 points, with higher scores indicating a more intense state of anxiety.[42,43]

Perception of the system. The SUS[44] and the NASA-TLX[45] were used to assess participant satisfaction with SPE-VATS. SUS is a reliable tool for measuring usability perception, with scores above 70 considered acceptable and

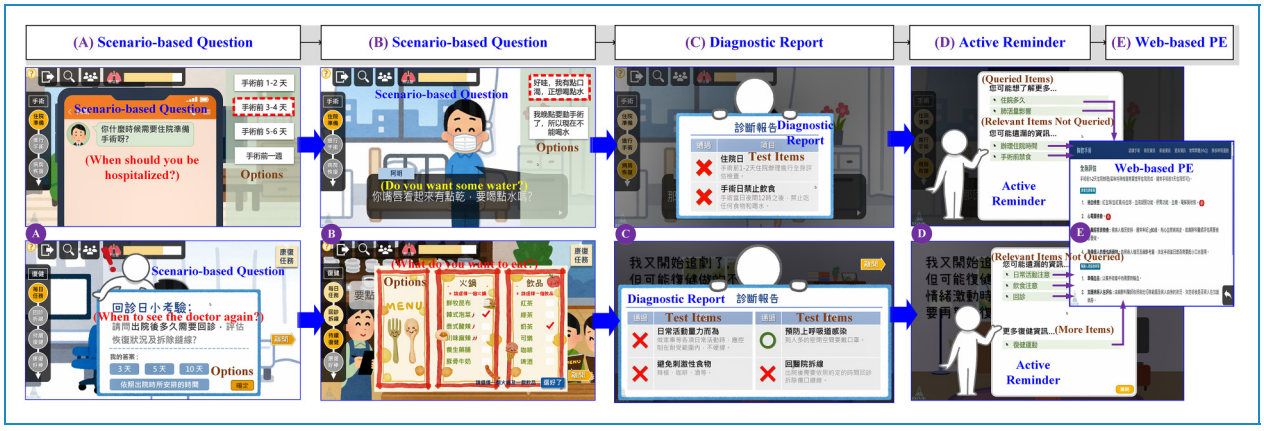

Figure 3. Scenario-based question and diagnostic report in the SPE-VATS. VATS: video-assisted thoracoscopic surgery.

Figure 4. Consulting with different people in the SPE-VATS. VATS: video-assisted thoracoscopic surgery.

74.1 to 77.1 indicating good usability.[46] The NASA-TLX, a validated tool,[47] measures mental workload during tasks. The TAM, a widely used framework in information systems research, explains computer usage behavior.[48] The system satisfaction questionnaire, designed based on TAM,[48–50] examined users' behavioral intentions to use the SPE-VATS and defined eight external variables for the system's effect. Table 1 describes the purpose of each measurement scale.

Table 1. Purpose of each measurement scale of the system satisfaction questionnaire (5-point Likert scale: 1 = strongly disagree; 5 = strongly agree).

Measurement scale	Purpose
Interactive scenario	To measure the effectiveness of the SPS-VATS' interactive scenario in assisting with querying and promoting an understanding of the PE content about VATS
Query guidance	To measure the effectiveness of actively guiding patients based on their query behavior in the app
Diagnostic report	To measure the usefulness of the scenario-based PE tests and diagnostic reports in the app
Experience sharing	To measure the usefulness of the app's interactive scenario containing patients' narratives and experience sharing
Anxiety reduction	To measure the effectiveness of the app in reducing anxiety in VATS patients
Comparison	To compare the assistance effects of the app to those of other systems that have been used in terms of information query and understanding
Recommendation	To measure the user's willingness to recommend this app to other patients
satisfaction	To measure the user's attitude toward using the app
Intention to use (ItU)	These scales are based on the TAM model[48–50] to measure: ItU: the behavioral intention to use the app in the future. Use: the user's perception of the app's use on performance improvement. EoU: the user's perception of the effort level required for using the app. IMG: the user's impression of the app on adoption willingness.[49] QUA: the user's perception of the app's output.[49] ENJ: the user's perception of the app's fun and engaging.[50]
Usefulness (Use)	
Ease of use (EoU)	
Image (IMG)	
Output quality (QUA)	
Enjoyment (ENJ)	

PE: patient education; VATS: video-assisted thoracoscopic surgery; TAM: technology acceptance model.

