Title

The Potential of Immersive Virtual Reality as a Non-Pharmacological Method for Postoperative Pain Relief Among Older Adults

Author

Keny, Christina

Publication Date

2024

Peer reviewed|Thesis/dissertation

The Potential of Immersive Virtual Reality as a Non-Pharmacological Method for Postoperative Pain Relief Among Older Adults

by
Christina Keny

DISSERTATION
Submitted in partial satisfaction of the requirements for degree of
DOCTOR OF PHILOSOPHY

in

Nursing

in the

GRADUATE DIVISION
of the
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Approved:

DocuSigned by:
Linda Park
F9BCC5CD52134D1...
Linda Park
Chair

DocuSigned by:
Laura Wagner
D0106B7861840F...
Laura Wagner

DocuSigned by:
Heather Leutwyler
012039073579437...
Heather Leutwyler

Committee Members

DEDICATION

I would like to dedicate this dissertation and academic achievement to my husband, Dr. Hemant Keny, and my children, whose unwavering love, support, and encouragement have been a cornerstone throughout the entire dissertation journey. My deepest thanks to my husband for the unconditional love and for constantly reminding me to cherish life's incredible journey, appreciating each critical milestone. I am eternally grateful for the joy and relaxation that he has brought into my life during challenging times, always finding ways to make me laugh and appreciate the beauty that surrounds us. His dedication to his geriatric surgical patients is remarkable and is demonstrated in his relentless efforts to improve their quality of life. His tireless work has been nothing short of inspirational.

To Alex, my son, this dissertation is dedicated to your honor and memory. Your courageous battle with cancer and your unwavering 'never give-up' attitude have not only reminded me but deeply inspired me to appreciate every moment, to face challenges with resilience, and to pursue my passions with an intensity that mirrors your strength. Your spirit, a beacon of hope and fortitude, has guided me through this journey, inspiring my research work with purpose and passion. Your light continues to shine, guiding and encouraging not just me, but all who learn of your journey.

ACKNOWLEDGEMENTS

The committee chair of this dissertation was Linda G. Park, PhD, NP, Associate Professor, Department of Community Health Systems, University of San Francisco, San Francisco. Members of the dissertation committee also included Heather Leutwyler PhD, NP, Professor, Department of Physiological Nursing, University of California, San Francisco, and Laura M. Wagner PhD, NP, Professor, Department of Community Health Systems, University of California, San Francisco.

The corresponding authors, Linda G. Park, Heather Leutwyler, and Laura M. Wagner directed and supervised the research described in this dissertation. Additional co-authors provided guidance on the research analysis and provided feedback during the drafting of the manuscripts included in this dissertation.

This dissertation work was supported by the National Institute of Nursing Research of the National Institutes of Health (T32NR01692), the University of California, San Francisco (UCSF), the UCSF Century Nursing Research award, the UCSF Graduate Mentorship Fellowship award, the UCSF Phillip R. Lee Health Policy Fellowship award, the UCSF Office of the Executive Vice Chancellor and Provost (EVCP) Social and Population Science Fellowship Research Award, and by the Department of Veterans Affairs, Veterans Health Administration, Office of Academic Affiliations VA Quality Scholars Advanced Fellowship Program (OAA 3Q072019C). One study in this dissertation was additionally funded by The National Institute of Aging of the National Institutes of Health (K76AG05993 and K23AG065438-03). The views and content in this dissertation are those of the author and do not necessarily reflect the

position or policy of the Department of Veterans Affairs, the United States government, or the National Institutes of Health.

The author extends a deep appreciation to the committee chair and academic advisor, Dr. Linda Park, whose steadfast dedication, and support were instrumental in advancing this research work. Enduring gratitude is owed to Dr. Park for the unwavering support and mentorship, which were pivotal throughout the entire dissertation process. Her encouragement not only facilitated the successful completion of the research but also significantly contributed to my professional development as an emerging nurse researcher. Dr. Park conveyed the vital lesson of balancing family and professional responsibilities, emphasizing the importance of taking the time to genuinely enjoy and reflect upon the entire doctoral and dissertation experience. Her mentorship, leadership, and professional acumen stand as a testament to her exemplary stature as a researcher and faculty member. Dr. Park's example has been profoundly inspiring across numerous aspects of my personal and professional life.

Furthermore, the author wishes to express profound gratitude towards to the other committee members, Drs. Heather Leutwyler and Laura Wagner, for their relentless support, insightful guidance, and valuable feedback on various segments of the dissertation. First, to Dr. Leutwyler, who gave so freely of her time and wisdom during the qualifying exam as well as the dissertation. She was regularly available to provide insight on key resources and support needed to move this research in older adults forward. To Dr. Wagner, who played a vital role as a professional mentor, especially significant during the educational journey as a first-generation college student. Dr. Wagner's generosity in providing a critical resource needed for the

dissertation study was pivotal towards completion of the study in a timely manner. The author is extremely fortunate to have benefitted from Dr. Wagner's mentorship and expertise. Her guidance throughout the entire process was truly extraordinary.

The author gratefully acknowledges the substantial support and guidance from other co-authors and mentors, which significantly propelled this research forward. Heartfelt gratitude is especially directed towards Dr. Victoria Tang for her compassionate mentorship, generosity, and insightful guidance in the realm of geriatric surgery research. Dr. Tang dedicated numerous hours to mentoring the author, facilitating the exploration of complex concepts and research initiatives. Her role as a principal mentor throughout the research residency and dissertation process was invaluable. With her guidance, several research manuscripts have advanced forward towards publication. Dr. Tang exemplifies the pinnacle of clinical research in geriatric surgery, instilling in both a profound sense of confidence and a resilient "never give up" approach to research.

The author is equally grateful to Dr. Marcia Russell for her critical feedback on several facets of this dissertation work. Dr. Russell has served as a key expert in geriatric research and pain management. She has always made herself available to provide guidance and feedback. Acknowledgment is also due to Dr. Karl Lorenz for his mentorship and for offering diverse, critical perspectives on virtual reality research and use in older adults. A heartfelt thanks also goes to Dr. Margaret Wallhagen for her dedication and the invaluable time she invested as a fellowship mentor. The collective encouragement and guidance from all mentors and the committee were indispensable to the completion of the dissertation. The author would like to thank the many faculty

members and peers from the Veterans Affairs Quality Scholars (VAQS) program for their support, guidance, mentorship, and friendship.

A special thank you also goes to Caitlin Rawlins for her organizational expertise on the use of virtual reality in the Veterans Affairs Healthcare setting. The author would also like to thank the UCSF Colorectal and General surgery departments for their assistance with participant recruitment, particularly Drs. Madhulika Varma, Elizabeth Wick, and Emily Finlayson, as well as Diane Rego, Nurse Practitioner. Finally, the author would like to thank Maria Yefimova, PhD, RN, Lead Nurse Scientist, Center for Nursing Excellence & Innovation, and Assistant Adjunct Professor, Department of Physiological Nursing, University of California, San Francisco for her guidance and assistance with ensuring the dissertation study went smoothly onsite at the medical center. Additionally, sincere appreciation is directed towards Sofia Sandoval for all her efforts in participant recruitment and study coordination.

Finally, the author can never express enough gratitude to family closest friends for their unwavering support and encouragement throughout the entire educational journey. The author would specifically like to thank a dear friend and colleague, Prudence, who has been a pillar of support to the author since the beginning of nursing school, several decades ago. She has always provided continuous support and understanding during so many critical phases of the author's life. The author will be forever grateful for the daily encouragement and love.

CONTRIBUTIONS

The text of this dissertation is, in part, a reprint of the following articles:

Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. "It's Incapacitated me in so Many Ways": Older Adults' Lived Experience with Postoperative Symptoms at Home Following Major Elective Surgery. Ann Surg. Published online December 5, 2023. doi:10.1097/SLA.0000000000006170

The Potential of Immersive Virtual Reality as a Non-Pharmacological Method for Postoperative Pain Relief Among Older Adults

Christina Keny

ABSTRACT

Problem Statement

Given the complexities in managing postoperative pain in the older adult demographic, there is mounting interest in exploring innovative nonpharmacological methods for pain. Among these emerging solutions, immersive virtual reality (IVR) has garnered significant interest. Recent studies have indicated possible efficacy of IVR in reducing postoperative pain in pediatric and young to middle-aged adults following various surgical operations. However, the feasibility, and acceptability of IVR for postoperative pain among older adults across a spectrum of major operations remains largely underexplored.

Therefore, the primary aim of this mixed-methods single-arm study was to investigate the initial feasibility and acceptability of IVR use among adults aged 55 years and older during the initial two days following inpatient elective abdominal surgery. Secondary aims were to: 1) observe the preliminary impact of IVR on postoperative pain and relaxation levels, and 2) explore and describe the older adult's overall user experience with IVR.

Methods

Individuals aged 55 and older undergoing elective inpatient abdominal surgery at an academic medical center in Northern California were recruited from October 2023 to February 2024. Feasibility was evaluated through accrual rate, intervention completion,

and questionnaire compliance; acceptability via the system usability scale (SUS), a user experience survey, and by monitoring self-reported side effects. The preliminary impact of IVR on self-reported pain intensity and relaxation levels was evaluated through pre- to post-IVR changes. A subgroup of participants from the parent feasibility study who had completed at least one IVR session, were additionally recruited to complete a one-time 15-minute semi-structured interview, which was aimed at capturing the user experience. Purposeful sampling was employed until no new themes were captured during interviews. An inductive thematic analysis approach was used to identify emerging themes though line by line coding of manuscript transcripts.

Summary of Findings

A total of 29 participants, with a median age of 73 years (range 55-81), were enrolled and completed one IVR session, with 19 additionally completing a second session. Perceived usability and overall acceptance of IVR was high, with minimal side effects reported. In terms of preliminary impact of IVR, statistically significant improvements were observed in both pain and relaxation levels from pre- to post-IVR changes on both Day 1 and Day 2. Of the original 29 participants in the parent feasibility study, 21 additionally completed a recorded interview. Semi-structured interviews revealed four themes: 1) IVR was a positive distraction from a variety postoperative symptom, including pain; 2) IVR provided a sense of escape from the hospital environment or worrisome medical conditions; 3) There was an expressed need to further tailor virtual reality content and equipment specifically for older surgical adults; and 4) Older adults endorsed the possibility of IVR use throughout perioperative care.

In conclusion, this study supports the feasibility and acceptability of IVR as a potential tool for postoperative pain management and enhancing relaxation among older adults following elective inpatient abdominal surgery. The positive preliminary results suggest the need for large scale studies across additional complex inpatient abdominal surgeries to confirm acceptance and efficacy of IVR as a postoperative pain management intervention across a wide range of diverse older demographics, including individuals from underrepresented minority groups and those facing physical and cognitive limitations. Despite minor critiques of the technology, participants verbally expressed that IVR following surgery helped to divert their attention away from pain and other symptoms. IVR also offered a temporary escape from hospitalization and concerns about underlying health issues, like cancer. This highlights the multifaceted potential of IVR as an intervention to improve various postoperative symptoms, including pain.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVATIONS

ACS = American College of Surgeons

AI = Artificial Intelligence

CABG = Coronary Artery Bypass Graft

CI = Confidence Interval

CMS = Centers for Medicare and Medicaid Services

CONSORT = Consolidated Standards of Reporting Trials

COREQ = Consolidated Criteria for Reporting Qualitative Research

ECG = Electrocardiography

EPHPP = Effective Public Health Practice Project

EQ-5D-5L = EuroQol 5-Dimension 5-Level Questionnaire

ERAS = Enhanced Recovery After Surgery

EVAN LR = Evaluation of Anesthesia Local Regional

FDA = Food and Drug Administration

FIM = Functional Independent Measure

GAD-7 = Generalized Anxiety Disorder 7-item

GED = General Education Development

GPE = Global Perceived Effect

HIPAA = Health Information Portability and Accountability Act

HMD = Head-Mounted Display

HR = Heart Rate

HRQOL = Health-Related Quality of Life

HSS = Hospital for Special Surgery

ICU = Intensive Care Unit

IPQ = Igroup Presence Questionnaire

IQR = Interquartile Range

IVR = Immersive Virtual Reality

MCI = Mild Cognitive Impairment

MDASI = MD Anderson Symptom Inventory

MME = Morphine Milligram Equivalents

NRS = Numeric Rating Scale

NSQIP = National Quality Improvement Program

OR = Operating Room

PACU = Post-Anesthesia Care Unit

PCS = Pain Catastrophizing Scale

PHQ-8 = Patient Health Questionnaire-8

PICOS = Population, Intervention, Comparison, Outcome, and Study Design

POQ-SF = Pain Outcomes Questionnaire Short Form

PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PRO = Patient Reported Outcome

PSQ-18 = Patient Satisfaction Questionnaire Short Form

PT = Physical Therapy

QOL = Quality of Life

QOR-40 = Quality of Recovery Survey

RCT = Randomized Controlled Trial

ROM = Range of motion

RR = Respiration Rate

SD = Standard Deviation

SPMSQ = Short Portable Mental Status Questionnaire

SSQ = Simulator Sickness Questionnaire

STAI-6 = State-Trait Anxiety Inventory Six Items

SUS = System Usability Scale

THA = Total Hip Arthroplasty

TJA = Total Joint Arthroplasty

TJR = Total Joint Replacement

TKA = Total Knee Arthroplasty

TV = Television

VAS = Visual Analog Scale

VR = Virtual Reality

VR-CORE = VR-CORE

WHO = World Health Organization

WOMAC = The Western Ontario and McMaster Universities

CHAPTER 1

INTRODUCTION

Background

The older adult population in the United States, defined by the National Institute on Aging as individuals aged 65 and older, is anticipated to increase exponentially over the next few decades.[1,2] This older adult demographic shift is anticipated to lead to a significant proportional increase in the number of operations performed in this population.[3] While mortality and severe morbidity serve as traditional indicators of surgical outcomes, it is imperative to recognize that older adults also often prioritize the impact of surgery on their quality of life and ability to engage in meaningful life activities.[4,5] The impact of various patient reported outcomes, such as postoperative pain, are considered critical measures of surgical success from the perspective of the older adult.[6–8] Although extensively studied in oncology settings, symptom burden, broadly defined as the subjective experience of symptoms, including the number of symptoms, frequency, severity, and the overall impact of those symptoms on physical or psychological heath, remains underexplored in elective major surgery among older adults.[8,9] Of the few studies that do exist, research has shown that the severity and persistence of postoperative symptoms, primarily pain, can adversely affect surgical recovery, leading to poor quality of life, compromised psychosocial and functional status, and increased risk of morbidity and mortality.[10–12]

One specific postoperative symptom that has garnered significant interest among geriatric clinicians and researchers is post-surgical pain among older adults. Effectively managing pain in older surgical adults is often complicated by challenges

stemming from age-related physiological changes, the presence of multiple comorbidities, and the intricacies of polypharmacy.[13–18] Moreover, as a result of postoperative pain, older adults have an increased risk of developing delirium, functional decline, opioid-related adverse events, addiction, and/or chronic pain following surgery when compared to younger age groups.[19–22] Given the difficulties and inherent risks in managing acute postoperative pain in this demographic, there is a growing interest to explore innovative nonpharmacological methods for pain.[23,24]

Immersive Virtual Reality for Acute Pain

Among possible nonpharmacological options, immersive virtual reality (IVR) has acquired significant interest over the last decade from both the clinical and research communities. Research has indicated the considerable potential of IVR to reduce acute pain across various clinical settings, including burn wound care, medical procedures, and surgery.[25–28] Recent reviews have also demonstrated that IVR is effective in reducing postoperative pain in pediatric and young to middle-aged adults following various types of operations.[26,29] Thus, IVR could serve as a promising alternative or adjunct to traditional pain management techniques in older adults during inpatient surgical hospitalization. However, the feasibility and acceptability of IVR for postoperative pain among older adults across a spectrum of major surgical procedures, including complex abdominal procedures, remains largely underexplored.

Immersive Virtual Reality Use in Older Adults

IVR stands out as a novel technological advancement due its potential as a tool to enhance the overall health of older adults.[30,31] Recent research supports the overall acceptance and use of IVR among older adults across a wide range of non-hospital

settings (e.g., residential care and community settings) to improve outcomes such as mitigating feelings of social isolation and loneliness,[32] boosting cognitive abilities,[33] providing psychological support,[33,34] improving chronic pain management,[35,36] optimizing physical rehabilitation,[37] and enhancing overall well-being.[33] Contrary to widespread misconceptions regarding older adults' hesitancy towards adopting technology, recent studies have demonstrated that older adults in the community setting exhibit high levels of IVR acceptance, even when cognitive or functional limitations are present.[38,39] A recent review also demonstrated that IVR was generally well-tolerated in older adults across various settings with minimal side effects reported.[40] However, the application of IVR use in older adults during surgical hospitalization remains limited. Specifically, research on the use of IVR in major elective abdominal and gastrointestinal operations involving older adults is notably scarce.[41,42] This gap highlights the need for more focused studies on the potential of IVR to aid in the management of postoperative pain during hospitalization, especially in older adults.

Overview of Immersive Virtual Reality Technology

While the specific neurobiological pathway that underpins the effectiveness of IVR on reducing pain remains ambiguous, positive distraction is one widely accepted mechanism of action that may help to explain the effects of IVR in decreasing pain.[43–45] It is hypothesized that humans have a limited ability to process multiple stimuli.[46,47] As such when attention is directed towards the multisensory experience of IVR, less attention is focused on pain.[27,46–51] Two main theories support the hypothesis of IVR as a compelling nonpharmacological pain analgesic, as a result of positive distraction.

These theories are Melzack's Gate Control theory, currently known as the Neuromatrix Theory of Pain, and The Multiple Resource Theory.[46,47,52,53] The Control Gate Theory proposes that the level of attention concentrated on pain, as well as the emotional and cognitive responses to pain, impact how pain is processed and ultimately perceived by an individual.[53] McCaul and Malott further propose that an individual must be focused on a painful stimulus in order to recognize pain.[54]The Multiple Resource theory further supports the nature of IVR technology as a sensory distraction, as the theory purports that humans have a limited set of resources available for sensory and mental processing.[46,55]

Virtual reality (VR) generally spans three primary categories, defined by the level of immersion, the sense of presence evoked, and the type of equipment used.[40,56–58] Non-immersive VR involves 2-dimensional (2D) screens on a computer, television, or smart device.[40,59] The user interacts with the 2D virtual environment using a keyboard, mouse, or another input device.[40,58] Semi-immersive VR provides advanced graphics on larger screens for a more captivating experience, albeit still leveraging a 2D environment.[58,59] Conversely, fully immersive virtual reality (IVR) uses three-dimensional (3D) images and videos to create a more realistic simulated environment using a blend of equipment such as a head-mounted display (HMD) unit with audio, handheld controllers, and a motion tracking system.[60] IVR engenders a compelling sense of 'presence' and immersion in the virtual environment.[44,50,51] Most modern IVR systems provide a 360-degree visual field with motion tracking through sensors embedded in the HMD unit. These motion sensors capture users' position and orientation, often in all possible directions, allowing the system to respond to

movements and to convey information about the virtual environment back to the user in real time.[61,62] This believable perception of 'being there' is thought to play a pivotal role in the beneficial impact of IVR on a wide array of outcomes, such a pain reduction.[63–65]

FOCUS OF THE DISSERTATION RESEARCH

Overview

The overall objective of this dissertation manuscript is to present the feasibility, acceptability, and preliminary impact of an IVR intervention on postoperative pain in older adults following elective inpatient abdominal surgery. The initial chapters of this dissertation, chapters 2 and 3, comprised foundational studies that supported the overarching objectives of the dissertation research. The first study (chapter 2) explored the symptom experiences of older adults following surgery, while the second study, a scoping review (chapter 3), examined the research literature on the use of IVR for managing postoperative pain among the older adult demographic. Together, these studies laid a solid foundation for the subsequent overall aims of the dissertation, which are discussed in chapters 4 and 5.

Dissertation Aims

Chapters 4 and 5, serve as the crux of the dissertation, and the aims along with the associated hypotheses are presented below:

Primary Aims:

1. To determine the feasibility of applying IVR as a pain adjunctive treatment following elective inpatient abdominal surgery in older adults.

H1a: We will be able to recruit older adults undergoing elective major surgery for participation in study activities such as recruitment, completion of study questionnaires, and compliance with the intervention.

2. To determine the acceptability and tolerability of IVR for postoperative pain following elective inpatient major surgery in older adults.

H2a: Older adults will consider their IVR user experience positive, effective, and practical in the inpatient postoperative period, with negligible side effects reported.

Secondary Aims:

1. To determine potential differences in self-reported postoperative pain intensity levels, and state of relaxation through pre-posttest IVR evaluation.

H1a: Older adults who receive IVR will demonstrate immediate improvements in self-reported pain intensity and state of relaxation levels from pre- to post-IVR.

Presentation of the Dissertation

This dissertation comprises six chapters. Chapter 1 discussed the negative impact of postoperative symptoms, such as pain, on older surgical adults' outcomes. This chapter provided background information on the application of IVR technology both in the surgical context and among various older adult settings. Chapter 1 also offered an overview of IVR technology. Chapter 2 discussed an initial qualitative study aimed at exploring the postoperative symptom experiences of older adults following major elective surgery. An inductive qualitative approach facilitated the identification of emerging themes related to challenging postoperative symptoms, notably pain. This study illuminated two significant findings that helped to frame the overall dissertation:

first, postoperative pain was frequently cited as severely affecting patients' valued life activities and psychosocial well-being; second, participants reported being unprepared for the intensity and duration of postoperative symptoms, leading to a universal request among participants for more technology-based educational and supportive interventions for symptom management, particularly for postoperative pain. Chapter 3 discussed a scoping review that aimed to map out and evaluate the current research landscape regarding the use of IVR for postoperative pain management in adults aged 65 and older, across various surgical procedures. Both chapters 2 and 3 served to support the main studies conducted in chapters four and five.

The main feasibility and acceptability study on the use of IVR for postoperative pain is fully described in chapter 4. Chapter 5 qualitatively described the older adults' user experience with IVR. Chapter 6 is the conclusion of the dissertation. A review of the dissertation chapters and findings are presented. Additionally, potential implications for research, clinical care, policy, the future direction of IVR, and ethical considerations are also considered.

Chapter 2 of this dissertation was recently published in the *Annals of Surgery*. Chapters 3, 4, and 5 will be submitted to peer-reviewed research journals for publication and are presented in this dissertation per the specifications of the respective journal.

References

1. Etzioni DA, Liu JH, Maggard MA, Ko CY. The Aging Population and Its Impact on the Surgery Workforce. *Ann Surg*. 2003;238(2):170-177. doi: 10.1097/01.SLA.0000081085.98792.3d
2. Age. National Institutes of Health (NIH). Published August 11, 2022. Accessed March 20, 2023. https://www.nih.gov/nih-style-guide/age
3. Etzioni DA, Liu JH, Maggard MA, Ko CY. The aging population and its impact on the surgery workforce. *Ann Surg*. 2003;238(2):170-177. doi: 10.1097/01.SLA.0000081085.98792.3d
4. Kata A, Dutt M, Sudore RL, Finlayson E, Broering JM, Tang VL. What Matters? The Valued Life Activities of Older Adults Undergoing Elective Surgery. *J Am Geriatr Soc*. 2019;67(11):2305-2310. doi:10.1111/jgs.16102
5. Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. “It’s Incapacitated me in so Many Ways”: Older Adults’ Lived Experience with Postoperative Symptoms at Home Following Major Elective Surgery. *Ann Surg*. Published online December 5, 2023. doi:10.1097/SLA.0000000000006170
6. Fried TR, Bradley EH, Towle VR, Allore H. Understanding the treatment preferences of seriously ill patients. *N Engl J Med*. 2002;346(14):1061-1066. doi:10.1056/NEJMsa012528
7. Berian JR, Mohanty S, Ko CY, Rosenthal RA, Robinson TN. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg*. 2016;151(9):e161689. doi:10.1001/jamasurg.2016.1689

8. Basch E. Patient-Reported Outcomes - Harnessing Patients' Voices to Improve Clinical Care. *N Engl J Med*. 2017;376(2):105-108. doi:10.1056/NEJMp1611252

9. Gapstur RL. Symptom burden: a concept analysis and implications for oncology nurses. *Oncol Nurs Forum*. 2007;34(3):673-680. doi: 10.1188/07.ONF.673-680

10. Connerney I, Shapiro PA, McLaughlin JS, Bagiella E, Sloan RP. Relation between depression after coronary artery bypass surgery and 12-month outcome: a prospective study. *Lancet Lond Engl*. 2001;358(9295):1766-1771. doi:10.1016/S0140-6736(01)06803-9

11. Hu ZY, Feng XQ, Fu MR, Yu R, Zhao HL. Symptom patterns, physical function and quality of life among head and neck cancer patients prior to and after surgical treatment: A prospective study. *Eur J Oncol Nurs Off J Eur Oncol Nurs Soc*. 2020;46:101770. doi:10.1016/j.ejon.2020.101770

12. Merlo A, Carlson R, Espey J, et al. Postoperative Symptom Burden in Patients Undergoing Lung Cancer Surgery. *J Pain Symptom Manage*. 2022;64(3):254-267. doi:10.1016/j.jpainsymman.2022.05.016

13. Deiner S, Westlake B, Dutton RP. Patterns of surgical care and complications in elderly adults. *J Am Geriatr Soc*. 2014;62(5):829-835. doi:10.1111/jgs.12794

14. Lautenbacher S, Peters JH, Heesen M, Scheel J, Kunz M. Age changes in pain perception: A systematic-review and meta-analysis of age effects on pain and tolerance thresholds. *Neurosci Biobehav Rev*. 2017;75:104-113. doi:10.1016/j.neubiorev.2017.01.039

15. Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg*. 2010;210(6):901-908. doi:10.1016/j.jamcollsurg.2010.01.028

16. Aalami OO, Fang TD, Song HM, Nacamuli RP. Physiological features of aging persons. *Arch Surg Chic Ill 1960*. 2003;138(10):1068-1076. doi:10.1001/archsurg.138.10.1068

17. Shellito AD, Dworsky JQ, Kirkland PJ, et al. Perioperative Pain Management Issues Unique to Older Adults Undergoing Surgery: A Narrative Review. *Ann Surg Open*. 2021;2(3):e072. doi:10.1097/AS9.0000000000000072

18. Schenning KJ, Deiner SG. Postoperative Delirium in the Geriatric Patient. *Anesthesiol Clin*. 2015;33(3):505-516. doi:10.1016/j.anclin.2015.05.007

19. Kessler ER, Shah M, Gruschkus SK, Raju A. Cost and quality implications of opioid-based postsurgical pain control using administrative claims data from a large health system: opioid-related adverse events and their impact on clinical and economic outcomes. *Pharmacotherapy*. 2013;33(4):383-391. doi:10.1002/phar.1223

20. Baker J, Brovman EY, Rao N, Beutler SS, Urman RD. Potential Opioid-Related Adverse Drug Events Are Associated With Decreased Revenue in Hip Replacement Surgery in the Older Population. *Geriatr Orthop Surg Rehabil*. 2020;11:2151459320915328. doi:10.1177/2151459320915328

21. Huhn AS, Strain EC, Tompkins DA, Dunn KE. A hidden aspect of the U.S. opioid crisis: Rise in first-time treatment admissions for older adults with opioid use

disorder. *Drug Alcohol Depend*. 2018;193:142-147. doi:10.1016/j.drugalcdep.2018.10.002

22. Hamilton HJ, Gallagher PF, O'Mahony D. Inappropriate prescribing and adverse drug events in older people. *BMC Geriatr*. 2009;9:5. doi:10.1186/1471-2318-9-5

23. Quick Safety 44: Non-pharmacologic and non-opioid solutions for pain management | The Joint Commission. Accessed October 1, 2022. https://www.jointcommission.org/resources/news-and-multimedia/newsletters/newsletters/quick-safety/quick-safety-44-nonpharmacologic-and-nonopioid-solutions-for-pain-management/#.YzjJV0zMKUk

24. Martinez V, Beloeil H, Marret E, Fletcher D, Ravaud P, Trinquart L. Non-opioid analgesics in adults after major surgery: systematic review with network meta-analysis of randomized trials. *Br J Anaesth*. 2017;118(1):22-31. doi:10.1093/bja/aew391

25. Chan E, Foster S, Sambell R, Leong P. Clinical efficacy of virtual reality for acute procedural pain management: A systematic review and meta-analysis. *PloS One*. 2018;13(7):e0200987. doi:10.1371/journal.pone.0200987

26. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82:87-94. doi:10.1016/j.ijsu.2020.08.033

27. Hoffman HG, Chambers GT, Meyer WJ, et al. Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures. *Ann*

Behav Med Publ Soc Behav Med. 2011;41(2):183-191. doi:10.1007/s12160-010-9248-7

28. Indovina P, Barone D, Gallo L, Chirico A, De Pietro G, Giordano A. Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review. *Clin J Pain*. 2018;34(9):858-877. doi:10.1097/AJP.0000000000000599
29. Iannicelli AM, Vito D, Dodaro CA, et al. Does virtual reality reduce pain in pediatric patients? A systematic review. *Ital J Pediatr*. 2019;45(1):171. doi:10.1186/s13052-019-0757-0
30. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. *Cyberpsychology Behav Soc Netw*. 2023;26(12):886-895. doi:10.1089/cyber.2023.0188
31. Tuena C, Pedroli E, Trimarchi PD, et al. Usability Issues of Clinical and Research Applications of Virtual Reality in Older People: A Systematic Review. *Front Hum Neurosci*. 2020;14:93. doi:10.3389/fnhum.2020.00093
32. Baker S, Waycott J, Robertson E, et al. Evaluating the use of interactive virtual reality technology with older adults living in residential aged care. *Inf Process Manag*. 2020;57(3):102105. doi:10.1016/j.ipm.2019.102105
33. Chaze F, Hayden L, Azevedo A, et al. Virtual reality and well-being in older adults: Results from a pilot implementation of virtual reality in long-term care. *J*

Rehabil Assist Technol Eng. 2022;9:20556683211072384. doi:10.1177/20556683211072384

34. Cieślik B, Juszko K, Kiper P, Szczepańska-Gieracha J. Immersive virtual reality as support for the mental health of elderly women: a randomized controlled trial. *Virtual Real*. 2023;27(3):2227-2235. doi:10.1007/s10055-023-00797-w
35. Benham S, Kang M, Grampurohit N. Immersive Virtual Reality for the Management of Pain in Community-Dwelling Older Adults. *OTJR Occup Particip Health*. 2019;39(2):90-96. doi:10.1177/1539449218817291
36. Stamm O, Dahms R, Müller-Werdan U. Virtual reality in pain therapy: a requirements analysis for older adults with chronic back pain. *J Neuroengineering Rehabil*. 2020;17(1):129. doi:10.1186/s12984-020-00753-8
37. Cieślik B, Mazurek J, Wrzeciono A, et al. Examining technology-assisted rehabilitation for older adults' functional mobility: a network meta-analysis on efficacy and acceptability. *Npj Digit Med*. 2023;6(1):1-10. doi:10.1038/s41746-023-00907-7
38. Appel L, Appel E, Bogler O, et al. Older Adults With Cognitive and/or Physical Impairments Can Benefit From Immersive Virtual Reality Experiences: A Feasibility Study. *Front Med*. 2019;6:329. doi:10.3389/fmed.2019.00329
39. Kim A, Darakjian N, Finley JM. Walking in fully immersive virtual environments: an evaluation of potential adverse effects in older adults and individuals with Parkinson's disease. *J Neuroengineering Rehabil*. 2017;14(1):16. doi:10.1186/s12984-017-0225-2

40. Drazich BF, McPherson R, Gorman EF, et al. In too deep? A systematic literature review of fully-immersive virtual reality and cybersickness among older adults. *J Am Geriatr Soc*. 2023;71(12):3906-3915. doi:10.1111/jgs.18553

41. Cockerham M, Eakins J, Hsu E, Tran A, Adjei NB, Guerrero K. Virtual reality in post-operative robotic colorectal procedures: An innovation study. *J Nurs Educ Pract*. 2023;13(6):1. doi:10.5430/jnep.v13n6p1

42. Schrempf MC, Zanker J, Arndt TT, et al. Immersive Virtual Reality Fitness Games to Improve Recovery After Colorectal Surgery: A Randomized Single Blind Controlled Pilot Trial. *Games Health J*. 2023;12(6):450-458. doi:10.1089/g4h.2023.0004

43. Wiederhold MD, Wiederhold BK. Virtual Reality and Interactive Simulation for Pain Distraction. *Pain Med*. 2007;8(s3):S182-S188. doi:10.1111/j.1526-4637.2007.00381.x

44. Gupta A, Scott K, Dukewich M. Innovative Technology Using Virtual Reality in the Treatment of Pain: Does It Reduce Pain via Distraction, or Is There More to It? *Pain Med Malden Mass*. 2018;19(1):151-159. doi:10.1093/pm/pnx109

45. Lambert V, Boylan P, Boran L, et al. Virtual reality distraction for acute pain in children. *Cochrane Database Syst Rev*. 2020;2020(10):CD010686. doi:10.1002/14651858.CD010686.pub2

46. Wickens CD. Multiple resources and mental workload. *Hum Factors*. 2008;50(3):449-455. doi:10.1518/001872008X288394

47. Melzack R. Pain and the Neuromatrix in the Brain. *J Dent Educ*. 2001;65(12):1378-1382. doi:10.1002/j.0022-0337.2001.65.12.tb03497.x

48. Van Damme S, Legrain V, Vogt J, Crombez G. Keeping pain in mind: a motivational account of attention to pain. *Neurosci Biobehav Rev*. 2010;34(2):204-213. doi:10.1016/j.neubiorev.2009.01.005

49. Hoffman HG. Interacting with virtual objects via embodied avatar hands reduces pain intensity and diverts attention. *Sci Rep*. 2021;11(1):10672. doi:10.1038/s41598-021-89526-4

50. Hoffman H, Sharar S, Coda B, et al. Manipulating presence influences the magnitude of virtual reality analgesia. *PAIN*. 2004;111(1-2):162-168. doi:10.1016/j.pain.2004.06.013

51. Hoffman HG, Richards TL, Van Oostrom T, et al. The Analgesic Effects of Opioids and Immersive Virtual Reality Distraction: Evidence from Subjective and Functional Brain Imaging Assessments. *Anesth Analg*. 2007;105(6):1776-1783. doi:10.1213/01.ane.0000270205.45146.db

52. Melzack R, Wall PD. Pain mechanisms: a new theory. *Science*. 1965;150(3699):971-979. doi:10.1126/science.150.3699.971

53. Melzack R. From the gate to the neuromatrix. *Pain*. 1999;Suppl 6:S121-S126. doi:10.1016/S0304-3959(99)00145-1

54. McCaul KD, Malott JM. Distraction and coping with pain. *Psychol Bull*. 1984;95(3):516-533.

55. Basil MD. Multiple Resource Theory. In: Seel NM, ed. *Encyclopedia of the Sciences of Learning*. Springer US; 2012:2384-2385. doi:10.1007/978-1-4419-1428-6_25

56. Baker NA, Polhemus AH, Haan Ospina E, et al. The State of Science in the Use of Virtual Reality in the Treatment of Acute and Chronic Pain: A Systematic Scoping Review. *Clin J Pain*. 2022;38(6):424-441. doi:10.1097/AJP.0000000000001029

57. Slobounov SM, Ray W, Johnson B, Slobounov E, Newell KM. Modulation of cortical activity in 2D versus 3D virtual reality environments: An EEG study. *Int J Psychophysiol*. 2015;95(3):254-260. doi:10.1016/j.ijpsycho.2014.11.003

58. Cipresso P, Giglioli IAC, Raya MA, Riva G. The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature. *Front Psychol*. 2018;9. doi:10.3389/fpsyg.2018.02086

59. García-Betances RI, Arredondo Waldmeyer MT, Fico G, Cabrera-Umpiérrez MF. A succinct overview of virtual reality technology use in Alzheimer's disease. *Front Aging Neurosci*. 2015;7:80. doi:10.3389/fnagi.2015.00080

60. Dahlquist LM, McKenna KD, Jones KK, Dillinger L, Weiss KE, Ackerman CS. Active and passive distraction using a head-mounted display helmet: Effects on cold pressor pain in children. *Health Psychol*. 2007;26:794-801. doi:10.1037/0278-6133.26.6.794

61. Vox JP, Weber A, Wolf KI, et al. An Evaluation of Motion Trackers with Virtual Reality Sensor Technology in Comparison to a Marker-Based Motion Capture System Based on Joint Angles for Ergonomic Risk Assessment. *Sensors*. 2021;21(9):3145. doi:10.3390/s21093145

62. Tham J, Duin AH, Gee L, Ernst N, Abdelqader B, McGrath M. Understanding Virtual Reality: Presence, Embodiment, and Professional Practice. *IEEE Trans Prof Commun*. 2018;61(2):178-195. doi:10.1109/TPC.2018.2804238

63. Triberti S, Repetto C, Riva G. Psychological factors influencing the effectiveness of virtual reality-based analgesia: a systematic review. *Cyberpsychology Behav Soc Netw*. 2014;17(6):335-345. doi:10.1089/cyber.2014.0054

64. Cummings JJ, Bailenson JN. How Immersive Is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence. *Media Psychol*. 2016;19(2):272-309. doi:10.1080/15213269.2015.1015740

65. Martingano AJ, Duane JN, Brown E, Persky S. Demographic differences in presence across seven studies. *Virtual Real*. 2023;27(3):2297-2313. doi:10.1007/s10055-023-00805-z

CHAPTER 2

"It's Incapacitated me in so many ways": Older Adults' Lived Experience with Postoperative Symptoms at Following Major Elective Surgery

This chapter is a reprint of previously published material as it appears in the *Annals of Surgery*: Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. "It's Incapacitated Me in so Many Ways": Older Adults' Lived Experience With Postoperative Symptoms at Home After Major Elective Surgery. *Ann Surg*. 2024;279(5):736-742. doi:10.1097/SLA.0000000000006170. The co-authors listed in this publication directed and supervised the research that formed the basis for this dissertation chapter.