Permission of measurement instruments. Regarding the SUS permission, in Brooke's article,[44] the author described that "*SUS has been made freely available for use in usability assessment, and has been used for a variety of research projects and industrial evaluations; the only prerequisite for its use is that any published report should acknowledge the source of the measure*." Regarding the NASA-TLX permission, the NASA-TLX website[51] states that "*The NASA TLX tool is 'open source', and is therefore available for immediate use by any person or organization (worldwide). It is not necessary to obtain permission from NASA to use TLX, nor is permission needed to make modifications to the tool itself (i.e. language translation).*" Moreover, this study has obtained permission to use the TAM questionnaire from Professor Davis for TAM[48] and Professor Venkatesh for TAM2[49] and TAM3.[50] The license to administer the STAI[43] is available from MindGarden.com.

Statistical analysis

Chi-Square test, independent sample *t*-test, and Mann–Whitney U test compared EG and CG outcomes. Paired sample *t*-test and Wilcoxon signed rank test compared anxiety changes within the same group pre- and post-intervention. Analysis of covariance assessed post-intervention effectiveness between groups while controlling for pre-intervention differences. Subgroup analysis (<30 participants each) employed Wilcoxon signed rank and Mann–Whitney U tests to ensure statistical power. Spearman correlation coefficient r_s measured variable correlation, with a range from 0.3 to 0.5 indicating fair to moderate correlation.[52,53]

Results

Participants

From 10 February 2022 to 20 November 2022, 64 lung tumor patients underwent VATS at the hospital. Sixty-one patients (72.1% females) were included in the follow-up analysis. Thirty patients were assigned to the EG (SPE-VATS) and 31 to the CG (pamphlets and videos). Table 2 presents the patients' demographics and clinical characteristics. Patients had an average age of 52 (32–75 range). A two-tailed chi-square test showed no statistically significant differences ($p > 0.05$) between the groups regarding demographic variables.

Analysis of postoperative anxiety

Primary outcome. Table 3 shows the STAI scores for each stage, and Table 4 presents the results of the comparison analysis between the STAI scores of the EG and the CG. The postoperative anxiety levels of both groups significantly decreased in Stages 2 and 3 compared with Stage 1, but there was no significant difference between the two groups. The internal consistency of the STAI questionnaire in this study was reliable (Cronbach's $\alpha = 0.883$).

Subgroup analysis. The following subgroup analysis focuses on comparing the state anxiety score because it measures a temporary emotional state.

Table 2. Demographics and clinical characteristics of the patients in the EG and CG.

	EG (n = 30)	CG (n = 31)	*p*-value
Gender (females%)	20 (66.6%)	24 (77.4%)	.402
Age (SD)	51.1 (10.5)	52.6 (11.2)	.596[b]
Education level (%)			.281
Elementary to high school (EH)	8 (26.7%)	13 (41.9%)	
Elementary school or below	0 (0.0%)	4 (12.9%)	
Middle school	2 (6.7%)	1 (3.2%)	
High school	6 (20%)	8 (25.8%)	
College or university (CU)	22 (73.3%)	18 (58.1%)	
Associate's degree	17 (56.6%)	15 (48.4%)	
Bachelor's degree or above	5 (16.7%)	3 (9.7%)	
Marital status (%)			.554
Married	24 (80%)	22 (71%)	
Single/widowed	6 (20%)	9 (29%)	
Pathological diagnosis (%)			.799
Malignant	16 (53.3%)	18 (58.1%)	
Benign	14 (46.7%)	13 (41.9%)	
Resection type[a] (%)			.860
VATS wedge	17 (56.7%)	20 (64.5%)	
VATS segmentectomy	10 (33.3%)	8 (25.8%)	
VATS lobectomy	3 (10.0%)	3 (9.7%)	
VATS pneumonectomy	0 (0%)	0 (0%)	
Inpatient days (SD)	4.5 (0.9)	4.6 (1.6)	.654[b]
Psychotropic medication (yes%)	3 (10.0%)	3 (9.7%)	1.00
Biopsy-confirmed patients (yes%)	0 (0.0%)	2 (6.5%)	.492