ABSTRACT

Objective: This qualitative study aimed to explore the challenges faced by older adults regarding the postoperative symptom experience following major elective surgery.

Background: Although extensively studied in oncology settings, the impact of postoperative symptom burden remains largely underexplored in elective major surgery among older adults.

Methods: We employed convenience sampling to recruit adults aged ≥65 years undergoing major elective surgery at the University of California, San Francisco. Semi-structured interviews regarding the surgical experience were conducted at one and three months postoperatively. An inductive qualitative approach was used to identify emerging themes. Symptoms revealed by participants during interviews were also captured.

Results: Nineteen participants completed a one-month postoperative interview, and seventeen additionally completed a three-month interview. Three themes emerged: 1) postoperative symptoms significantly impacted valued life activities and psychosocial well-being, 2) participants felt "caught off guard" by the intensity and duration of postoperative symptoms, and 3) participants expressed the need for additional support, resources, and education on symptom management. The most frequently mentioned symptoms were postoperative pain (n=12, 63.1%), gastrointestinal discomfort (n=8, 42.1%), and anxiety/stress (n=8, 42.1%) at one-month post-surgery, compared to pain and depression (both n=6, 35.3%) at three months.

Conclusions: Study participants were surprised by the negative impact of postoperative symptoms on their psychosocial well-being and ability to engage in valued life activities. Symptom burden is an important patient-reported outcome that should be assessed postoperatively. Interventions to minimize postoperative symptom burden in older adults could optimize quality of life and participation in meaningful activities during surgical recovery.

INTRODUCTION

Older adults, defined by the National Institutes on Aging as individuals aged 65 years and older, represent a significant proportion of surgical patients in the United States.[1,2] With the older adult population projected to reach 95 million by 2060, the demand for surgical operations in this demographic is expected to rise substantially.[3–5] Older adults face an elevated risk of mortality and morbidity following surgery owing to comorbidities and age-related physiological changes.[6,7] While mortality and severe morbidity serve as traditional indicators of surgical quality of care and outcomes, it is crucial to acknowledge that older adults often prioritize understanding the potential impact of surgery on their quality of life (QOL), psychosocial functioning, independence, and engagement in valued life activities (e.g., recreational activities, activities of daily living, and social activities).[8–10] Thus, patient-reported outcomes (PROs) are essential measures of surgical success, particularly from the perspective of the older adult.[11,12]

One crucial PRO warranting evaluation and consideration following surgery is symptom burden, defined as “a variety of symptoms experienced by patients, including the number of symptoms, frequency of occurrence, severity, physical impairment, and psychological impairment.[13] Although extensively studied in oncology settings, and to a lesser degree in specific major surgical procedures, such as coronary artery bypass grafting (CABG) surgery, symptom burden remains underexplored in elective major surgery among older adults.[14,15] Research has shown that the severity and persistence of postoperative symptoms can adversely affect surgical recovery, leading to poor QOL, compromised psychosocial and functional status, and increased risk of morbidity

and mortality.[15–19] Nonetheless, clinical providers often fail to detect as many as half of all patient-reported symptoms, limiting opportunities for early intervention and preventable emergency room visits or hospital readmissions.[20] Little is known about the trajectory of postoperative symptom experiences from the viewpoint of older adults across a range of major elective surgical procedures. Therefore, this qualitative study aimed to elucidate the lived experiences of older adults regarding challenging postoperative symptoms and the impact of those symptoms on daily life and psychosocial well-being for up to three months after major elective surgery.

METHODS

Design

A qualitative study design was utilized to identify prevalent themes from one-to-one semi-structured interviews with older adults who had recently undergone a major elective surgery at one and three months postoperatively. The philosophical underpinnings of this qualitative thematic analysis study design were guided by a constructivist approach that maintains that perceived reality is subjective and constructed from the viewpoint of the individual.[21] Qualitative methods were reported following the Consolidated Criteria for Reporting Qualitative Research (COREQ).[22] The study was approved by the University of California, San Francisco (UCSF) Institutional Review Board (IRB # 19-28391).

Participants

English-speaking adults aged 65 years of age or older having elective major surgery were recruited from the UCSF Prepare clinic, a preoperative patient readiness clinic, if scheduled to have a major operation as defined by the American Medical

Association (i.e., >1% 30-day in-hospital mortality).[23] Convenience sampling was used due to its suitability for the initial exploration of a phenomenon with limited prior understanding.[24,25] After obtaining informed consent, the participants completed a demographics questionnaire and were scheduled for a phone interview. All participants received a $25 gift card for participation.

Data Collection

We employed semi-structured telephone interviews to collect data from participants one and three months after their surgical procedures. The interviews were conducted between November 2020 and November 2021. Two interviewers (SA and MR) conducted the interviews, both of whom received training on the research subject matter and on qualitative interviewing protocols from a senior qualitative researcher. The research team developed and pilot-tested an interview guide (Appendix 2), that covered the following broad topics: 1) postoperative experiences after discharge, 2) unexpected components of recovery, and 3) recommendations for how the healthcare system can better support surgical recovery after discharge. Although the one- and three-month interview guides were similar, the latter included additional questions regarding changes or new challenges since the previous interview. Each interview lasted for approximately 30 minutes. Interviews were audio-recorded, transcribed verbatim, and uploaded into Atlas.ti, a qualitative data analysis software program.[26] All participant interviews were de-identified.

Data Analysis

The data analysis process involved three coders (CK, SA, and AC), who employed an inductive approach to identify emerging themes through line-by-line

coding of transcripts. The coders initially identified codes and overarching themes during a comprehensive first-pass reading of all the transcripts. They then organized the codes into a standardized codebook, which served as a guide for the second-pass coding. A second coder reviewed each transcript during a second round of coding. The coding team discussed any discrepancies during the weekly collaborative meetings to reach a consensus.

The research team iteratively discussed and refined the categorization of identified codes into broader themes until data saturation was achieved, with no new themes emerging. Final themes were shared with the surgery and geriatric clinical providers on the research team for their input. The team selected exemplar quotes from the transcribed interviews to accompany the identified themes. Field notes from the interviews were captured and discussed as part of assessing for reflexivity (subjective perspective).[27.]

RESULTS

Nineteen participants completed a one-month postoperative interview, and seventeen additionally completed a three-month interview (Table 1). Prior to the three-month interview, one participant died, and the other did not respond to research team outreach. The participants were predominantly male (63.2%), white (73.7%), married (73.7%), and had at least some level of college education (90.9%). The median age was 74.5 years (range 67-82). All participants were English-speaking. Participants underwent diverse surgeries encompassing a wide range of surgical specialties, with cancer as the most common indication for surgery (n=8, 42.1%) (see Table 1 for a list of operations).

Three themes were identified: 1) valued life activities and psychosocial well-being were significantly impacted by patient-reported symptoms for at least three months following surgery; 2) participants reported feeling surprised by the intensity and duration of postoperative symptoms; and 3) participants voiced the need for additional support, resources, and education on postoperative symptom management at home.

Theme 1: Impact of Postoperative Symptoms on Valued Life Activities and Psychosocial Well-being

Participants reported physical and psychological symptoms that negatively impacted their ability to participate in valued daily activities or their psychosocial well-being (Table 2). During one-month post-surgical interviews, all 19 participants reported at least one challenging postoperative symptom. At three-months post-surgery, 12 (70%) participants continued to report at least one bothersome symptom that adversely affected their daily life or psychosocial well-being. Postoperative pain (n=12, 63.1%) was the most reported symptom at one-month post-surgery, followed by gastrointestinal discomfort (n=8, 42.1%), anxiety/stress (n=8, 42.1%), and fatigue (n=7, 36.8%). Depressive symptoms were not initially reported one-month after surgery; however, during the three-month post-surgical interviews, 6 (35.3%) older adults reported depressive symptoms. Postoperative pain (n=6, 35.3%) and fatigue (n=4, 23.6%) persisted.

Participants spoke at length about the impact of postoperative symptoms experienced at home and how the symptoms prohibited them from participating in the daily activities they valued, such as driving a car, exercise, or social interactions (Table 3). One participant stated, "*I can't go out dancing anymore. I can't do hardly anything*

anymore [due to pain].” During the three-month interview another participant mentioned limitations related to both pain and fatigue, “*I like working on the RV or changing out batteries in the car. And I can’t do that anymore [due to pain and fatigue].”* Patients who continued to describe postoperative symptoms during the three-month interview also tended to concurrently to report depressive symptoms. As one patient stated, “*I was getting really depressed because of the pain.”*

Theme 2: Surprised by the Intensity and Duration of Symptoms

Participants reported feeling surprised by the intensity and duration of their postoperative symptoms. Several participants mentioned that despite receiving comprehensive preoperative education, they felt frustrated, overwhelmed, and unprepared to manage their symptoms at home. Regarding pain, one participant stated, “*You would think I’d be out of pain, I’m not.”* Another participant stated, *“Well, it’s like way worse than I ever thought [Gastrointestinal-related Issues]. So yeah, this has been very rough.”* Several participants also reported how surprised they were regarding the emotional component of recovery at home, *“You know, there are highs and lows emotionally while I go through all this [pain]. The operation was a lot more than I thought it would be.”* There was also hesitancy to share personal challenges with postoperative symptoms with clinicians. As one participant stated, “*I am not talking to my doctor about every symptom that I experience. And a lot of it won’t do any good. There’s nothing the doctor can do to help me.”* Another participant stated that they did not think their doctor understood the extent of the impact of postoperative symptom burden after discharge, “*I think doctors don’t even realize what you’re feeling because they haven’t been through it. It’s incapacitated me in so many ways.”*

While participants conveyed their surprise at the intensity and duration of postoperative symptoms, along with the detrimental influence of these symptoms on their capacity to partake in meaningful daily activities over the initial three-month period following surgery, there was no evidence they regretted having surgery, i.e., decisional regret.[28]

Theme 3: Recommendations for Postoperative Symptom Management

Older adults universally agreed that more education, support, and resources are needed for effective symptom management at home (Table 4). Participant suggestions fell into three categories: more support and communication, tailored patient-centered information on what to expect related to symptom management, and technology-based modes of delivery for additional education and support.

Study participants indicated that more support for symptom management was needed. One recommended form of support was the use of support groups. Support group infrastructure suggestions varied from peer-led to healthcare system-led. One participant stated, *"I think they [other surgical patients] should talk to someone like me, a veteran surgical patient. It would help [with coping with recovery at home]."*

Participants additionally requested more routine communication and follow-up from the clinical team beyond the routine surgical postoperative follow-up appointment. One participant noted, "*It would be nice if they just had [clinical] people who had the time to just make routine calls [after discharge]. Like how you are doing [with symptoms], how's your feeding coming, do you understand about taking your medications."*

In our study, most participants acknowledged receiving comprehensive information about the risks and technical aspects of their surgical procedures. However, the majority noted a lack of both pre and postoperative education regarding postoperative symptom management at home. One participant remarked, "*Nobody showed you how to cough, or at least how to use a pillow on your abdomen [to prevent additional incisional pain]. They could provide more information on matters like that. I had to search online."* Moreover, participants frequently recommended that educational resources and information should be tailored to their individual needs and experiences. As one participant stated, *"There needs to be a wider range of information [education on symptom management] that people can understand. They could be somewhere in between or either end; we are all different."*

A final overarching suggestion by several participants was the use of technology as a mode of delivery for symptom management resources and education. Technology-based suggestions varied and included an online library of informational videos, smartphone technology, computer-based application programs (e.g., programs on distraction and relaxation), and various social media platforms. One participant stated, *“We have enough smart people to design a [software application] program, to help people have a positive attitude about going through this [symptom experience] and how to manage things at home.”*

DISCUSSION

This qualitative study aimed to explore the postoperative symptom experience faced by older adults following major elective surgery. Study participants reported feeling surprised by the extent of post-surgical symptoms and the widespread impact of

those symptoms on their psychosocial functioning and ability to engage in daily meaningful life activities during the first three months after major surgery. Participants felt inadequately prepared to manage their symptoms at home and expressed the necessity for additional support, resources, and education on symptom management. The findings from this study highlight the need for surgeons to recognize postoperative symptom burden as an important patient-reported outcome measure to consider in older adults given its distressful impact on the ability to engage in valued life activities following surgery.

Our study findings share both similarities and differences with the literature on the impact of postoperative symptom burden on psychosocial functioning after major surgery. Previous research on coronary artery bypass graft (CABG) surgery indicates that patients rarely encounter isolated symptoms, but rather often experience multiple simultaneous postoperative symptoms, leading to reduced psychosocial functioning.[24,35] Our study echoes these findings, with approximately 75% of participants reporting two or more symptoms affecting their psychosocial well-being one-month post-surgery, and nearly 40% reporting two or more symptoms during the three-month interview. Previous research also suggests that psychological symptoms such as anxiety and depression are among the most frequently occurring postoperative symptoms affecting psychosocial functioning after major surgery.[24,36] While our study findings did capture the occurrence of anxiety and depressive symptoms, we found that pain was the most frequently reported symptom one month after surgery, with depression initially absent. However, at three months postoperatively, pain and depression emerged concurrently as the most frequently reported symptoms. This is

potentially a key finding, as acute postoperative pain may contribute to the onset of depression.[33,34] Our findings about depression being more prominent at 3 months postoperatively, while potentially important, should be interpreted cautiously. Due to the study design and sampling methodology, conclusions about pain as a primary contributor of depression, cannot be made. It is also important to recognize that cancer was the indication for surgery in approximately 42% (n=8) of participants, suggesting that depression could be related to other factors, such as the underlying disease trajectory or prognosis. Additional longitudinal research in a larger representative sample with systematic validated questionnaires focused on capturing depression, pain, and other symptoms would be needed to robustly understand postoperative symptom co-occurrence, symptom trajectory, and variation of symptom occurrence by type of surgery or presenting medical condition.

The participants in our study emphasized the need for more information on symptom management before and after surgery, highlighting the inadequacy of perioperative education on symptom management at home. This finding aligns with a recent review on postoperative hospital-to-home care transitions in older adults, revealing a gap in the provision of patient symptom management education.[35] Study participants also expressed receptiveness to a variety of technology-based options for the delivery of education and support for symptom management. This finding is consistent with current research demonstrating that older adults are open to using a variety of technologies, including immersive virtual reality, for the delivery of education on symptom management, so as long as training and support are available.[36–39]

Our research differs from the existing surgical literature on postoperative symptom burden in several key aspects. First, our research sheds light on not only the detrimental effects of postoperative symptoms on older adults' psychosocial well-being, but also the negative impact on daily engagement in valued life activities following surgery. Valued life activities comprise a wide array of enjoyable or meaningful pursuits, including self-care tasks, social interactions, and leisure-based activities.[10,40] This finding is particularly significant for understanding the potential negative effects of surgery on older adults' engagement in meaningful life activities postoperatively. It highlights the importance of delivering patient-centered care that aligns with the patient's surgical goals and personal values.[10,41]

Second, our study leveraged qualitative methods to capture patient-reported symptoms. In contrast, previous studies have relied on a variety of heterogenous symptom burden questionnaires, tailored to a specific type of surgery, to acquire patient-reported symptoms. Symptom burden instruments are often restricted in their ability to detect certain symptoms.[17] For example, our study captured patient-reported memory loss, which is not a symptom typically captured in common surgery-specific PRO instruments, such as the Cardiac Symptom Survey or the MD Anderson Symptom Inventory (MDASI).[42,43] Our findings support the need for research to establish a standardized validated symptom burden assessment questionnaire that captures the full spectrum of psychological and physical postoperative symptoms across a variety of major surgeries.

Finally, our research expands upon previous studies that have predominantly focused on evaluating postoperative symptom burden on psychosocial functioning in

specific types of major operations, such as CABG and lung cancer surgery.[17,18] In contrast, our study delves into the essence of the symptom burden experience across a diverse array of major elective surgeries. We found that, irrespective of the type of major elective operation, postoperative symptom burden was considerable and universally experienced by all participants, profoundly impeding not only psychosocial functioning but also involvement in activities deemed valuable. It is vital to recognize the pervasive nature of the adverse impact of symptom burden across all types of major elective surgeries examined in our study. This highlights the need for proactive assessment and management of postoperative symptoms in older adults, ensuring their well-being and enabling them to continue living meaningful lives after surgery.

Our study contributes to the growing body of knowledge on symptom burden in older adults as a vital postoperative patient-reported outcome, and our findings have important implications for the surgical care of older adults. First, effective pre- and post-operative interventions focused on offering patient-centered education, support, and resources for symptom management at home for older adults could potentially lessen symptom burden, thereby improving psychosocial functioning and enhancing engagement in valued life activities after surgery. Evidence from other patient care settings, such as oncology, suggests that providing sufficient education and support for symptom management can alleviate psychological distress in patients undergoing treatment.[39]

Second, patient-reported outcome measures, such as postoperative symptom burden or psychosocial distress in older adults, are scarcely captured in surgical research literature or as part of national surgical quality improvement programs.

Consequently, surgeons may not be fully aware of the extent of symptom distress that older adults face during the recovery process. National programs aimed at enhancing surgical care and quality for older adults, such as the American College of Surgeons (ACS) National Quality Improvement Program (NSQIP) and the ACS's Geriatric Surgical Verification Program, should contemplate expanding program standards to encompass PRO measures in older adults, including postoperative symptom burden.[11,12,44,45] Assessing for and addressing symptom burden proactively could help surgical teams identify quality improvement opportunities for geriatric surgical patient populations throughout the perioperative care continuum. Furthermore, surgeons' understanding of postoperative symptom burden in older adults may play a crucial role in preoperative care discussions, decision-making, expectation setting, and proactive planning of postoperative care needs.

Lastly, evidence-based surgical protocols, such as Enhanced Recovery After Surgery (ERAS), have reduced the mean length of hospital stay by 2.3 days.[46] As a result, ERAS patients may have fewer opportunities to consult with healthcare professionals and receive symptom management education prior to discharge.[47] Some studies evaluating the use of ERAS protocols in older adults have reported a readmission rate of up to 19% within 30 days of certain types of major surgery because of complications, including challenges in the management of postoperative symptoms, such as pain and nausea.[46,48,49] Most ERAS protocols include patient education regarding the protocol components; however recent research indicates the need for additional patient education as part of the ERAS programs.[47,50] We recommend expanding ERAS patient education to include symptom management education.

This study has several limitations that warrant acknowledgment. First, although informative, the findings are not generalizable due to the qualitative nature of the study design and the small sample size. Moreover, the study findings represent a homogeneous convenience sample of predominantly educated English-speaking white males with good access to care at a large academic center. Although our sample may represent an ideal case scenario, the participants were nevertheless significantly affected by their postoperative symptoms and expressed the need for additional symptom management education and support. Further, while our sample reflects the underlying population seeking care at one academic hospital, it is important to recognize that those from varying cultural or ethnic backgrounds, women, non-English speaking patients, individuals with lower education levels, or those with less access to care could perceive and express symptoms after surgery in a manner not captured in this study. Additionally, this study only included participants who underwent planned inpatient surgeries with preoperative preparation. It remains unknown whether older adults undergoing urgent, or emergency surgery would report similar symptom experiences. Moreover, the absence of systematic screening utilizing validated questionnaires may have led to potential underreporting of specific symptoms. Finally, the ability to capture postoperative symptoms could have been limited by participants' discretion in verbally expressing their symptoms during interviews.

In conclusion, postoperative symptom burden may have a more significant impact on older adults than surgeons realize, making it a crucial patient-reported outcome measure that should be evaluated postoperatively. Future research is needed to identify approaches for routinely assessing for and evaluating postoperative

symptom burden in older adults. Future studies are also warranted to evaluate the postoperative symptom experience of older adults who identify with historically marginalized groups or those who may experience frailty or functional limitations. Finally, the development and testing of interventions aimed at providing efficacious management of postoperative symptoms experienced by older adults are warranted.

Sources of Support: This work was funded by The National Institute of Aging of the National Institutes of Health (K76AG05993 and K23AG065438-03). This work was supported by the National Institute of Nursing Research of the National Institutes of Health (T32NR01692), the University of California, San Francisco (UCSF), UCSF School of Nursing Century Research award, the UCSF Graduate Mentorship Fellowship award, the UCSF Phillip R. Lee Health Policy Fellowship award, the UCSF Office of the Executive Vice Chancellor and Provost (EVCP) Social and Population Science Fellowship Research Award, and by the Department of Veterans Affairs, Veterans Health Administration, Office of Academic Affiliations VA Quality Scholars Advanced Fellowship Program (OAA 3Q072019C).

Conflict of Interest: All authors report no conflicts of interest. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

Table 2.1. Patient Demographic and Clinical Characteristics

Age (n=19)	
Median, years	74.5 (range 67-82)
Gender (n=19)	**n (%)**
Male	12 (63.2)
Female	7 (36.8)
Race/ethnicity (n=19)	
White/Caucasian	14 (73.7)
Asian	3 (15.8)
Hispanic	1 (5.0)
Black or African American	1 (5.0)
Relationship Status (n=11)[1]	
Currently Married	8 (73.7)
Divorced	1 (9.1)
Widowed	2 (18.2)
Level of Education(n=11)[1]	
High school diploma or GED	1 (9.1)
Some college, no degree	5 (45.5)
Any college, graduate, or professional degree	5 (45.5)
Surgical Specialty & Primary Procedure (n=19)	
General Surgery	**9 (47.3)**
Pancreaticoduodenectomy	3 (15.8)
Open hepatectomy	2 (10.5)
Open colorectal resection	2 (10.5)
Open Adrenalectomy	1 (5.3)
Open small bowel resection	1 (5.3)
Neurosurgery	**2 (10.5)**
Craniotomy	2 (10.5)
Cardiac	**2 (10.5)**
Aortic Valve Replacement	1 (5.3)
Tricuspid Valve Replacement	1 (5.3)
Vascular	**2 (10.5)**
Aorto-ilio-femoral bypass	1 (5.3)
Open repair of abdominal aortic aneurysm	1 (5.3)
Transplant	**2 (10.5)**
Kidney transplant	2 (10.5)
Thoracic	**1 (5.3)**
Open thoracotomy lobectomy	1 (5.3)
Urologic	**1 (5.3)**
Radical cystectomy	1 (5.3)

[1]Sociodemographic data were collected by participant self-report through a secure online survey; however, despite several attempts by the research team to partner with study participants to complete missing data on survey questionnaires, eight participants declined to answer relationship status or level of education.

Table 2.2 Symptoms Participants Chose to Reveal During Semi-Structured Interviews

Self-Reported Distressing Symptoms[1]	1 Month After Surgery n=19	3 Months After Surgery n=17
	n (%)	n (%)
Reported at least one surgery-related symptom	19(100.0)	12 (70.6)
Reported two surgery-related symptoms	14 (73.7)	7 (41.2)
Reported three or more surgery-related symptoms	9 (47.4)	5 (29.4)
Pain	12 (63.2)	6 (35.3)
Gastrointestinal	8 (42.1)	2 (11.8)
Anxiety/Stress[2]	8 (42.1)	2 (11.8)
Fatigue	7 (36.8)	4 (23.5)
Medication-Related Side Effects	5 (26.3)	1 (5.9)
Neuropathy	3 (15.8)	2 (11.8)
Shortness of Breath	1 (5.3)	1 (5.9)
Depression[2]	0 (0.0)	6 (35.3)
Memory Loss	0 (0.0)	1 (5.9)

[1] Self-reported as verbally mentioned by the participant during interviews.
[2] Anxiety/Stress and depression were only captured if the patient specifically mentioned feeling depressed, stressed, or anxious.

Table 2.3 Exemplar Quotes Illustrating Patient-Reported Bothersome Symptoms

Types of Symptoms	Exemplar Quotes
Pain	"But I wake up at night, and that's a son of a bitch, it really is. Excuse my language. It's more than the man can handle [the pain]." (1- month, 78 y/o Male, Radical Cystectomy)
Gastrointestinal	"It's a burning acid pain right in the middle of stomach. It was just constant, constant, constant pain." (1-month, 69 y/o Male, Pancreaticoduodenectomy)
Anxiety/Stress	"It is very stressful because you don't want to put any weight or any pressure on your wound or your ribcage due to pain." (1-month, 78 y/o Male, Aortic Valve Replacement)
Fatigue	"I have bouts of tiredness where I just, maybe three times a day I need to go lay down for half an hour. So that kind of interferes with my ability [to participate in daily activities]." (1-month, 74 y/o Male, Open Colorectal Resection)
Medication-Related Side Effects	"They had me on Oxycontin; I'll never go back on that stuff again. it's a hallucinating thing. Oh my God." (1- month, 67 y/o Female, Open Colorectal Resection).
Neuropathy	"This numbness and this not feeling of the leg is annoying. That foot is my driving foot. I'm hoping that will end [so I can drive], but who knows?" (1- month, 78 y/o Female, Aorto-ilio-Femoral Bypass)
Dyspnea	"If I take a walk around the house, for some time after that I have to sit down to relieve my breath because it seems like I'm always out of breath" (1-month, 68 y/o Male, Pancreaticoduodenectomy)
Depression	"I guess symptoms of being really down, what's the word? Depression." (3-months post-op, 82 y/o Female, Open Hepatectomy)
Memory Changes	"My memory is not OK. Every time they ask me a question I can answer it, but sometimes when I talk about something, I forget what it is. I didn't have that before [the surgery]." (3- months, 80 y/o Female, Open Adrenalectomy)

Table 2.4 Patient Recommendations for Additional Support and Education

Theme	Subtheme	Exemplar Quote
More Support	Peer Support	"It's the support thing, that's probably the number one thing [that is needed]. Like you can call somebody who's going to be going through the same thing or has gone through it." (3 months, 74 y/o Male, Open Colorectal Resection)
	Clinical Team Communication	"They [the clinical team] need a better flow of communication, a simpler, easier way of providing that information [on symptom management]." (3- months, 71 y/o Female, Open repair of Abdominal Aortic Aneurysm)
More Education & Information	Customizable	"This is ordinary stuff to surgeons, but to the patient, this is a once-in-a-lifetime thing. I think that there are all these opportunities to teach the patient more about what to expect [on symptom management] according to personal needs." (1-month, 76 Female, Tricuspid Valve Replacement)
	Patient-Centered	"There is much more attention to the technical aspect of surgery [referring to education] of what a person goes through, and it is, from my experience, really shortchanging the individual personal experience." (1- month, 74 y/o Male, Open Colorectal Resection)
Technological Mode of Delivery	Software Applications	"We need the ability to recapture some of the information [on symptom management] and having access to a little video library application or something like that would help." (1-month, 71 y/o Male, Kidney Transplant)
	Websites	"It would be nice if there was kind of a website where you can check in to see what's going [with symptoms]. I've been trying get my head wrapped around it how it could be easier." (1-month, 73 y/o Male, Kidney Transplant)
	Social Media	"So having it [education on symptom management] come from a reliable source means a lot to me. To be publishing education material over YouTube videos." (3-months, 78 Female, Aorto-ilio-Femoral Bypass)

References

1. Etzioni DA, Liu JH, Maggard MA, Ko CY. The Aging Population and Its Impact on the Surgery Workforce. *Ann Surg*. 2003;238(2):170-177. doi:10.1097/01.SLA.0000081085.98792.3d
2. National Institutes of Health (NIH). Published August 11, 2022. Accessed March 20, 2023. https://www.nih.gov/nih-style-guide/age
3. Fact Sheet: Aging in the United States. PRB. Accessed January 28, 2023. https://www.prb.org/resources/fact-sheet-aging-in-the-united-states/
4. Federal Interagency Forum on Aging-related Statistics. American Institutes for Research. Accessed July 13, 2022. https://www.air.org/project/federal-interagency-forum-aging-related-statistics
5. Deiner S, Westlake B, Dutton RP. Patterns of surgical care and complications in elderly adults. *J Am Geriatr Soc*. 2014;62(5):829-835. doi:10.1111/jgs.12794
6. Gill TM, Vander Wyk B, Leo-Summers L, Murphy TE, Becher RD. Population-Based Estimates of 1-Year Mortality After Major Surgery Among Community-Living Older US Adults. *JAMA Surgery*. Published online October 19, 2022:e225155. doi:10.1001/jamasurg.2022.5155
7. Tang VL, Jing B, Boscardin J, et al. Association of Functional, Cognitive, and Psychological Measures With 1-Year Mortality in Patients Undergoing Major Surgery. *JAMA Surg*. 2020;155(5):412-418. doi:10.1001/jamasurg.2020.0091
8. Fried TR, Bradley EH, Towle VR, Allore H. Understanding the treatment preferences of seriously ill patients. *N Engl J Med*. 2002;346(14):1061-1066. doi:10.1056/NEJMsa012528

9. Berian JR, Mohanty S, Ko CY, Rosenthal RA, Robinson TN. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surgery*. 2016;151(9):e161689. doi:10.1001/jamasurg.2016.1689

10. Kata A, Dutt M, Sudore RL, Finlayson E, Broering JM, Tang VL. What Matters? The Valued Life Activities of Older Adults Undergoing Elective Surgery. *J Am Geriatr Soc*. 2019;67(11):2305-2310. doi:10.1111/jgs.16102

11. Basch E. Patient-Reported Outcomes - Harnessing Patients' Voices to Improve Clinical Care. *N Engl J Med*. 2017;376(2):105-108. doi:10.1056/NEJMp1611252

12. Geriatric Surgery Verification. ACS. Accessed September 16, 2022. https://www.facs.org/quality-programs/accreditation-and-verification/geriatric-surgery-verification/

13. Gapstur RL. Symptom burden: a concept analysis and implications for oncology nurses. *Oncol Nurs Forum*. 2007;34(3):673-680. doi:10.1188/07.ONF.673-680

14. Basch E, Deal AM, Kris MG, et al. Symptom Monitoring With Patient-Reported Outcomes During Routine Cancer Treatment: A Randomized Controlled Trial. *J Clin Oncol*. 2016;34(6):557-565. doi:10.1200/JCO.2015.63.0830

15. Connerney I, Shapiro PA, McLaughlin JS, Bagiella E, Sloan RP. Relation between depression after coronary artery bypass surgery and 12-month outcome: a prospective study. *Lancet*. 2001;358(9295):1766-1771. doi:10.1016/S0140-6736(01)06803-9

16. Hu ZY, Feng XQ, Fu MR, Yu R, Zhao HL. Symptom patterns, physical function and quality of life among head and neck cancer patients prior to and after surgical treatment: A prospective study. *Eur J Oncol Nurs*. 2020;46:101770. doi:10.1016/j.ejon.2020.101770

17. Merlo A, Carlson R, Espey J, et al. Postoperative Symptom Burden in Patients Undergoing Lung Cancer Surgery. *J Pain Symptom Manage*. 2022;64(3):254-267. doi:10.1016/j.jpainsymman.2022.05.016

18. Abbott AA, Barnason S, Zimmerman L. Symptom Burden Clusters and Their Impact on Psychosocial Functioning following Coronary Artery Bypass Surgery. *J Cardiovasc Nurs*. 2010;25(4):301-310. doi:10.1097/JCN.0b013e3181cfbb46

19. Hallet J, Zuckerman J, Guttman MP, et al. Patient-Reported Symptom Burden After Cancer Surgery in Older Adults: A Population-Level Analysis. *Ann Surg Oncol*. Published online September 6, 2022. doi:10.1245/s10434-022-12486-0

20. Pakhomov SV, Jacobsen SJ, Chute CG, Roger VL. Agreement between patient-reported symptoms and their documentation in the medical record. *Am J Manag Care*. 2008;14(8):530-539.

21. Appleton JV, King L. Journeying from the philosophical contemplation of constructivism to the methodological pragmatics of health services research. *Journal of Advanced Nursing*. 2002;40(6):641-648. doi:10.1046/j.1365-2648.2002.02424.x

22. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care*. 2007;19(6):349-357. doi:10.1093/intqhc/mzm042

23. Schwarze ML, Barnato AE, Rathouz PJ, et al. Development of a list of high-risk operations for patients 65 years and older. *JAMA Surg*. 2015;150(4):325-331. doi:10.1001/jamasurg.2014.1819

24. Denzin NK, Lincoln YS. *The SAGE Handbook of Qualitative Research*. SAGE Publications; 2011. https://books.google.com/books?id=AIRpMHgBYqIC

25. Etikan I, Musa SA, Alkassim RS. Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*. 2015;5(1):1. doi:10.11648/j.ajtas.20160501.11

26. ATLAS.ti: The Qualitative Data Analysis & Research Software. ATLAS.ti. Accessed January 10, 2022. https://atlasti.com/

27. Olmos-Vega FM, Stalmeijer RE, Varpio L, Kahlke R. A practical guide to reflexivity in qualitative research: AMEE Guide No. 149. *Medical Teacher*. 2022;0(0):1-11. doi:10.1080/0142159X.2022.2057287

28. Wilson A, Ronnekleiv-Kelly SM, Pawlik TM. Regret in Surgical Decision Making: A Systematic Review of Patient and Physician Perspectives. *World J Surg*. 2017;41(6):1454-1465. doi:10.1007/s00268-017-3895-9

29. Gallagher R, McKinley S, Dracup K. Post discharge problems in women recovering from coronary artery bypass graft surgery. *Aust Crit Care*. 2004;17(4):160-165. doi:10.1016/s1036-7314(04)80021-3

30. Oxlad M, Wade TD. Longitudinal risk factors for adverse psychological functioning six months after coronary artery bypass graft surgery. *J Health Psychol*. 2008;13(1):79-92. doi:10.1177/1359105307084314

31. Duits AA, Duivenvoorden HJ, Boeke S, et al. A structural modeling analysis of anxiety and depression in patients undergoing coronary artery bypass graft surgery: a model generating approach. *J Psychosom Res*. 1999;46(2):187-200. doi:10.1016/s0022-3999(98)00046-4

32. Gallo LC, Malek MJ, Gilbertson AD, Moore JL. Perceived cognitive function and emotional distress following coronary artery bypass surgery. *J Behav Med*. 2005;28(5):433-442. doi:10.1007/s10865-005-9010-y

33. Ghoneim MM, O'Hara MW. Depression and postoperative complications: an overview. *BMC Surg*. 2016;16:5. doi:10.1186/s12893-016-0120-y

34. Katz J, Seltzer Z. Transition from acute to chronic postsurgical pain: risk factors and protective factors. *Expert Rev Neurother*. 2009;9(5):723-744. doi:10.1586/ern.09.20

35. Hladkowicz E, Dumitrascu F, Auais M, et al. Evaluations of postoperative transitions in care for older adults: a scoping review. *BMC Geriatrics*. 2022;22(1):329. doi:10.1186/s12877-022-02989-6

36. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82((Ding L.; Hua H.; Zhu H.; Zhu S.; Lu J.; Zhao K.; Xu Q., qinxu@njmu.edu.cn) School of Nursing, Nanjing Medical University, Nanjing, China):87-94. doi:10.1016/j.ijsu.2020.08.033

37. Elimelech OC, Ferrante S, Josman N, et al. Technology use characteristics among older adults during the COVID-19 pandemic: A cross-cultural survey. *Technol Soc*. 2022;71:102080. doi:10.1016/j.techsoc.2022.102080

38. Yu Y, Li M, Kang R, et al. The effectiveness of telephone and internet-based supportive care for patients with esophageal cancer on enhanced recovery after surgery in China: A randomized controlled trial. *Asia Pac J Oncol Nurs*. 2022;9(4):217-228. doi:10.1016/j.apjon.2022.02.007

39. Aranda S, Jefford M, Yates P, et al. Impact of a novel nurse-led prechemotherapy education intervention (ChemoEd) on patient distress, symptom burden, and treatment-related information and support needs: results from a randomised, controlled trial. *Ann Oncol*. 2012;23(1):222-231. doi:10.1093/annonc/mdr042

40. Katz PP, Yelin EH. Activity loss and the onset of depressive symptoms: do some activities matter more than others? *Arthritis Rheum*. 2001;44(5):1194-1202. doi:10.1002/1529-0131(200105)44:5<1194::AID-ANR203>3.0.CO;2-6

41. Berian JR, Rosenthal RA, Baker TL, et al. Hospital Standards to Promote Optimal Surgical Care of the Older Adult: A Report From the Coalition for Quality in Geriatric Surgery. *Annals of Surgery*. 2018;267(2):280. doi:10.1097/SLA.0000000000002185

42. MD Anderson Symptom Inventory (MDASI). MD Anderson Cancer Center. Accessed April 6, 2023. https://www.mdanderson.org/research/departments-labs-institutes/departments-divisions/symptom-research/symptom-assessment-tools/md-anderson-symptom-inventory.html

43. Nieveen JL, Zimmerman LM, Barnason SA, Yates BC. Development and content validity testing of the Cardiac Symptom Survey in patients after coronary artery bypass grafting. *Heart Lung*. 2008;37(1):17-27. doi:10.1016/j.hrtlng.2006.12.002

44. ACS NSQIP. ACS. Accessed September 16, 2022. https://www.facs.org/quality-programs/data-and-registries/acs-nsqip/

45. Lavallee DC, Chenok KE, Love RM, et al. Incorporating Patient-Reported Outcomes Into Health Care To Engage Patients And Enhance Care. *Health Aff (Millwood)*. 2016;35(4):575-582. doi:10.1377/hlthaff.2015.1362

46. Zhang X, Yang J, Chen X, Du L, Li K, Zhou Y. Enhanced recovery after surgery on multiple clinical outcomes: Umbrella review of systematic reviews and meta-analyses. *Medicine (Baltimore)*. 2020;99(29): e20983. doi:10.1097/MD.0000000000020983

47. Wang D, Hu Y, Liu K, et al. Issues in patients' experiences of enhanced recovery after surgery (ERAS) : a systematic review of qualitative evidence. *BMJ Open*. 2023;13(2):e068910. doi:10.1136/bmjopen-2022-068910

48. Bu J, Li N, Huang X, He S, Wen J, Wu X. Feasibility of Fast-Track Surgery in Elderly Patients with Gastric Cancer. *J Gastrointest Surg*. 2015;19(8):1391-1398. doi:10.1007/s11605-015-2839-7

49. Karran A, Wheat J, Chan D, Blake P, Barlow R, Lewis WG. Propensity Score Analysis of an Enhanced Recovery Programme in Upper Gastrointestinal Cancer Surgery. *World J Surg*. 2016;40(7):1645-1654. doi:10.1007/s00268-016-3473-6

50. Gillis C, Gill M, Marlett N, et al. Patients as partners in Enhanced Recovery After Surgery: A qualitative patient-led study. *BMJ Open*. 2017;7(6):e017002. doi:10.1136/bmjopen-2017-017002

CHAPTER 3

A Scoping Review of Immersive Virtual Reality and Postoperative Pain Among Older Adults

ABSTRACT

Objective: The primary aim of this scoping review was to map out and evaluate the current landscape of studies examining immersive virtual reality (IVR) interventions for postoperative pain management in surgical adults 65 years of age and older.