aArranged in ascending order based on surgical risk level; bindependent sample *t*-test; SD, standard deviation; VATS: video-assisted thoracoscopic surgery; CG: control group; EG: experimental group.

In the gender analysis, no significant gender-based differences were observed between and within the EG and CG groups (Table 5). However, significant differences were observed in female patients within each group, but not in male patients. State anxiety was significantly reduced in Stage 2 for female patients in the CG. For female patients in the EG, state anxiety was significantly reduced in Stages 2 and 3. Further analysis of gender demographics for the EG and CG groups, both within and between groups, revealed no significant differences. These findings

Table 3. State-trait anxiety inventory (STAI) scores.

	State score			Trait score		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
CG (n = 31)	45.4 (13.6)	37.9 (9.9)	39.8 (10.9)	43.7 (10.2)	40.6 (9.6)	39.6 (9.2)
EG (n = 30)	48.4 (11.9)	39.9 (12.1)	41.8 (12.6)	42.9 (8.0)	39.2 (7.2)	39.2 (7.8)

CG: control group; EG: experimental group.

Table 4. Differences in the STAI scores between the groups and the stages (*p*-values).

	State score			Trait score		
	Stage 1 vs. 2	Stage 1 vs. 3	Stage 2 vs.3	Stage 1 vs. 2	Stage 1 vs. 3	Stage 2 vs.3
CG[a]	.039*	.014*	.437	.039*	.014*	.437
EG[a]	.023*	.015*	.974	.023*	.015*	.974
EG vs. CG[b]	.764	.786		.608	.959	

*$p < .05$, **$p < .01$, ***$p < .001$; aPaired sample *t*-test; bAnalysis of covariance; SD: standard deviation; STAI: state-trait anxiety inventory; CG: control group; EG: experimental group.

Table 5. State anxiety scores by gender groups (Wilcoxon signed rank test).

		State score				
		Stage 1	Stage 2	Stage 3	1 vs. 2	1 vs. 3
		Mean (SD)	Mean (SD)	Mean (SD)	*p*-value	*p*-value
CG	Male (n = 7)	44.7 (12.7)	36.4 (12.2)	35.0 (11.7)	.128	.108
	Female (n = 24)	45.7 (14.1)	38.3 (9.4)	41.3 (10.5)	.006**	.156
	Male vs. Female (*p*-value)[a]	.925	.636	.185		
EG	Male (n = 10)	47.2 (11.5)	40.7 (13.0)	44.5 (15.6)	.192	.514
	Female (n = 20)	49.1 (12.4)	39.6 (11.9)	40.5 (11.0)	.006**	.003**
	Male vs. Female (*p*-value)[a]	.509	.965	.809		
CG vs. EG	Male (*p*-value)[a]	.769	.406	.204		
	Female (*p*-value)[a]	.234	.768	.962		

*$p < .05$, **$p < .01$, ***$p < .001$; aMann–Whitney U test; SD: standard deviation; CG: control group; EG: experimental group.

suggest that the use of the SPE-VATS may be more effective than traditional MPE in reducing postoperative anxiety in female patients, although there were no significant differences observed between the EG and CG groups.

In the education level analysis, patients were further divided into EH and CU groups by education level (see Table 2). Table 6 revealed no significant postoperative anxiety differences between the CG and the EG based on

Table 6. State anxiety scores by education level (Wilcoxon signed rank test).

		State score				
		Stage 1	Stage 2	Stage 3	1 vs. 2	1 vs. 3
		Mean (SD)	Mean (SD)	Mean (SD)	*p*-value	*p*-value
CG	EH (n = 13)	51.6 (14.2)	43.8 (8.6)	42.6 (10.0)	.036*	.084
	CU (n = 18)	40.9 (11.6)	33.6 (8.7)	37.8 (11.4)	.016*	.191
	EH vs. CU (*p*-value)	.060[a]	.005**[a]	.221[a]		
EG	EH (n = 8)	52.5 (8.6)	47.1 (9.9)	44.1 (8.9)	.399	.028*
	CU (n = 22)	47.0 (12.8)	37.4 (12.0)	41.0 (13.8)	.005**	.031*
	EH vs. CU (*p*-value)	.231[a]	.046*[a]	.313[a]		
CG vs. EG	EH (*p*-value)	.690[a]	.537[a]	.611[a]		
	CU (*p*-value)	.161[a]	.320[a]	.531[a]		

* $p < .05$, ** $p < .01$, *** $p < .001$; aMann–Whitney U test; bAnalysis of covariance; SD: standard deviation; EH, elementary to high school; CU, college or university; CG: control group; EG: experimental group.

education level. The CU groups in the EG and CG showed a significant reduction in state anxiety than the EH groups in Stage 2. These findings suggest that a higher education level may contribute to a more significant reduction in postoperative anxiety. In the EG, the CU group demonstrated significant reductions in state anxiety in Stage 2 and Stage 3, and the EH group also showed a significant reduction in state anxiety in Stage 3. In contrast to the CG, the EH and CU groups only exhibited a significant reduction in state anxiety in Stage 2. These findings show that the EG's CU group may be more effective in anxiety improvement than the CG's CU group.

Further analysis of the demographic differences in education level between the EG and CU groups revealed no significant differences. However, the CU and EH groups showed significant age differences within each group. In the EG, the average age for the CU group was 48.64 (10.76) compared to 57.88 (6.11) years for the EH group ($p = .029$, $z = -2.185$). Similarly, in the CG, the average age for the CU group was 47.89 (9.57) compared to 59.08 (10.14) for the EH group ($p = .004$, $z = -2.908$). This phenomenon aligns with current educational trends, where opportunities for higher education are more accessible than ever, leading to a younger average age for the CU group compared to the EH group.

Analysis of patient satisfaction

Table 7 presents the analysis results of the system satisfaction questionnaire overall, by gender, and by educational level. Overall, all scale scores were greater than 4.2 (4.2–4.4 range), indicating that users were highly satisfied with the SPE-VATS. The mean SUS score was 68.8 (SD: 14.5) out of 100, indicating a marginal-acceptable level.[46] The Task Load score was 40.9 (12.9) out of 100, indicating a low mental workload. In this study, Cronbach's alpha values were 0.980 for the system satisfaction questionnaire, 0.847 for SUS, and 0.913 for NASA-TLX, indicating high reliability across all questionnaires.

Regarding the satisfaction analysis by gender, all scale scores were greater than 4.1 (4.1 to 4.5 range), and no significant differences were observed between females and males. The SUS and Task Load scores also showed no significant differences, indicating that gender did not significantly affect patient feedback for the SPE-VATS.

Regarding the satisfaction analysis by education level, the elementary to high school (EH) and college or university (CU) groups exhibited no significant differences in all scales of the system satisfaction questionnaire. Furthermore, the CU group did not significantly differ from the EH group in the SUS but did in the Task Load ($p = .008$), indicating that although the education level did not influence the use of the SPE-VATS, the EH group did experience a higher mental load when using it.

Correlation among the variables

The analysis in Table 8 found that older patients had higher Task Load ($r_s = .440$, $p = .015$), but SUS scores were not correlated with age. Patients with higher education levels

Table 7. Differences in system satisfaction, SUS, and task load scores between gender and education level groups using the Mann–Whitney U test.