Background: There is a growing interest in non-pharmacological interventions to address challenges tied to pain management in older adults. Immersive virtual reality has shown promise in mitigating acute pain across various clinical settings, especially in younger age ranges. However, its application in older adult populations across to manage postoperative pain a spectrum of surgical procedures remains largely unknown.

Methods: A comprehensive literature search of five online peer-reviewed databases was conducted up through January 2024. Quantitative and mixed methods studies were eligible for inclusion if: (a) mean or median age of participants was 65 years or older; (b) surgical procedures were conducted in an inpatient or outpatient operating room setting; (c) the intervention group received an IVR intervention before, during, or after surgery; and (d) postoperative pain scores were numerically collected and reported as a primary or secondary outcome measure. Study titles and abstracts underwent initial screening against inclusion/exclusion criteria. Selected full-text articles meeting eligibility criteria underwent a second level of review. A narrative report

was compiled with the identified studies. Methodological quality was assessed with the Effective Public Health Practice Project Quality Assessment Tool.

Results: A literature search yielded 1049 results, 10 of which were included in the review. In total, the 10 studies included 545 participants with a median sample size of 53 (range:12-106). The reported mean age range was 65.5 to 75.7 years. Five of the ten studies were conducted in the United States. Three main findings emerged from included studies: 1) IVR for postoperative pain occurred predominantly in total joint replacement (TJR) surgery; 2) while over half of the studies in this review indicate that IVR could improve postoperative pain management, weak to moderate study designs and small sample sizes limited the ability to draw firm conclusions about IVR use in the older adult demographic; and 3) there is significant heterogeneity in how IVR is administered (timing, phase of care, frequency, and duration), as well as the types of IVR program content and equipment used for postoperative pain management.

Conclusions*:* The literature is sparse and heterogenous on the use of IVR for postoperative pain in older adults who have non-total joint surgery. Therefore, conclusions about acceptability, feasibility, and efficacy are not possible. This review highlights both the promise and the need for more rigorous randomized clinical trials on the efficacy of IVR in older adults across a spectrum of surgical procedures, and older adult subgroups (e.g., underrepresented minority groups and those with physical and cognitive limitations).

INTRODUCTION

Aging and Postoperative Pain

The projected near doubling of the U.S. older adult population to approximately 95 million by 2060 is expected to result in a corresponding significant increase in the number of surgeries performed within this demographic.[1–3] Although aging is thought to be linked to an increase in pain threshold and loss of pain sensitivity, adequate postoperative pain management in older adults nevertheless remains a substantial challenge.[4] Managing postoperative pain in older adults through pharmacological interventions poses inherent complexity, stemming from the physiological changes associated with aging and age-related diseases.[5,6] These factors may contribute to increased susceptibility to pain medication contraindications and an increased risk of adverse side effects, consequently presenting unique challenges in obtaining postoperative pain control in the older adult.[7] Moreover, the implications of inadequate postoperative pain management in older adults can precipitate geriatric-specific conditions including, delirium, functional decline, susceptibility to the development of chronic pain, and increased risk of chronic opioid addiction.[8–11]

Immersive Virtual Reality for Acute Pain

Amidst the innumerable challenges associated with pharmacological pain management in older surgical adults, a burgeoning interest has emerged in non-pharmacological interventions as a result of changes to policy and practice guidelines.[12–14] One non-pharmacological approach that holds significance in reducing postoperative pain is positive distraction, which entails engaging in thoughts or activities that divert attention away from pain perception.[15] Research into positive

distraction techniques, including music, imagery, and relaxation, has consistently shown efficacy in alleviating postoperative pain.[17–19] A relatively recent technological intervention that is making strides in healthcare is virtual reality (VR). Virtual reality broadly spans three primary categories, defined by the level of immersion and the sense of presence evoked.[16] Non-immersive VR involves basic interaction via 2D screens on computers, while semi-immersive VR provides advanced graphics on larger screens for a more captivating experience.[17–19] However, fully immersive virtual reality (IVR) facilitates an individual's interaction with a 3-dimensional (3D) environment using a combination of equipment, such as a head-mounted display (HMD).[16] This multisensory response (visual, auditory, and other senses) is thought to create a profound sense of 'presence,' or a feeling of physically being in the virtual space, which is hypothesized to increase the level of distraction away from painful stimuli.[20–26]

Immersive virtual reality, as a form of positive distraction, has demonstrated promise in mitigating acute pain across various clinical settings, such as burn wound care treatment and medical procedures in both adults under the age of 65 and pediatric populations.[27–32] A recent review also highlighted the efficacy of IVR in reducing postoperative pain levels in younger to middle aged surgical adults.[33] However, the application of IVR in the surgical older adult population has been comparatively understudied.

Given that older adults undergoing various surgical procedures may engage differently with IVR content and equipment than those in younger age groups, a more thorough evaluation of IVR for postoperative pain is needed in this demographic. Though some research has included older adults in IVR intervention studies for

postoperative pain management, there is scant research in the literature explicitly focused on the age 65 and older age range across a spectrum of surgical procedures.[34–36] Thus, the primary aim of this scoping review was to map out and critically appraise current studies examining IVR interventions as part of postoperative pain management in adults 65 years of age and older across a variety of surgical procedures. Future research endeavors are discussed based on the resulting body of evidence.

Key Study Definitions and Justifications

It is critical to define and justify several components of this scoping review. In the United States, the specific age that defines an “older adult” can vary based on context; however, 65 years of age and older is often considered to be the start of the "older adult" category, especially in the setting of certain types of medical conditions, housing, and community and federal programs.[37,38] This study defined “older adult” as 65 and older, to capture a broad spectrum of older adult age ranges. Furthermore, for the purposes of this review, only fully immersive virtual reality was captured. Finally, a scoping review approach was chosen as it enables a narrative description of the range and extent of existing evidence available on a given topic, particularly when a body of literature is newly developing and expected to be heterogeneous in nature, as is the case in the use of IVR for postoperative pain in older adults.[39]

METHODS

Protocol and Registration

This scoping review follows the procedures as outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR).[4] As this was a scoping review and not a systematic review, the study protocol was not eligible to be registered with PROSPERO, the international register of prospective reviews.[41]

Eligibility Criteria

Included in this scoping review are studies published in peer-reviewed journals up through January 2024 that met the following criteria organized by population, intervention, comparison, outcome, and study design (PICOS) (Table 1).[42] Randomized controlled trials, non-randomized controlled trials, pilot and feasibility studies, single arm cohort, and mixed method studies were eligible for inclusion if: (a) mean or median age of participants was 65 years or older; (b) surgical procedures were conducted in an inpatient or outpatient operating room setting; (c) the intervention group received an IVR intervention before, during, or after surgery; and (d) postoperative pain scores were numerically collected and reported as a primary or secondary outcome measure. Exclusions included: (a) medical procedures performed outside of an operating room; (b) case studies, observational studies, qualitative only studies, where pain as an outcome measure was not reported as a numeric score; (c) non-English language studies; (d) non-peer reviewed studies; and (e) non-immersive or semi-immersive VR (e.g., 2D virtual reality using only a computer and keyboard as the VR experience) were used as the intervention.

Information Sources and Search Strategy

With the input of a medical librarian, a comprehensive literature search of five online peer-reviewed databases (PubMed, EMBASE, PsycINFO, CINAHL, and Web of Science) was conducted on January 8, 2024 to identify publications that met eligibility criteria (Figure 1). A Google Scholar search was also conducted, as was a reference list search of previous reviews to ensure all possible relevant articles were included in the scoping review. The following overarching keyword search terms used were “virtual reality” or related synonyms and "postoperative pain.” The search was carried out with the following filters in place: English language and full text studies. No date limit was set. As IVR in healthcare is a relatively recent development, no limitations were placed on publication dates.

Screening

All retrieved studies from the database search were imported into Zotero reference management software.[43] Studies were then uploaded into Covidence software for duplication removal and screening.[44] This review consisted of two independent reviewers (CK and CR). To increase consistency among reviewers, both reviewers screened the same 853 studies imported from the five databases and the hand search of references (Figure 2). There were two levels of screening and selection. First, all study titles and abstracts were screened against initial inclusion and exclusion criteria. A second level of selection included a review of full-text articles that met eligibility criteria. All exclusions were justified in the Covidence software (Figure 2). Disagreements were discussed between the two reviewers and escalated to a third party (LP) for a final decision.

Data Abstraction and Synthesis of Results

A data collection abstraction form was developed using a standardized Microsoft Excel spreadsheet (version 6.627, 2016, Washington, U.S.) to extract key variables. One reviewer (CK) independently charted the data and discussed results regularly with the other reviewer (CR). Study characteristics collected were: first author, year of publication, country of publication, study design, sample size, and main findings. As related to the population of interest, the following was also collected: the mean or median age, sex, and type of primary surgical procedure (Table 2). Other items extracted were type of IVR equipment, content or environment, duration and frequency, the type of IVR used as described by study authors (e.g., interactive or passive), and the phase(s) of perioperative care that that IVR was administered (Table 3). Other relevant non-pain outcomes that were captured alongside postoperative pain were also extracted (Table 4). A narrative descriptive report of the data is presented to capture the range of evidence identified in the literature.

Article Quality Appraisal

Two raters (CK and CR) independently evaluated each article for methodological quality using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool.[45] Quality of each study was evaluated using the following criteria: selection bias, study design, treatment confounders, blinding, data collection methods, and dropout rate (Table 5).[45] This tool was selected due to its ability to allow the reviewers to appraise studies with varying study designs. Quality assessment ratings for the EPHPP instrument follow a standardized guide and dictionary, categorizing studies as strong, moderate, or weak.[45,46] The overall rating is derived from the component ratings, with studies deemed strong if they receive no weak

ratings, moderate if they have fewer than four strong ratings, and classified as weak if there are two or more weak ratings.

RESULTS

Selection of Sources of Evidence

A total of 1,049 study articles were identified from database search results (Figure 2). After 196 duplicates were removed, a total of 853 studies were screened by title and abstracts using eligibility criteria. Of these, 729 studies did not meet inclusion criteria. A total of 124 full text articles were retrieved and further assessed for eligibility. Of the full text articles reviewed, 114 studies were excluded for reasons noted in the PRISMA flow diagram (Figure 2). The remaining 10 articles met criteria for inclusion and were reviewed as part of the scoping review (Table 2).

Participant Characteristics

In total, the 10 studies included 545 participants with a median sample size of 53 (range:12-106). The reported mean age range was 61.0 to 75.7 (SD 4.3) years, with nearly half of the studies chiefly represented by at least 60% females.[47–50] No studies in this review captured socio-economic elements, level of education, partner or caregiver status, or cultural/ethnic group self-identification.

Geographical Context

Five of the ten studies were conducted in the United States.[47,48,51–53] The remaining studies were represented in the following countries: China,[54] Isarel,[49] Belgium,[55] France,[56] and Australia.[57] All included studies that met eligibility for inclusion were published within the last six years, between 2018 and 2024, despite no filters placed on date ranges.

Study Design

Eight studies were prospective randomized controlled trials (RCT), with two of those studies additionally including qualitative analyses. The remaining two studies were non-randomized, as participants self-selected membership in the control or intervention group per their preference.[53,56] One study was single blinded to the participant only;[51] however, all other studies were not blinded to the researcher or the participant. Each study occurred in a single medical center.

Types of Surgical Procedures

Most IVR studies focusing on postoperative pain outcomes in adults 65 years of age or older, were predominantly concentrated on elective total joint replacement (TJR) surgeries (n=8). Among these TJR surgeries, five studies specifically targeted total knee arthroplasty (TKA) surgery;[48,49,52,54,56] with two studies additionally including elective total hip arthroplasty (THA) surgery.[51,57] The remainder of the studies included the following surgical procedures: coronary artery graft surgery [55] and minimally invasive inpatient foregut surgery.[47]

Article Quality Assessment

The EPHPP methodological quality assessment revealed 9 of the 10 included studies received either an overall weak (n=5) or moderate (n=4) rating, with only one study rated as strong (Table 5). The overall ratings were impacted negatively by the absence of blinding and the omission of participant dropout or withdrawal rate reporting.

Outcome Measures

Postoperative Pain Scores

Seven of the ten studies evaluated self-reported postoperative pain as the primary outcome of the study. In the studies which reported postoperative pain as a secondary measure, the primary outcome measure of interest was one of the following: anxiety, [58] intraoperative patient controlled sedation,[57] intraoperative sedation, or opioid consumption.[53] Nearly all studies reported postoperative pain using the either the Visual Analog Scale or the Numeric Rating Scale; both instruments are self-report and use a numeric rating scale to indicate the level of pain intensity.[59] One study, however, reported postoperative pain on a 5-point Likert scale from the pain intensity domain on the Quality of Recovery Survey (QOR-40).[57] No studies leveraged multidimensional pain measurement instruments, such as the Brief Pain Inventory, which in addition to measuring pain intensity, also measures the emotional and cognitive experiences of pain.[60] Furthermore, one study additionally measured physiological surrogate indicators of pain, which included respiration rate and various domain metrics for heart rate variability, along with self-reported pain scores.[50] In this particular study significant differences in favor of IVR were noted in all physiological indicators, as well as pain scores both within and between the control and intervention groups.[52]

Finally, four of the ten studies showed a statistically significant difference in lower postoperative pain scores in the IVR intervention group as compared to the control group (Table 2).[48,52,54,58] One additional study showed lower absolute postoperative pain scores in the IVR group as compared to the control group but was not statistically significant;[47] however the IVR group included more complex types of foregut surgical procedures in the sample as compared to the control group.[47] Another

study showed significant reductions in pain in the IVR group immediately following IVR as compared to pre-IVR baseline pain scores;[49] however, no statistically significant differences were noted between the IVR group and the control group in this study.

Non-Pain Outcome Measures

In addition to capturing postoperative pain as either a primary or secondary outcome, all included studies concurrently evaluated at least one non-pain related outcome measures (Table 4). Anxiety, IVR related side effects, system usability, user experience, or patient satisfaction were employed as outcome measures in over half of the studies. Two studies additionally reported the IVR user experience using qualitative semi-structed interviews with thematic analysis.[50,57] Approximately 40% of studies measured total opioid consumption or physiological responses to IVR (e.g., respiration rate, heart rate variability, etc.).[47,48,51–53,55] Other outcomes less frequently measured were quality of life, mobility or first ambulation after surgery, depression, relaxation, various orthopedic joint functional outcomes (e.g., range of motion), and fatigue (Table 4). One study additionally measured the cost of the IVR use per patient.[47] Finally, two studies measured participants' sense of presence (e.g., overall presence, spatial presence, involvement, and perceived realism) using the Igroup Presence Questionnaire (IPQ), a validated instrument. [61] One of the two studies indicated a significant difference in the IPQ scores between the IVR group and the control group, where the IVR groups reported higher scores, indicating a higher level of perceived presence in the virtual envirnoment.[52] Level of immersion during IVR use was not measured in any of the ten studies.

Regarding anxiety, six studies measured anxiety using either a Visual Analog Scale or a multidimensional anxiety measurement tool, such as the State-Trait Anxiety Inventory Six Items or the Anxiety-Amsterdam Preoperative Anxiety Score.[47–49,52,55,58] Four of the six studies demonstrated statistically significant lower anxiety levels in the IVR intervention group as compared to the control group.[47–49,52] Only one study demonstrated a decrease in pain levels attributable to IVR without a simultaneous reduction in anxiety;[58] all other others studies measuring pain and anxiety tended to indicated significant reductions in both.

As related to evaluating tolerability of IVR, only half of the included studies specifically aimed to capture side effects related to IVR use.[47,48,52,57,58] However, of these five studies only two used a valid and reliable measurement instrument specific to assessing known side effects of IVR (e.g., nausea, eye strain, dizziness, etc.), the Kennedy Simulator Sickness Questionnaire.[48,50] Side effects related to IVR were minimally reported by participants in those studies, indicating good tolerability of the intervention. No studies examined tolerability of the IVR equipment (e.g., weight of the headset) or skin irritation.