	Overall	Gender			Education level		
	Mean (SD)	Male	Female	*p*-value	EH	CU	*p*-value
Interactive situation	4.3 (0.6)	4.5 (0.5)	4.3 (0.6)	.442	4.1 (0.6)	4.4 (0.6)	.271
Query guidance	4.3 (0.6)	4.2 (0.5)	4.3 (0.6)	.593	4.1 (0.2)	4.3 (0.6)	.234
Diagnostic report	4.3 (0.6)	4.3 (0.5)	4.3 (0.7)	.880	4.5 (0.4)	4.4 (0.7)	.239
Case sharing	4.3 (0.5)	4.1 (0.3)	4.4 (0.6)	.173	4.0 (0.0)	4.4 (0.6)	.068
Comparison	4.3 (0.6)	4.3 (0.5)	4.3 (0.6)	.919	4.1 (0.4)	4.3 (0.7)	.329
Enjoyment	4.3 (0.6)	4.1 (0.7)	4.4 (0.5)	.311	4.0 (0.3)	4.3 (0.7)	.108
Anxiety reduction	4.3 (0.6)	4.1 (0.7)	4.4 (0.5)	.270	4.1 (0.4)	4.4 (0.7)	.239
Satisfaction	4.3 (0.5)	4.3 (0.4)	4.3 (0.5)	.669	4.1 (0.3)	4.4 (0.5)	.270
Intention to use	4.4 (0.6)	4.4 (0.6)	4.3 (0.5)	.744	4.1 (0.4)	4.4 (0.6)	.204
Recommendation	4.4 (0.6)	4.5 (0.5)	4.4 (0.6)	.530	4.1 (0.4)	4.5 (0.6)	.073
Perceived usefulness	4.4 (0.6)	4.4 (0.7)	4.3 (0.5)	.640	4.2 (0.4)	4.4 (0.6)	.213
Perceived ease of use	4.2 (0.7)	4.2 (0.7)	4.2 (0.7)	.982	4.0 (0.5)	4.3 (0.7)	.373
Image	4.4 (0.5)	4.5 (0.5)	4.3 (0.5)	.376	4.1 (0.4)	4.5 (0.5)	.111
Output quality	4.2 (0.7)	4.2 (0.9)	4.1 (0.7)	.853	4.0 (0.5)	4.2 (0.8)	.140
SUS	68.8 (14.5)	67.8 (19.7)	69.3 (11.7)	.930	59.7 (14.8)	72.0 (13.2)	.070
Task load	40.9 (12.9)	39.3 (13.8)	41.7 (12.8)	.531	52.5 (12.1)	36.7 (10.6)	.008**

*$p < .05$, **$p < .01$, ***$p < .001$; SD, standard deviation; EH, elementary to high school; CU, college or university; SUS: system usability scale.

Table 8. Spearman correlation coefficients among patient characteristics and system measurement scales.

	Age r_s (*p*-value)	Education level	Resection type	Inpatient days	Pathological diagnosis
Interactive situation	-.118 (.533)	.158 (.404)	.394* (.031)	.321 (.083)	-.160 (.398)
Experience sharing	-.217 (.249)	.397* (.030)	.357 (.053)	.078 (.683)	.019 (.992)
Satisfaction	-.135 (.478)	.124 (.514)	.407* (.025)	.349 (.059)	-.114 (.547)
Ease of use	-.029 (.878)	.046 (.808)	.412* (.024)	.370* (.044)	-.024 (.901)
Image	-.039 (.839)	.228 (.226)	.395* (.031)	.103 (.587)	-.169 (.373)
Output quality	-.044 (.819)	.112 (.556)	.525** (.003)	.103 (.589)	-.118 (.543)
SUS	-.283 (.129)	.375* (.041)	-.020 (.915)	-.112 (.557)	.364* (.048)
Task load	.440* (.015)	-.579** (.001)	-.043 (.821)	.356 (.054)	-.318 (.087)

*$p < .05$, **$p < .01$, ***$p < .001$. SUS: system usability scale.

showed significantly lower Task Load ($r_s = -.579$, $p = .001$), higher SUS ($r_s = .375$, $p = .041$), and greater appreciation for SPE-VATS's Experience Sharing feature ($r_s = .397$, $p = .030$). Notably, patient Resection Type significantly correlated with multiple system measurement scales, indicating that patients with more risky resection types (e.g. VATS lobectomy) were more satisfied with the SPE-VATS ($r_s = .407$, $p = .025$) and significantly more appreciation for the Interactive Scenario functionality ($r_s = .394$, $p = .031$). Patients with higher risk resection types and longer hospital stays (Inpatient Days) had higher Ease of Use ($r_s = .370$, $p = .044$), possibly due to increased system use for surgical information. Additionally, younger patients with benign pathological diagnoses had a more favorable perception of the system's usability (SUS).

Discussion

Analysis of postoperative anxiety reduction

According to the experimental results, there was no significant difference in postoperative anxiety levels on the STAI between the EG and the CG overall. This result is consistent with previous research findings.[13,54,55] Steves and Scafide[18] analyzed the effects of different forms of MPE (video-based, app-based, and program-based) on adults undergoing cancer surgery and found that MPE resulted in decreased anxiety and improved knowledge acquisition within-group, but there was no significant difference when compared with traditional methods.

Besides, virtual, augmented, and mixed reality (VR) technologies have been used for pain management, postoperative rehabilitation, and patient relaxation and education.[56] VR-based MPE provides patients with an enhanced sense of immersion, knowledge acquisition, memorability, and retention.[57] VR-based videos have been found to reduce preoperative anxiety in adult patients undergoing cardiothoracic procedures.[58] VR-based MPE may have similar results, as evidenced by Koo et al.,[34] who found that it was more effective for pediatric patients than for adults. However, VR-based MPE's high development cost, requirement for additional equipment, and limited usability in specific spaces restrict its convenience and ease of use.

Accordingly, MPE does not necessarily outperform traditional methods in reducing anxiety for adult patients. Moreover, MPE may also not be effective in reducing anxiety for children. Nair et al.[22] provided a home preparation kit consisting of an animated video on pre-operative preparation for child patients but found that it did not reduce their anxiety in the pre-operative waiting area or during the induction of anesthesia.

In terms of the resection type, wedge, segmentectomy, lobectomy, and pneumonectomy are ranked from low risk to high risk.[59] Previous studies have found that higher surgical risk is associated with increased patient anxiety.[10] In a study on thoracotomy patients with lung cancer, Cetkin and Tuna[9] found that providing a health education booklet 24 h before surgery significantly reduced postoperative pain and STAI's state anxiety compared with providing only usual clinical nursing information. However, it should be noted that the majority of participants in their study underwent lobectomy and pneumonectomy, accounting for 79.9% in the EG and 83.2% in the CG. Moreover, thoracotomy is traditionally an open surgical procedure, which poses higher physical risks and can cause more pain and anxiety than VATS.

In contrast, the present study had a small number of VATS lobectomy cases in both groups, with only three participants in the EG (10.0%) and three in the CG (9.7%). Additionally, VATS has been reported to have advantages over open surgery in terms of faster postoperative recovery and shorter hospital stays.[25,26] These factors may contribute to the overall lower levels of anxiety in both groups in this study. These findings suggest that the nature of VATS may be one of the reasons for the rapid decrease in postoperative anxiety. It is worth noting that the low percentage of high-risk surgeries such as lobectomy and pneumonectomy in this study may be attributed to the promotion of lung cancer screening campaigns, which enable the early detection of preclinical symptoms. Additionally, older patients may have been less likely to participate in this study during the recruitment phase due to their unfamiliarity with smartphones. In short, the majority of the participants in this study underwent VATS wedge and segmentectomy. Additionally, in comparison with previous studies[9,10] with an average age of around 61 years, the participants in this study were younger, with a mean age of 51.9 years. These factors may have contributed to the lack of significant difference in postoperative anxiety between the EG and CG groups in this study.