Six of the ten studies additionally captured patient satisfaction, user experience, or perceived usability of the IVR. The most common validated instruments used were the Evaluation of Anesthesia Local Regional (EVAN LR), the Patient Satisfaction Questionnaire, or the System Usability Scale (SUS).[62–64] Of the two studies that examined the usability of IVR, there were no significant differences in the SUS scores between the control group and the intervention group.[51,52] Moreover, the studies evaluating patient satisfaction revealed no statistically significant differences in the EVAN LR or PSQ-18 scores between the IVR group and the control group.[47,55]

However, other studies assessed patient satisfaction through a blend of non-validated, custom survey questionnaires employing Likert scales and open-ended, semi-structured interviews focused on the total experience of using IVR.[47,48,52,57] Overall, qualitative findings and survey results yielded positive responses with themes such as: satisfaction with the IVR experience;[47,48,52,57] a desire to use IVR again during another procedure;[47,48] and participants felt that a IVR program designed exclusively for postoperative pain would have improved their experience.[47] One study noted that a moderate number of participants (n=9) experienced boredom due to the limited content available in the IVR intervention, leading them to discontinue the treatment prematurely.[57]

Finally, four of the ten studies measured postoperative opioid consumption either as Morphine Milligram Equivalents (MME), frequency of opioid doses given, or number of opioid medication refills. None of the studies demonstrated a statistically significant reduction in opioid consumption between the IVR intervention and the control groups; however, one study demonstrated fewer opioid refills in the IVR group, while another study indicated a decreased trend in opioid use in the IVR group as compared to the control group.[47,53] Two studies evaluated intraoperative sedation requirements during the operation. In these two studies, IVR was only used for the duration of the operation. While one study failed to demonstrate a reduction in overall intraoperative sedation medications (e.g., propofol),[57] the other study did indicate a statistically significant reduction in sedation requirements in the IVR intervention group as compared to the control.[58]

Characteristics of IVR Software Content and Equipment

The included studies using IVR broadly identified two main types of user participation in the virtual environment (Table 3).The first type of user engagement was interactive, which allowed the user to interact with the virtual environment, through movement, voice commands, or controllers, thereby having the environment responded to user prompts.[21,65,66] The second type of IVR was passive, whereby the interaction with the virtual space was through observation of the 360-degree visual field, allowing for the visual exploration of the virtual space in all directions, but without the user interacting directly with the virtual environment. [67] Of the ten studies, five studies were described by the authors as passive,[47,49,55–57] three were noted as interactive[48,52,54], and two studies allowed participants the option for either passive or interactive content.[51,53] Two of the three interactive studies leveraged enhanced IVR with biofeedback, which is the use of IVR to provide feedback on the users' breathing and heart rate. [48,52,68] Moreover, one study that was categorized as passive included voice recorded hypnosis alongside the IVR environment.[55]

Regarding the content utilized in IVR, the most featured environments were natural landscapes, particularly ocean and beach scenes, followed by forests and lakes. The primary mechanism of action identified by authors across most of the included studies was positive distraction or relaxation. Notably, two of the four studies that indicated a statistically significant reduction in pain scores employed a passive approach, offering participants IVR experiences centered around nature scenes.[49,56]

The remaining two studies, which also reported significant differences in pain scores, integrated interactive IVR with biofeedback techniques.[48,52] An additional study leveraged an interactive exercise where participants performed a "row the boat" activity, integrating knee flexion movements within the IVR experience.[54] This study likewise reported significant reductions in pain scores among participants in the intervention group compared to the control group.

Study participants experienced variability in their ability to choose the software content, reflecting heterogeneity in the options provided across studies. In studies where interactive IVR content was leveraged, the program content was predetermined by the research team with no option for participant content selection. Of the studies that leveraged passive IVR, two of the five passive IVR studies allowed participants the option to choose a nature landscape scene of their preference.[56,57] Additionally, two studies allowed participants the option to select an environment from a variety of both interactive and passive VR content, including games or mindfulness.[51,53]

All studies included the use of an HMD with built-in audio. A version of either “Oculus,” “Samsung Gear,” “VIVE,” or “PICO” were the most frequently used hardware HMD units in the included studies (Table 3). Most studies did not mention the use of hand controllers, chest plates, or other ancillary equipment used with IVR; however, two studies did apply biofeedback equipment to measure heart rate and respiration rate.[48,50]

IVR Duration, Frequency, and Perioperative Phase of Care Used

There was heterogeneity in terms of duration and frequency of the IVR intervention (Table 3). Total duration of each IVR session varied widely from 2 minutes

up to 30 minutes. Frequency of IVR sessions also varied from just one session to as many as up to six sessions. Frequency of IVR sessions was primarily determined by the research team. Of the five studies that reported a statistically significant reduction in postoperative pain scores, only two offered IVR to participants on two or more occasions.[49,54]

There was also variation in the phase of perioperative care that IVR was first initiated. Four of the ten studies applied the IVR intervention just before entry into the operative room, and again initiated subsequent IVR sessions as early as three hours after surgery in the postoperative care unit to as late as the first day following surgery.[47,48,52,55] Three studies provided the IVR intervention only during the operation.[53,57,58] Finally, three of the ten studies initiated the first IVR intervention during the inpatient postoperative phase of care, starting as early as the first day after surgery to as late as the second day after surgery.[49,51,54]

DISCUSSION

The primary aim of this scoping review was to map out and evaluate the current landscape of studies examining immersive virtual reality (IVR) interventions for postoperative pain management in surgical adults 65 years of age and older. While a broad set of inclusion criteria were used, only ten studies were identified, with most studies concentrated on the use of IVR for pain following minor elective TJA operations. As related to postoperative pain, approximately half of the studies in this review reported significant results of lower postoperative pain scores in the IVR intervention group as compared to the control group. Our review findings suggest there is significant heterogeneity in how IVR is administered (timing, phase of care,

frequency, and duration), as well as the types of IVR program content and equipment leveraged during pain management. While heterogeneity and lack of large scale randomized controlled trials in this review preluded meta-analysis, our scoping review contributes to the expanding body of knowledge regarding the potential of IVR as a non-pharmacological method for managing post-surgical pain among older adults by highlighting research gaps and by offering recommendations to inform future research and clinical care.

Our results both align with and differ from previous studies on the use of IVR for pain. Except for TKA, a procedure categorized as minor surgery,[69] there is a notable gap in research regarding the efficacy, acceptability, and feasibility of IVR for pain among older surgical adults across various types of major surgeries. The focus on IVR studies within the context of TKA is reasonable as it is among the most common elective surgeries performed on individuals aged 65 and older. [70] Managing pain in TKA post-discharge frequently presents a challenge. In the TKA demographic, IVR is thought to mitigate pain and promote improved physiotherapy and rehabilitation.[71] While existing research is promising for IVR in reducing postoperative pain in a select few major inpatient surgeries, such as colorectal, cranial, and head and neck surgery, these studies are scarce and typically include a younger segment of the older adult population, with a mean age of <65 years.[72–74]

The lack of inclusion of older adults in IVR studies for postoperative pain management may exist for several reasons. First, a common assumption is that older adults are either less capable or less willing to adopt new technological innovations.[75,76] Such attitudes may inadvertently lead to exclusion from IVR clinical trials.[77]

Second, some studies suggest that hospitalized older adults over the age of 60 are more likely to decline participation in IVR studies related to lack of understanding the intention of IVR or perceived usefulness.[35,78–80] Contrary to these findings, recent research in both community and residential settings have shown that IVR use is both feasible and well-received among older adults, particularly as a method for managing chronic pain.[81–83]

Our findings also reveal that pain intensity was the only dimension of pain assessed, with most measurements taken on the day of surgery up through the second day following surgery. Unidimensional short-term postoperative pain evaluation may be insufficient to evaluate the true clinical value of an IVR intervention on pain. The use of IVR in clinical trials recommends that outcome measures should be captured for a sufficient period, such as days or weeks after IVR treatment to determine the actual impact on the outcome of interest.[26] Moreover, included studies did not examine the multidimensional aspect of postoperative pain, such as the affective or cognitive domains of pain.[84] Pain severity alone may not provide an adequate portrait of postoperative pain or its acceptability in the older adult after a surgical procedure.[85] Many older adults place high value on how pain may impact their physical functionality and psychosocial well-being.[86,87] Thus, when evaluating the effectiveness of IVR on postoperative pain, the sensory, affective, and cognitive domains of pain in older surgical adults should be captured, using a multidimensional instrument such as the Brief Pain Inventory Scale.[88–90]

While included studies did not measure other aspects of pain, at least half of the included studies did concurrently measure anxiety levels, with a few studies also

evaluating relaxation or depression. Although these pain related outcomes were concurrently measured with postoperative pain, no studies in this review examined the potential relationships between pain and anxiety, depression, relaxation, or any other pain related outcome. As postoperative pain seldom presents as an isolated symptom following surgery, recognizing this gap is crucial.[87,91–93]

Additionally, few studies in this review reported feasibility metrics as related to recruitment, attrition, or rationale for study withdrawal; therefore, the various reasons for study drop-out or non-participation are among this older population is unknown. The rationale for refusal of study non-participation and early withdrawal are all important factors used to evaluate overall feasibility of an intervention, especially in the older adult demograhic.[94,95] Previous research has indicated that older age may be associated with a more negative view of newer technology, including IVR.[35,78,79] Thus, more robustly capturing feasibility and acceptability metrics in the older adult age range could help to inform future studies on participant attitudes, acceptance, perception of IVR as part of the integration into their surgical care.

Furthermore, the studies included in this review were not sufficiently designed or powered to evaluate the effects of various IVR characteristics (i.e., content type, frequency or duration, or phase of care) as predictors of pain outcomes. The current literature presents a diverse range of recommendations regarding the optimal length of individual IVR sessions, the frequency of treatment, and the total duration necessary to achieve effective pain management. In terms of duration of use, or example, some expert panels and operational manuals recommend pausing IVR after 30 minutes of use to prevent side effects, such a dizziness and eye strain.[96,97]

As related to frequency of use some studies suggest that one IVR session may be ample for short-term positive distraction; however, other studies indicate that longer lasting IVR analgesia may be dose dependent, requiring multiple IVR sessions.[96,98–101] One small-scale feasibility study indicated that among younger older adults (mean=61.0 years, SD=10.57) who underwent colorectal surgery, an increase in the number of IVR sessions could was associated with a decrease in postoperative pain scores.[74]

Closely related to understanding dose-dependence of duration and frequency of IVR use on pain is tolerability. Although few participants across all included studies experienced side effects related to IVR, tolerability was most often reported through self-reported side effects, with only one study that applied a reliable and validated questionnaire to evaluate cybersickness. A recent review of IVR use in older adults across a wide spectrum of scenarios found cybersickness (e.g., dizziness, nausea, eye strain, etc.) to be minimal across 39 studies.[16] Another consideration as related to the tolerance of IVR in older adults is the equipment used to deliver the virtual environment, namely the HMD. Although not reported in any of the included studies in this review, several IVR studies in the community setting indicate that intolerance of IVR in older adults might be due to the perceived weight or uncomfortable fit of the HMD unit, rather than cybersickness.[102–104] This point emphasizes the importance of evaluating HMD devices for bedridden users or those with limitations due to recent surgery or aging.

Another key finding in our review is the variability in the timing of the first IVR initiation during perioperative care. Notably, studies initiating IVR either intraoperatively

or postoperatively demonstrated statistically significant reductions in postoperative pain compared to those that began IVR in the preoperative phase. This outcome aligns with findings from a recent review, which also reported no significant decrease in postoperative pain when IVR was exclusively initiated in the preoperative phase of care.[33]

Additionally, research indicates that the characteristics of the IVR environment, whether passive or interactive, or the specific type of content, can influence the degree of pain relief experienced by users.[105] Our review presents varied results. First, studies using interactive IVR environments did tend to show significant decreases in pain scores. Research in the literature corroborates these finds indicating that interactive IVR utilizes more concentration reserves, thereby promoting increased distraction from pain.[31] Passive IVR in our review also demonstrated significant reductions in pain. The predominant passive IVR environments included in this study were primarily nature scenes. Mounting evidence in the literature does suggests that nature based IVR may be particularly efficacious for pain management, albeit few of studies have included older adults.[52,106,107]

Various theories describe a more complex relationship between the type of IVR content and its efficacy in pain management. Theoretical models such as the Multiple Resource Theory,[108] the Gate Control Theory,[109] and the Neuromatrix Theory of Pain[84] shed light on the potential processes through which specific types of IVR content may shift focus away from pain. Particularly, in the context of IVR nature scenes, additional theories such as the Attention Restoration Theory[110] and Ulrich's Stress Reduction Theory[111,112] may offer additional insightful perspectives on how IVR can reduce

pain through use of nature-based environments.

Finally, it is important to note that only a minority of the studies in this review evaluated the concept of "presence," or the feeling of being present within a virtual environment.[113] A sense of "presence" is considered fundamental for the analgesic effect of IVR distraction potential according to existing literature.[113–115] Some evidence suggests that more interactive virtual environments may enhance a more intense feeling of presence.[115,116] Thus, evaluating fundamental components of IVR, such as level of presence, are key to future studies attempting to identify predictors of pain level.

Implications for Future Research

Overall, this review indicates the need for rigorous randomized clinical trials on the use of IVR for pain management in the older surgical adult across a wide spectrum of inpatient and outpatient operations. It is key to recognize that the user experience and acceptance of IVR may differ across various older adult subgroups, including those from various cultural backgrounds or those with existing physical and cognitive limitations. As such, future research should be intentional about including older adult subgroups in IVR studies. Furthermore, considering the heterogeneity and overall scarcity of research on acceptance of IVR among older adults in the inpatient setting, it is also paramount to delve deeper into this demographics' tolerance, perceptions, attitudes, and preferences towards the use of IVR for pain management during early postoperative inpatient care. Finally, larger samples sizes with improved study designs are indicated not only to examine efficacy, but also to evaluate if certain characteristics of participants (e.g., race/ethnicity, cognitive and physical functioning, or age

subgroups) and IVR (e.g., frequency, duration, content) are associated with decreases in postoperative pain levels.

Limitations

There are limitations to this review that should be examined. First, this scoping reviews cannot contribute to definitive conclusions about the efficacy of IVR use on postoperative pain due to the limited number of studies that met the inclusion criteria (i.e., ten) as well as the heterogeneity and small sample sizes of included studies. Furthermore, most of the studies included in this review were focused on TJA operations. Thus, it is unknown if acceptance, and feasibility of IVR to reduce postoperative pain will hold true in other types of major surgical procedures. Finally, due to the heterogeneity of the included studies, robust recommendations in terms of the types of IVR content, timing, duration, or frequency of use to optimize postoperative pain reduction in the older adults cannot be made.

CONCLUSIONS

The integration of technological innovation coupled with the increasing older adult population highlights the need for a more thorough examination of IVR as a novel method for improving postoperative pain management. Despite our limited knowledge, it appears that IVR may potentially represent a promising safe and cost-effective innovative treatment option for postoperative pain and pain related symptoms in older adults. This promising intervention warrants additional both quantitative and qualitative research to understand the full potential of IVR in the perioperative and outpatient setting. This study contributes to the expanding field of knowledge on non-pharmacological approaches to manage postoperative pain and challenges the various

misconceptions regarding older adults' hesitancy to adopt new technologies such as IVR.

Sources of Support: This work was supported by the National Institute of Nursing Research of the National Institutes of Health (T32NR01692), the University of California, San Francisco (UCSF), UCSF School of Nursing Century Research award, the UCSF Graduate Mentorship Fellowship award, the UCSF Phillip R. Lee Health Policy Fellowship award, the UCSF Office of the Executive Vice Chancellor and Provost (EVCP) Social and Population Science Fellowship Research Award, and by the Department of Veterans Affairs, Veterans Health Administration, Office of Academic Affiliations VA Quality Scholars Advanced Fellowship Program (OAA 3Q072019C).

Conflict of Interest: All authors report no conflicts of interest. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

PubMed Search

#	Search Query	Results
1	(((((((Virtual Reality/) OR (Virtual realit*)) OR (VR)) OR (virtual environment*)) OR (immersive virtual reality)) OR (virtual reality exposure therapy)) OR ("Augmented Reality"[All Fields])) OR ("Enhanced Reality"[All Fields])	46,562
2	("pain postoperative"[All Fields]) OR ("Pain, Postoperative"[Mesh] OR "postoperative pain"[Tiab])	65,954
3	#1 AND #2	129
4	Filters: Full text	28

EMBASE Search

#	Search Query	Results
1	'virtual reality'/exp OR 'virtual reality'	35,334
2	'virtual reality exposure therapy'	1,117
3	'immersive virtual reality'	1,461
4	'augmented reality'	5,878
5	'virtual environment'	4,127
6	#1 OR #2 OR #3 OR #4 OR#5	41,465
7	''postoperative pain'/exp OR 'postoperative pain'	99,798
8	#6 AND #7	129
9	Filters: Full text, Randomized Controlled Trial, Clinical Trial	

Web of Science

#	Search Query	Results
1	(((((((((ALL=('virtual reality')) OR ALL=(VR)) OR ALL=(virtual environment)) OR ALL=(virtual reality exposure therapy)) OR ALL=(augmented reality)) OR ALL=(mixed reality)) OR ALL=(extended reality)) OR ALL=(immersi*)) OR ALL=(immersive virtual reality)) OR ALL=(virtual reality Vr)	265,669 433,156
2	(ALL=('postoperative pain')) OR ALL=('surgical pain')	173,725

Figure 3.1 Online Database Search.

3	#1 AND #2	662
4	Filters: Free full text, Randomized Controlled Trial, English	69

CINAHL Complete

#	Search Query	Results
1	virtual reality OR (virtual reality exposure therapy or vr or virtual reality therapy) OR immersive virtual reality OR augmented reality OR virtual environment OR mixed reality OR extended reality	16,225
2	(Postoperative pain OR surgical pain)	24,710
3	#1 AND #2 Filters: Free full text, Randomized Controlled Trial, English	36

PsycINFO

#	Search Query	Results
1	('virtual reality') OR ('immersive virtual reality') OR ('virtual reality exposure therapy') OR ('augmented reality') OR ('virtual environment') OR ('enhanced reality') OR ('mixed reality') OR ('extended reality') OR (vr (virtual reality))	26,320
2	('postoperative pain') OR ('postoperative and pain') OR ('surgical pain')	6,655
3	#1 AND #2 Filters: Full text, Randomized Controlled Trial, English	34

Figure 3.1 Online Database Search.