Understanding patient needs and addressing concerns through meaningful physician–patient interactions has been shown to reduce anxiety and enhance satisfaction.[27] However, healthcare workers in clinical settings (including physicians and nurses) often lack time for such interactions.[27] Therefore, providing effective PE methods to assist them can save time[17] and workload.[12] Analyzing patient satisfaction in Table 7 reveals high satisfaction with SPE-VATS, particularly in terms of Intention to Use, Recommendation, Perceived Usefulness, Perceived Ease of Use, and Image scale scores, averaging 4.4 points. This confirms that SPE-VATS is effective in facilitating PE.

Analysis of the outcomes by gender

Although there was no significant difference in postoperative anxiety levels and demographics between genders in both the EG and CG, Table 5 reveals that SPE-VATS had a significant postoperative anxiety reduction effect for female patients in both EG and CG but not for male patients. This finding is consistent with previous

research showing that females tend to have higher surgical anxiety than males,[10,30] emphasizing the importance of reducing anxiety in female patients. However, the experimental results also indicate that the SPE-VATS showed a non-significant but favorable postoperative anxiety reduction for the EG females than the CG females. In addition, based on the EG's feedback (Table 7), both female and male patients expressed high satisfaction with the app, with no gender differences.

Analysis of the outcomes by education level

Although there was no significant difference in postoperative anxiety and demographics based on the education level between the EG and CG, patients who received traditional MPE (CG) did not experience better effects. The CG did not show significant reductions in postoperative state anxiety (Stage 3). In contrast, the EH and CU groups in the EG exhibited significant reductions in postoperative state anxiety due to the use of the SPE-VATS, regardless of education level.

Previous studies have also indicated that patients with lower levels of education and health literacy may not benefit from traditional MPE,[19,20,28,29] so making MPE mechanisms more effective in assisting patients' understanding is crucial.[10,31] The SPE-VATS can effectively facilitate patients to understand VATS-related PE content through interactive scenarios and guided inquiries, resulting in better postoperative anxiety reduction effects than those of traditional MPE.

In the EG, the system satisfaction analysis (Table 7) revealed that the CU group had higher scores on several measurement scales than the EH group, although the Diagnostic Report scale was higher in the EH group (mean:4.5, SD: 0.4) than in the CU group (mean: 4.4, SD: 0.7). The Diagnostic Report feature of the SPE-VATS provides patients with self-learning and problem-understanding after the scenario-based PE testing, which may be helpful for EH patients with lower comprehension abilities.[31] In addition, although there were no significant differences between the EH and CU groups in most measurement scales, the CU group had higher average scores in the Experience Sharing and Recommendation scales than the EH group, indicating that the CU group was more interested in learning about actual surgical cases; their feedback also mentioned the need for more experience sharing. The correlation analysis (Table 8) also showed a significant positive correlation ($r_s =$ .397, $p < .05$) between education level and Experience Sharing. Moreover, the CU group showed significantly lower Task Load scores than the EH group (Table 7). The correlation analysis (Table 8) also showed significant correlations between education level and SUS ($r_s = .375$, $p =$ .041) and Task Load ($r_s = -.579$, $p = .001$), indicating that the CU group was more effective in using the app. Table 6 also showed that the CU group significantly reduced state anxiety in Stages 2 and 3, whereas the EH group did not see a signification reduction until Stage 3, indicating that patients with higher education levels can benefit more quickly from using the SPE-VATS.

Limitations and future works

The present study had several limitations: (a) a small sample size (N = 64) obtained from a single hospital, (b) the adoption of a nonrandomized controlled trial design, (c) the collection of patient satisfaction data only from the EG without comparison with the CG, (d) the lack of comparison of the interventions' effectiveness on PE knowledge, (e) a low proportion of the participants undergoing high-risk VATS surgical resection types, and (f) the system's limited support for iOS devices.

The current method of assigning groups based on admission order and biopsy-confirmed patients may introduce potential bias. Future large-scale studies will implement robust randomization methods, e.g. random assignment or block randomization, to enhance the validity and generalizability.