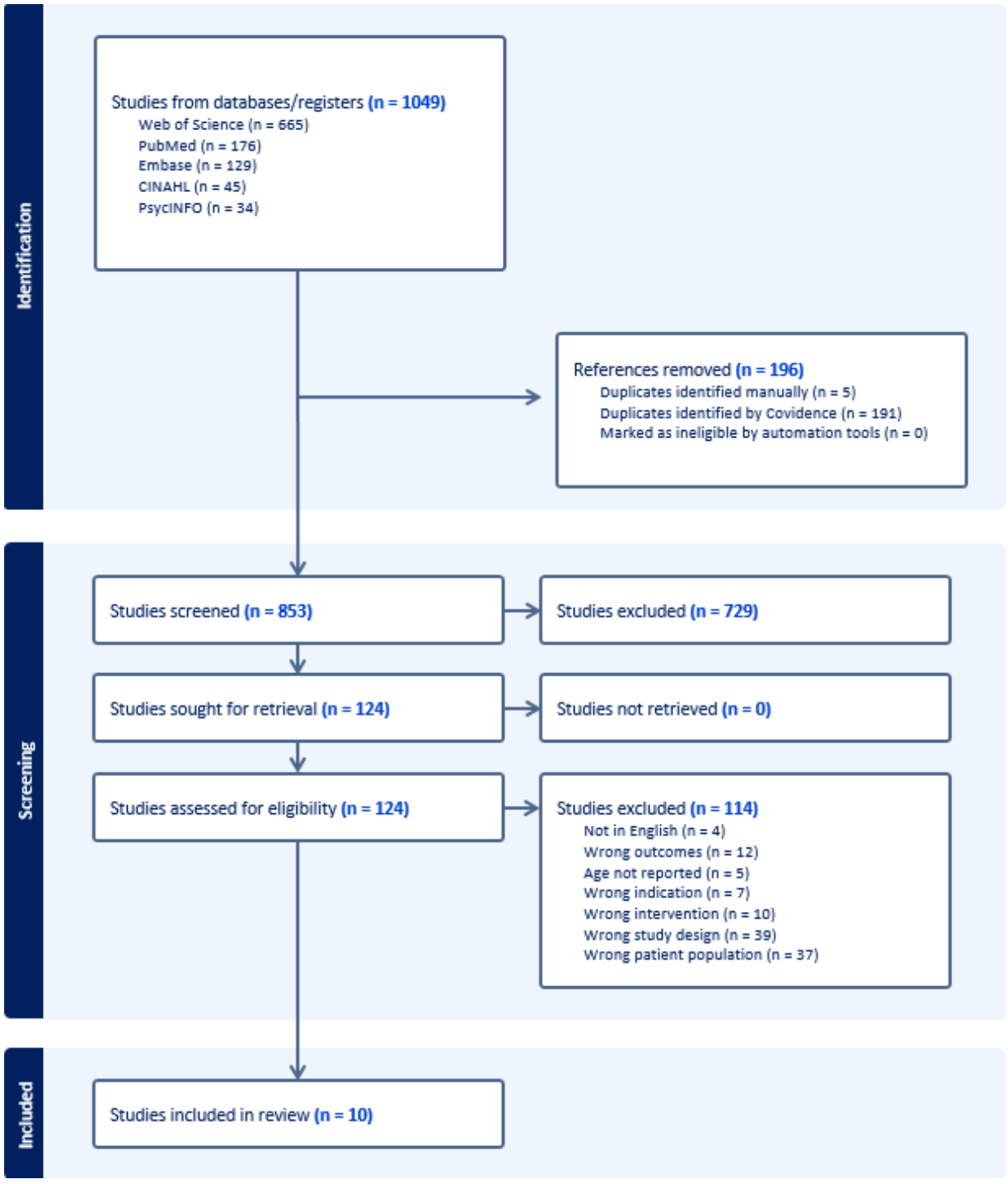

Figure 3.2 PRISMA flowchart of study selection process. Figure adapted from*:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

Table 3.1 Population, Intervention, Comparison, Outcome, and Study Design (PICOS)

PICOS	Inclusion	Exclusion
Population	Patients who are 65 years of older who have an operation in an inpatient or outpatient operating room	-Patients who receive a medical procedure in the hospital, outside of an operating room, in a procedural unit, or in the clinic; Articles without age reported
Intervention	Immersive Virtual Reality	2-dimensional Video games, telehealth, computer, or other virtual interventions that did not include a 3-dimensional immersive component with head mounted display unit
Comparison	A control group who did not receive an IVR intervention or single arm pre/post intervention within group comparison	None
Outcome(s)	Patient self-reported numeric pain scores as a primary or secondary outcome of the study	Qualitative only pain themes
Study Design	Non-randomized and randomized controlled studies, single arm/cohort, mixed methods	Case-control, qualitative studies without numeric pain scores reported as an outcome measure, conference, or dissertation paper
Publication Characteristics	English language, full-text articles, no date filter	Non-English and studies where full-text articles could not be obtained

Table 3.2 Description of Included Studies

Author, Year, Country	Study Design, Sample Size	Mean/Median Age (SD/range), Sex	Type of Surgery	Findings: Pain	Other Findings
Jin et al., 2018 China	RCT N=66	66.45 (3.39) Male-45.5% Female-54.5%	Total Knee Arthroplasty	VAS pain scores were significantly lower in the VR group as compared to the control group on days 3, 7, and 10 days after TKA	-No differences in WOMAC or HSS Knee Score between the groups
Huang et al., 2020 Australia	RCT and Mixed Methods N=50	70.0 (2.33) Male-50.0% Female- 50%	Total Knee or Total Hip Arthroplasty	No significant differences were noted in pain scores	-No significant differences were noted in propofol use or pain scores -Positive comments from patients. -9 patients felt bored and removed the IVR
Haisley et al., 2020 United States	RCT and Mixed Methods N=52	65.5 (29-82) Male-26.9% Female-73.1%	Inpatient Foregut Surgery >24 Inpatient Stay	While not statistically significant, lower absolute pain scores	-No significant lower anxiety scores in the IVR group as compared to the control. -Fewer narcotic prescription refills for the IVR group, even though the VR group received significantly more complex operations by chance. -76% of patients would use IVR again.

Author, Year, Country	Study Design, Sample Size	Mean/Median Age (SD/range), Sex	Type of Surgery	Findings: Pain	Other Findings
Prabhu et al., 2020 United States	RCT and Mixed Methods N=12	66.1 (7.2) Male-25% Female-75.0%	Total Knee Arthroplasty	-Significant differences in IVR group pre and postop pain scores -Significantly lower postoperative pain in the IVR group as compared to the control group.	-Significant differences in preoperative anxiety between the control and IVR intervention groups. -Open-ended questions about attitude and acceptance towards the IVR were positive.
Peuchot et al., 2021 France	Non-randomized N=20	75.7 (5.9) Male-70% Female-30%	Total knee Arthroplasty	- There was a significant difference in postoperative pain in the IVR group as compared to the control group	- No differences in anxiety levels - Sedation and intraoperative adverse events were decreased in the IVR group compared to the control
Barry et al., 2022 United States	Non-randomized N=54	74 (9.75) Male- 55.6% Female-44.4%	Total Knee or Total Hip Arthroplasty	- Pain scores were similar between the groups.	-Patients undergoing THA and TKA with IVR adjunct to spinal anesthesia required significantly less sedation and showed a trend toward less narcotics during the

Author, Year, Country	Study Design, Sample Size	Mean/Median Age (SD/range), Sex	Type of Surgery	Findings: Pain	Other Findings
					procedure compared to non-IVR controls. -Postoperative pharmacologic requirements and 30-day outcomes were similar between the groups.
Fuch, L. et al., 2022 Israel	RCT N=55	70.1 (7.0) Male-40% Female-60%	Total Knee Arthroplasty	-Significant differences in pain as measured immediately before and after the IVR on both postop day 1 and 2. -No significant difference noted between the IVR group and control group.	-Significant differences anxiety measured as immediately before and after the IVR on both postop day 1 and 2. -No significant difference noted between the control and the intervention group with regards to WOMAC or anxiety.
Rousseaux et al., 2022 Belgium	RCT N=100	66.3 (11.5) Male-76% Female-24.0%	Coronary Artery Bypass Surgery (CABG)	-No differences between the groups for pain scores.	-No differences between the groups for any of the outcome variables

Author, Year, Country	Study Design, Sample Size	Mean/Median Age (SD/range), Sex	Type of Surgery	Findings: Pain	Other Findings
Araujo-Duran, et al., 2023 United States	RCT with single blinding N=106	66.1 (10.0) Male-48% Feamle-52%	Hip Arthroplasty	There was no statistically significant or reductions in average pain scores	-No statistically significant reductions in opioid consumption as compared to the sham group. -No significant differences in the SUS scores in IVR group. -Mobility were not improved a week after hospital discharge.
Prabhu et al., 2023 United States	RCT N=30	66.3 (8.2) Male-23.3% Female-76.7%	Total Knee Arthroplasty	Statistically significant reductions in the IVR groups as compared to the control group.	- Anxiety post-intervention compared with the control group was significant p <0.01. -Significant differences in the SUS usability scores and levels of presence between the IVR group and the control.

*RCT=Randomized Controlled Trials, VR=Virtual Reality, VAS=Visual Analog Scale, NRS= Numeric Rating Score, WOMAC=The Western Ontario and McMaster Universities Arthritis Index, Knee HSS=Hospital for Special Surgery, ROM= Range of Motion, TKA=Total Knee Arthroplasty, CABG=Coronary Artery Bypass Surgery, MME=Morphine Milligram Equivalents, PSQ-18=Patient Satisfaction Questionnaire Short Form, RR=Respiratory Rate, HR=Heart Rate, ECG=Electrocardiogram, STAI-6=State-Trait Anxiety Inventory Six Items, Kennedy SSQ= Simulator Sickness Questionnaire, SUS=System Usability Scale, PT=Physical Therapy, QoR-40= Quality of Recovery Survey, HRQoL=Health-related quality of life, GPE=Global Perceived Effect, FIM=Functional Independent Measu

Table 3.3 Characteristics of Immersive Virtual Reality

Authors	Type of IVR	Content	Equipment	Duration	Frequency	Phase(s) of Perioperative Care Used
Jin et al., 2018	Interactive	-Custom program - “Row a Boat” plus conventional rehabilitation protocol for knee flexion	-HMD with audio -Hardware and software unspecified company	30 minutes each session	3 times per day until discharge	Postoperative day 2
Huang et al., 2020	Passive	-Nature- river floating by “EdenRiver” -Iceland Artic Tundra scenes by “VergeVR”	-HMD Samsung Gear (Samsung, Korea) or the Oculus Rift 2	Duration of the surgery	Once during surgery	Intraoperative
Haisley et al., 2020	Passive	“Flow VR Meditation for Modern Life” -6 separate guided sessions- Breathe, Focus, Move, Let Go, Calm, and Restore- Meditation and Mindfulness	-HMD Oculus Go platform	13-15 mins each session	-3 sessions just before entry into the operative room -3 sessions started one day after surgery	-Preoperative -Postoperative on day 1

Authors	Type of IVR	Content	Equipment	Duration	Frequency	Phase(s) of Perioperative Care Used
Prabhu et al., 2020	Interactive with biofeed-back	-Custom content - Beach nature scene/audio of sea and waves -Biofeedback immersive VR with Heart Rate Variability (HRV)	- HMD HTC Vive Pro -Biofeedback -Wireless Biopac MP160 transmitter-receiver pair (RR, HR, ECG)	-30 mins prior to surgery -30 mins starting 2 hours after surgery in the PACU	-Once just before surgery -Once after surgery in the Post-operative Care Unit	-Preoperative, just prior to OR entry -Postoperative- in the PACU approximately 2 hours after surgery
Peuchot et al., 2021	Passive	The patient had the option to choose 1 of 5 nature scenes for IVR; choice of male or female voice from "HypoVR"	-HMD with integrated software content (HypoVR)	Duration of the surgery	Once during surgery	Intraoperative
Barry et al., 2022	Passive and Interactive	-Participant allowed to choose 1 of 4 voice guided relaxation with nature scenes from "HypoVR"	-PICO G2	Duration of the surgery	Once during surgery	Intraoperative

Authors	Type of IVR	Content	Equipment	Duration	Frequency	Phase(s) of Perioperative Care Used
Fuch, L. et al., 2022	Passive	-Nature or music movie. Participant allowed the option to choose	-HMD Samsung Gear	15 minutes per session	-One session per day	Started on Postoperative day 1 up through day 2
Rousseaux et al., 2022	Passive with hypnosis	-Nature landscape mountain cabin plus recorded voice recorded hypnosis by "Oncomfort"	-HMD with googles by "Oncomfort"	20 minutes per session	-Once on the day of surgery in the Pre-operative area -Once after surgery	Preoperative 20 mins before entering the operating room and on postoperative day 1
Araujo-Duran, et al., 2023	Passive and Interactive	Various games, mindfulness, guided breathing, and nature scenes	-HMD PICO G2	-2 to 8 minutes per session	-Three sessions per day with one hour break between sessions	Starting on Postoperative day 1 up through day 2
Prabhu et al., 2023	Interactive with biofeed-back	-Custom content -Beach nature scene/audio of sea and waves	- HMD VIVE Pro -Biofeedback -Wireless Biopac MP160 transmitter-receiver pair (RR, HR, ECG)	-10 mins before surgery -10 minutes after surgery	-Once just before surgery and once after surgery	-Once Preoperative, just prior to OR entry -Postoperative 2 hours after the surgery in the Post-Anesthesia Care Unit (PACU).

*HMD=Head Mounted Display

Table 3.4 Types of Measured Outcomes During or After Immersive Virtual Reality

Author	Pain	Pain Medication	Anxiety	Adverse Events	Satisfaction Usability	Other
Jin et al., 2018	VAS					-WOMAC index -HSS Score -Knee ROM
Huang et al., 2020	Quality of Recovery Pain Score			Self-report	Qualitative interviews	Intra-Operative Propofol
Haisley et al., 2020	NRS	-Opioid MME -Opioid refills	NRS	Self-report	-PSQ-18 -Open-ended interview questions	Cost
Prabhu et al., 2020	VAS		-STATI-6 -VAS	Cybersickness using the Kennedy SSQ	-SUS -Qualitative interview questions	IPQ
Peuchot et al., 2021	VAS		STATI-6	Hypotension, apnea, oxygen level	-EVAN LR Score -Comfort VAS	Sedation Requirement during surgery
Barry et al., 2022	NRS	-Opioid MME				-Anesthesia recovery time -Intraoperative sedation requirements -Complications Ambulation -Length of stay
Fuch et al., 2022	VAS		STATI-6			WOMAC
Rousseaux et al., 2022	VAS	-Opioids via patient-controlled analgesia “on-demand doses”	VAS			-Fatigue (VAS) -Relaxation (VAS) -Physiological Measures- RR, HR, arterial pressure, pupil size, and oxygen level

Author	Pain	Pain Medication	Anxiety	Adverse Events	Satisfaction Usability	Other
Araujo-Duran et al., 2023	NRS	-Opioid MME			SUS	-POQ-SF -Antiemetic medication use -Mobility
Prabhu et al., 2023	VAS			Cybersickness using the Kennedy SSQ	-System Usability Scale (SUS) -Semi structured user experience interview	-IPQ - Physiological Measures- RR, HR

*ECG=Electrocardiogram, HRQoL=Health-related quality of life, HR=Heart Rate, IPQ=iGroup Presence Questionnaire, MME=Morphine Milligram Equivalents, NRS=Numeric Rating Score, POQ-SF= The Pain Outcomes Questionnaire-Short Form (POQ-SF), PSQ-18=Patient Satisfaction Questionnaire Short Form, QoR-40=Quality of Recovery Survey, ROM=Range of Motion, RR= Respiratory Rate, STAI-6=State-Trait Anxiety Inventory Six Items, Kennedy SSQ= Simulator Sickness Questionnaire, SUS=System Usability Scale, VAS=Visual Analog Scale, WOMAC=The Western Ontario and McMaster Universities Arthritis.

Table 3.5 Study Quality Assessment Rating

Article	Study Design Type	Design	Selection Bias	Confounders	Blinding	Data Collection Methods	Withdrawals/ Dropouts	Intervention Integrity	Analyses	Overall Rating
Jin et al., 2018	Randomized Controlled Trial	Strong	Moderate	Strong	Weak	Strong	Weak	Strong	Moderate	Weak
Rousseaux et al., 2022	Randomized Controlled Trial	Strong	Strong	Strong	Weak	Strong	Moderate	Strong	Strong	Moderate
Peuchot et al., 2021	Non-randomized	Moderate	Moderate	Strong	Weak	Moderate	Weak	Strong	Moderate	Weak
Huang et al., 2020	Randomized Controlled Trial	Strong	Strong	Moderate	Weak	Strong	Moderate	Moderate	Strong	Moderate
Haisley et al., 2020	Randomized Controlled Trial	Strong	Strong	Strong	Weak	Strong	Moderate	Moderate	Strong	Moderate
Prabhu et al., 2020	Randomized Controlled Trial	Strong	Weak	Weak	Weak	Moderate	Weak	Weak	Weak	Weak
Araujo-Duran, et al., 2023	Randomized Controlled Trial	Strong	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Strong
Fuch, L. et al., 2022	Randomized Controlled Trial	Strong	Strong	Strong	Weak	Strong	Weak	Moderate	Strong	Weak
Prabhu et al., 2023	Randomized Controlled Trial	Strong	Strong	Weak	Weak	Strong	Moderate	Strong	Strong	Moderate
Barry et al., 2022	Non-randomized	Moderate	Moderate	Moderate	Weak	Strong	Weak	Moderate	Moderate	Weak

*The quality assessment rating table criteria are adapted from: Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews Evid Based Nurs*. 2004;1(3):176-184. doi:10.1111/j.1524-475X.2004.04006.x. Quality assessment ratings for the Effective Public Healthcare Project (EPHPP) instrument are rated as strong, moderate, or weak according to a standardized guide and dictionary. The overall rating for the study is determined by assessing the component ratings. Those with no weak ratings and at least four strong ratings are considered strong. Those with less than four strong ratings and one weak rating are considered moderate. Finally, those with two or more weak ratings are considered weak.