Although the effectiveness of MPE in PE knowledge retention has been widely proven, the present study did not investigate such effectiveness specifically in VATS knowledge because the main focus was to assess the usability of SPE-VATS in terms of postoperative anxiety and patient satisfaction. However, Sim and Galbraith[17] found that MPE interventions did not show significant improvement in knowledge compared with traditional methods due to insufficient evidence on knowledge retention over time. Therefore, future studies should investigate whether the SPE-VATS can contribute to PE knowledge retention.

Besides, the low proportion of participants with high-risk surgical types in this study (only 10%) may have notably influenced the scores on patient anxiety, potentially restricting the findings' generalizability to a broader population of VATS patients. Future research will focus on further investigating the effectiveness of the SPE-VATS, specifically for patients undergoing high-risk VATS.

Lastly, the SPE-VATS is a web-based application (web app), which means it can be accessed not only through smartphones but also through computers using web browsers. This advantage eliminates the need for app installation and makes it more convenient for users. However, mobile network latency may affect the smoothness of use. Although most patients found the SPE-VATS easy to use, the limited support for iOS devices might have caused usability issues for iOS users. Addressing this technical limitation is necessary to enhance the app's effectiveness and user experience.

Despite high satisfaction with SPE-VAST's effectiveness in assisting PE, factors such as unfamiliarity with mobile devices, limited finger dexterity, and poor vision in older patients may affect their willingness to use SPE-VAST through mobile devices consistently or at all.

Fortunately, SPE-VATS' web-based feature can mitigate these issues by allowing patients to use computers instead.

Furthermore, SPE-VAST's "Additional Questions" feature (Figure 4A.1.a-c) requires responses from healthcare workers, leading to potential delays due to manual review. Future enhancements can integrate AI techniques using BERT,[60] GPT-4,[61] or BLOOM[62] to enable real-time responses to improve patient experience and healthcare workers' workload. Therefore, the SPE-VAST's advantages benefit future clinical applications, but current limitations necessitate further research directions to improve its practicality and applicability in real-world clinical settings.

Conclusion

This study developed a scenario-based MPE web app (SPE-VATS) to assist lung tumor patients undergoing VATS in facilitating the PE process and evaluated its usability on postoperative anxiety and patient satisfaction. The study results did not find a statistically significant difference in postoperative anxiety reduction between the SPE-VATS and traditional methods, possibly because 90% of the participants had low-risk surgical types, and VATS is known to be advantageous in alleviating surgical anxiety. However, females and higher educated EG participants showed a non-significant but favorable reduction than their CG counterparts. Moreover, EG participants were highly satisfied with the SPE-VATS, particularly with the interactive scenarios, experience sharing, and diagnostic analysis features. Notably, participants with higher education levels, higher surgical risks, and longer hospital stays tended to have higher acceptance and satisfaction with the SPE-VATS. The findings of this study demonstrated that the SPE-VATS shows potential for educating lung tumor patients undergoing VATS, especially for females and those with higher education levels. As a result, more extensive randomized studies for high-risk patients are warranted to evaluate its impact on clinical practice. For future clinical applications, the usability and functionality of the SPE-VATS require further improvement.

Acknowledgements: We want to thank the patients, their families, and colleagues from the hospital for participating and assisting in this study.

Contributorship: Jun-Ming Su: conceptualization, methodology, software, formal analysis, validation, data analysis, visualization, manuscript drafting, manuscript review, manuscript finalization. Wei-Li Huang: conceptualization, methodology, resources, investigation, data curation, manuscript review, and manuscript finalization. Hui-Chen Huang: conceptualization, methodology, investigation, data curation, manuscript review, manuscript finalization, project administration. Yau-Lin Tseng: conceptualization, methodology, resources, supervision. Meng-Jhen Li: software, data analysis.

Declaration of conflicting interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval: This study was approved by National Cheng Kung University's Institutional Review Board (A-ER-110-367)

Funding: This study was supported by grants from the Taiwan Centers for Disease Control (MOHW109-CDC-C-114-000110), the National Science and Technology Council of Taiwan (MOST 111-2410-H-024-002-MY2), and the Clinical Medicine Research Center, National Cheng Kung University Hospital (NCKUH-11107029).

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