References

1. Koo KI, Park DK, Youm YS, Cho SD, Hwang CH. Enhanced Reality Showing Long-Lasting Analgesia after Total Knee Arthroplasty: Prospective, Randomized Clinical Trial. *Sci Rep*. 2018;8(1):2343. doi:10.1038/s41598-018-20260-0
2. Federal Interagency Forum on Aging-related Statistics. American Institutes for Research. Accessed July 13, 2022. https://www.air.org/project/federal-interagency-forum-aging-related-statistics
3. Deiner S, Westlake B, Dutton RP. Patterns of surgical care and complications in elderly adults. *J Am Geriatr Soc*. 2014;62(5):829-835. doi:10.1111/jgs.12794
4. Lautenbacher S, Peters JH, Heesen M, Scheel J, Kunz M. Age changes in pain perception: A systematic-review and meta-analysis of age effects on pain and tolerance thresholds. *Neurosci Biobehav Rev*. 2017;75:104-113. doi:10.1016/j.neubiorev.2017.01.039
5. Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg*. 2010;210(6):901-908. doi:10.1016/j.jamcollsurg.2010.01.028
6. Aalami OO, Fang TD, Song HM, Nacamuli RP. Physiological features of aging persons. *Arch Surg Chic Ill 1960*. 2003;138(10):1068-1076. doi:10.1001/archsurg.138.10.1068
7. Shellito AD, Dworsky JQ, Kirkland PJ, et al. Perioperative Pain Management Issues Unique to Older Adults Undergoing Surgery: A Narrative Review. *Ann Surg Open*. 2021;2(3):e072. doi:10.1097/AS9.0000000000000072

8. Schenning KJ, Deiner SG. Postoperative Delirium in the Geriatric Patient. *Anesthesiol Clin*. 2015;33(3):505-516. doi:10.1016/j.anclin.2015.05.007

9. Apfelbaum JL, Chen C, Mehta SS, Gan TJ. Postoperative pain experience: results from a national survey suggest postoperative pain continues to be undermanaged. *Anesth Analg*. 2003;97(2):534-540, table of contents. doi:10.1213/01.ane.0000068822.10113.9e

10. Gan TJ. Poorly controlled postoperative pain: prevalence, consequences, and prevention. *J Pain Res*. 2017;10:2287-2298. doi:10.2147/JPR.S144066

11. Hah JM, Bateman BT, Ratliff J, Curtin C, Sun E. Chronic Opioid Use After Surgery: Implications for Perioperative Management in the Face of the Opioid Epidemic. *Anesth Analg*. 2017;125(5):1733-1740. doi:10.1213/ANE.0000000000002458

12. Martinez V, Beloeil H, Marret E, Fletcher D, Ravaud P, Trinquart L. Non-opioid analgesics in adults after major surgery: systematic review with network meta-analysis of randomized trials. *Br J Anaesth*. 2017;118(1):22-31. doi:10.1093/bja/aew391

13. OEI-02-17-00250.pdf. Accessed March 10, 2021. https://oig.hhs.gov/OEI/REPORTS/OEI-02-17-00250.pdf

14. Quick Safety 44: Non-pharmacologic and non-opioid solutions for pain management. The Joint Commission. Accessed October 1, 2022. https://www.jointcommission.org/resources/news-and-multimedia/newsletters/newsletters/quick-safety/quick-safety-44-nonpharmacologic-and-nonopioid-solutions-for-pain-management/#.YzjJV0zMKUk

15. Johnson MH. How does distraction work in the management of pain? *Curr Pain Headache Rep*. 2005;9(2):90-95. doi:10.1007/s11916-005-0044-1

16. Drazich BF, McPherson R, Gorman EF, et al. In too deep? A systematic literature review of fully-immersive virtual reality and cybersickness among older adults. *J Am Geriatr Soc*. 2023;71(12):3906-3915. doi:10.1111/jgs.18553

17. García-Betances RI, Arredondo Waldmeyer MT, Fico G, Cabrera-Umpiérrez MF. A Succinct Overview of Virtual Reality Technology Use in Alzheimer's Disease. *Front Aging Neurosci*. 2015;7:80. doi:10.3389/fnagi.2015.00080

18. Baus O, Bouchard S. Moving from virtual reality exposure-based therapy to augmented reality exposure-based therapy: a review. *Front Hum Neurosci*. 2014;8:112. doi:10.3389/fnhum.2014.00112

19. Ma M, Zheng H. Virtual Reality and Serious Games in Healthcare. In: Brahnam S, Jain LC, eds. *Advanced Computational Intelligence Paradigms in Healthcare 6. Virtual Reality in Psychotherapy, Rehabilitation, and Assessment*. Vol 337. Studies in Computational Intelligence. Springer Berlin Heidelberg; 2011:169-192. doi:10.1007/978-3-642-17824-5_9

20. Baños R m., Botella C, Garcia-Palacios A, Villa H, Perpiña C, Alcañiz M. Presence and Reality Judgment in Virtual Environments: A Unitary Construct? *Cyberpsychol Behav*. 2000;3(3):327-335. doi:10.1089/10949310050078760

21. Gupta A, Scott K, Dukewich M. Innovative Technology Using Virtual Reality in the Treatment of Pain: Does It Reduce Pain via Distraction, or Is There More to It? *Pain Med*. 2018;19(1):151-159. doi:10.1093/pm/pnx109

22. Gutierrez-Maldonado J, Gutierrez-Martinez O, Cabas-Hoyos K. Interactive and passive virtual reality distraction: effects on presence and pain intensity. *Stud Health Technol Inform*. 2011;167:69-73.

23. Gutiérrez-Martínez O, Gutiérrez-Maldonado J, Loreto-Quijada D. Control over the virtual environment influences the presence and efficacy of a virtual reality intervention on pain. *Stud Health Technol Inform*. 2011;167:111-115.

24. Li A, Montaño Z, Chen VJ, Gold JI. Virtual reality and pain management: current trends and future directions. *Pain Manag*. 2011;1(2):147-157. doi:10.2217/pmt.10.15

25. Tanja-Dijkstra K, Pahl S, White MP, et al. Improving dental experiences by using virtual reality distraction: a simulation study. *PloS One*. 2014;9(3):e91276. doi:10.1371/journal.pone.0091276

26. Birckhead B, Khalil C, Liu X, et al. Recommendations for Methodology of Virtual Reality Clinical Trials in Health Care by an International Working Group: Iterative Study. *JMIR Ment Health*. 2019;6(1):e11973. doi:10.2196/11973

27. Chan P, Scharf S. Virtual Reality as an Adjunctive Nonpharmacological Sedative During Orthopedic Surgery Under Regional Anesthesia: A Pilot and Feasibility Study. *Anesth Analg*. 2017;125(4):1200-1202. doi:10.1213/ANE.0000000000002169

28. Dahlquist LM, McKenna KD, Jones KK, Dillinger L, Weiss KE, Ackerman CS. Active and passive distraction using a head-mounted display helmet: Effects on cold pressor pain in children. *Health Psychol*. 2007;26:794-801. doi:10.1037/0278-6133.26.6.794

29. Das DA, Grimmer KA, Sparnon AL, McRae SE, Thomas BH. The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: a randomized controlled trial [ISRCTN87413556]. *BMC Pediatr*. 2005;5(1):1. doi:10.1186/1471-2431-5-1

30. Eijlers R, Utens EMWJ, Staals LM, et al. Systematic Review and Meta-analysis of Virtual Reality in Pediatrics: Effects on Pain and Anxiety. *Anesth Analg*. 2019;129(5):1344-1353. doi:10.1213/ANE.0000000000004165

31. Gutierrez-Maldonado J, Gutierrez-Martinez O, Cabas-Hoyos K. Interactive and Passive Virtual Reality Distraction: Effects on Presence and Pain Intensity. *Annu Rev Cybertherapy Telemed 2011*. Published online 2011:69-73. doi:10.3233/978-1-60750-766-6-69

32. Indovina P, Barone D, Gallo L, Chirico A, De Pietro G, Giordano A. Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review. *Clin J Pain*. 2018;34(9):858-877. doi:10.1097/AJP.0000000000000599

33. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82:87-94. doi:10.1016/j.ijsu.2020.08.033

34. Baker NA, Polhemus AH, Haan Ospina E, et al. The State of Science in the Use of Virtual Reality in the Treatment of Acute and Chronic Pain: A Systematic Scoping Review. *Clin J Pain*. 2022;38(6):424-441. doi:10.1097/AJP.0000000000001029

35. Wang S, Lim SH, Aloweni FBAB. Virtual reality interventions and the outcome measures of adult patients in acute care settings undergoing surgical procedures: An integrative review. *J Adv Nurs*. 2022;78(3):645-665. doi:10.1111/jan.15065

36. Peng L, Zeng Y, Wu Y, Si H, Shen B. Virtual reality-based rehabilitation in patients following total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. *Chin Med J (Engl)*. 2022;135(02):153-163. doi:10.1097/CM9.0000000000001847

37. The Fair Housing Act: Housing for Older Persons. HUD.gov / U.S. Department of Housing and Urban Development (HUD). Accessed October 10, 2023. https://www.hud.gov/program_offices/fair_housing_equal_opp/fair_housing_act_housing_older_persons

38. Program of All-Inclusive Care for the Elderly (PACE) | CMS. Accessed October 10, 2023. https://www.cms.gov/medicaid-chip/medicare-coordination/qualified-beneficiary-program/program-all-inclusive-care-elderly-pace

39. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc*. 2015;13(3):141-146. doi:10.1097/XEB.0000000000000050

40. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018;169(7):467-473. doi:10.7326/M18-0850

41. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation | Annals of Internal Medicine. Accessed August 28, 2022. https://www.acpjournals.org/doi/full/10.7326/M18-0850

42. Methley AM, Campbell S, Chew-Graham C, McNally R, Cheraghi-Sohi S. PICO, PICOS and SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC Health Serv Res*. 2014;14:579. doi:10.1186/s12913-014-0579-0

43. Zotero. Your personal research assistant. Accessed September 14, 2022. https://www.zotero.org/

44. Covidence. Better systematic review management. Accessed September 28, 2022. https://www.covidence.org/

45. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. *Worldviews Evid Based Nurs*. 2004;1(3):176-184. doi:10.1111/j.1524-475X.2004.04006.x

46. Berghs M, Atkin K, Graham H, Hatton C, Thomas C. Effective public health practice project quality assessment tool. In: *Implications for Public Health Research of Models and Theories of Disability: A Scoping Study and Evidence Synthesis*. NIHR Journals Library; 2016. Accessed November 12, 2023. https://www.ncbi.nlm.nih.gov/books/NBK378949/

47. Haisley KR, Straw OJ, Müller DT, et al. Feasibility of implementing a virtual reality program as an adjuvant tool for peri-operative pain control; Results of a

randomized controlled trial in minimally invasive foregut surgery. *Complement Ther Med*. 2020;49:102356. doi:10.1016/j.ctim.2020.102356

48. Prabhu V, Stanley L, Morgan R. A Biofeedback Enhanced Adaptive Virtual Reality Environment for Managing Surgical Pain and Anxiety. *Int J SEMANTIC Comput*. 2020;14(3):375-393. doi:10.1142/S1793351X20400152

49. Fuchs L, Kluska A, Novak D, Kosashvili Y. The influence of early virtual reality intervention on pain, anxiety, and function following primary total knee arthroplasty. *Complement Ther Clin Pract*. 2022;49:101687. doi:10.1016/j.ctcp.2022.101687

50. Girishan Prabhu V, Stanley L, Morgan R, Shirley B. Designing and developing a nature-based virtual reality with heart rate variability biofeedback for surgical anxiety and pain management: evidence from total knee arthroplasty patients. *Aging Ment Health*. 2023;0(0):1-16. doi:10.1080/13607863.2023.2270442

51. Araujo-Duran J, Kopac O, Montalvo Campana M, et al. Virtual Reality Distraction for Reducing Acute Postoperative Pain After Hip Arthroplasty: A Randomized Trial. *Anesth Analg*. 2024;138(4):751-759. doi:10.1213/ANE.0000000000006642

52. Girishan Prabhu V, Stanley L, Morgan R, Shirley B. Designing and developing a nature-based virtual reality with heart rate variability biofeedback for surgical anxiety and pain management: evidence from total knee arthroplasty patients. *Aging Ment Health*. 2023;0(0):1-16. doi:10.1080/13607863.2023.2270442

53. Barry KS, Nimma SR, Spaulding AC, Wilke BK, Torp KD, Ledford CK. Perioperative Outcomes of Immersive Virtual Reality as Adjunct Anesthesia in Primary Total

Hip and Knee Arthroplasty. *Arthroplasty Today*. 2022;18:84-88. doi:10.1016/j.artd.2022.09.015

54. Jin C, Feng Y, Ni Y, Shan Z. Virtual reality intervention in postoperative rehabilitation after total knee arthroplasty: a prospective and randomized controlled clinical trial. *Int J Clin Exp Med*. 2018;11(6):6119-6124.

55. Rousseaux F, Dardenne N, Massion PB, et al. Virtual reality and hypnosis for anxiety and pain management in intensive care units: A prospective randomised trial among cardiac surgery patients. *Eur J Anaesthesiol*. 2022;39(1):58-66. doi:10.1097/EJA.0000000000001633

56. Peuchot H, Khakha R, Riera V, Ollivier M, Argenson JN. Intraoperative virtual reality distraction in TKA under spinal anesthesia: a preliminary study. *Arch Orthop Trauma Surg*. 2021;141(12):2323-2328. doi:10.1007/s00402-021-04065-x

57. Huang MY, Scharf S, Chan PY. Effects of immersive virtual reality therapy on intravenous patient-controlled sedation during orthopaedic surgery under regional anesthesia: A randomized controlled trial. *PloS One*. 2020;15(2):e0229320. doi:10.1371/journal.pone.0229320

58. Peuchot H, Khakha R, Riera V, Ollivier M, Argenson J. Intraoperative virtual reality distraction in TKA under spinal anesthesia: a preliminary study. *Arch Orthop TRAUMA Surg*. 2021;141(12):2323-2328. doi:10.1007/s00402-021-04065-x

59. Chiarotto A, Maxwell LJ, Ostelo RW, Boers M, Tugwell P, Terwee CB. Measurement Properties of Visual Analogue Scale, Numeric Rating Scale, and Pain Severity Subscale of the Brief Pain Inventory in Patients With Low Back Pain: A

Systematic Review. *J Pain*. 2019;20(3):245-263. doi:10.1016/j.jpain.2018.07.009

60. Gjeilo KH, Stenseth R, Wahba A, Lydersen S, Klepstad P. Validation of the Brief Pain Inventory in Patients Six Months After Cardiac Surgery. *J Pain Symptom Manage*. 2007;34(6):648-656. doi:10.1016/j.jpainsymman.2007.01.010
61. igroup presence questionnaire (IPQ) overview | igroup.org – project consortium. Accessed November 28, 2022. http://igroup.org/pq/ipq/index.php
62. Maurice-Szamburski A, Bruder N, Loundou A, Capdevila X, Auquier P. Development and Validation of a Perioperative Satisfaction Questionnaire in Regional Anesthesia. *Anesthesiology*. 2013;118(1):78-87. doi:10.1097/ALN.0b013e31827469f2
63. Thayaparan AJ, Mahdi E. The Patient Satisfaction Questionnaire Short Form (PSQ-18) as an adaptable, reliable, and validated tool for use in various settings. *Med Educ Online*. 2013;18:10.3402/meo.v18i0.21747. doi:10.3402/meo.v18i0.21747
64. Affairs. System Usability Scale (SUS). Published September 6, 2013. Accessed November 29, 2022. https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html
65. Wender R, Hoffman HG, Hunner HH, Seibel EJ, Patterson DR, Sharar SR. Interactivity influences the magnitude of virtual reality analgesia. *J Cyber Ther Rehabil*. 2009;2(1):27-33.
66. Chuan A, Zhou JJ, Hou RM, Stevens CJ, Bogdanovych A. Virtual reality for acute and chronic pain management in adult patients: a narrative review. *Anaesthesia*. 2021;76(5):695-704. doi:10.1111/anae.15202

67. Payne O, Smith V, Rolnik DL, et al. Virtual reality and its use in post-operative pain following laparoscopy: a feasibility study. *Sci Rep*. 2022;12(1):13137. doi:10.1038/s41598-022-17183-2

68. Kerr JI, Weibel RP, Naegelin M, et al. The effectiveness and user experience of a biofeedback intervention program for stress management supported by virtual reality and mobile technology: a randomized controlled study. *BMC Digit Health*. 2023;1(1):42. doi:10.1186/s44247-023-00042-z

69. Bodrogi A, Dervin GF, Beaulé PE. Management of patients undergoing same-day discharge primary total hip and knee arthroplasty. *CMAJ*. 2020;192(2):E34-E39. doi:10.1503/cmaj.190182

70. Singh JA, Yu S, Chen L, Cleveland JD. Rates of Total Joint Replacement in the United States: Future Projections to 2020–2040 Using the National Inpatient Sample. *J Rheumatol*. 2019;46(9):1134-1140. doi:10.3899/jrheum.170990

71. Chan EY, Blyth FM, Nairn L, Fransen M. Acute postoperative pain following hospital discharge after total knee arthroplasty. *Osteoarthritis Cartilage*. 2013;21(9):1257-1263. doi:10.1016/j.joca.2013.06.011

72. Bekelis K, Calnan D, Simmons N, MacKenzie TA, Kakoulides G. Effect of an Immersive Preoperative Virtual Reality Experience on Patient Reported Outcomes: A Randomized Controlled Trial. *Ann Surg*. 2017;265(6):1068-1073. doi:10.1097/SLA.0000000000002094

73. Pandrangi V, Shah S, Bruening J, et al. Effect of Virtual Reality on Pain Management and Opioid Use Among Hospitalized Patients After Head and

Neck Surgery A Randomized Clinical Trial. *JAMA Otolaryngol-HEAD NECK Surg*. 2022;148(8):724-730. doi:10.1001/jamaoto.2022.1121

74. Cockerham M, Eakins J, Hsu E, Tran A, Adjei NB, Guerrero K. Virtual reality in post-operative robotic colorectal procedures: An innovation study. *J Nurs Educ Pract*. 2023;13(6):1. doi:10.5430/jnep.v13n6p1

75. Heinz M, Martin P, Margrett JA, et al. Perceptions of technology among older adults. *J Gerontol Nurs*. 2013;39(1):42-51. doi:10.3928/00989134-20121204-04

76. Vaportzis E, Giatsi Clausen M, Gow AJ. Older Adults Perceptions of Technology and Barriers to Interacting with Tablet Computers: A Focus Group Study. *Front Psychol*. 2017;8:1687. doi:10.3389/fpsyg.2017.01687

77. Mace RA, Mattos MK, Vranceanu AM. Older adults can use technology: why healthcare professionals must overcome ageism in digital health. *Transl Behav Med*. doi:10.1093/tbm/ibac070

78. Mosadeghi S, Reid MW, Martinez B, Rosen BT, Spiegel BMR. Feasibility of an Immersive Virtual Reality Intervention for Hospitalized Patients: An Observational Cohort Study. *JMIR Ment Health*. 2016;3(2):e28. doi:10.2196/mental.5801

79. Tashjian VC, Mosadeghi S, Howard AR, et al. Virtual Reality for Management of Pain in Hospitalized Patients: Results of a Controlled Trial. *JMIR Ment Health*. 2017;4(1):e7387. doi:10.2196/mental.7387

80. Hauk N, Hüffmeier J, Krumm S. Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Comput Hum Behav*. 2018;84:304-319. doi:10.1016/j.chb.2018.01.020

81. Benham S, Kang M, Grampurohit N. Immersive Virtual Reality for the Management of Pain in Community-Dwelling Older Adults. *OTJR Occup Particip Health*. 2019;39(2):90-96. doi:10.1177/1539449218817291

82. Dermody G, Whitehead L, Wilson G, Glass C. The Role of Virtual Reality in Improving Health Outcomes for Community-Dwelling Older Adults: Systematic Review. *J Med Internet Res*. 2020;22(6):e17331. doi:10.2196/17331

83. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. *Cyberpsychology Behav Soc Netw*. 2023;26(12):886-895. doi:10.1089/cyber.2023.0188

84. Melzack R. Pain and the Neuromatrix in the Brain. *J Dent Educ*. 2001;65(12):1378-1382. doi:10.1002/j.0022-0337.2001.65.12.tb03497.x

85. Lapkin S, Ellwood L, Diwan A, Fernandez R. Reliability, validity, and responsiveness of multidimensional pain assessment tools used in postoperative adult patients: a systematic review of measurement properties. *JBI Evid Synth*. 2021;19(2):284-307. doi:10.11124/JBISRIR-D-19-00407

86. Keefe FJ, Porter L, Somers T, Shelby R, Wren AV. Psychosocial interventions for managing pain in older adults: outcomes and clinical implications. *BJA Br J Anaesth*. 2013;111(1):89-94. doi:10.1093/bja/aet129

87. Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. “It’s Incapacitated me in so Many Ways”: Older Adults’ Lived Experience with Postoperative Symptoms

at Home Following Major Elective Surgery. *Ann Surg*. Published online December 5, 2023. doi:10.1097/SLA.0000000000006170

88. Atkinson TM, Mendoza TR, Sit L, et al. The Brief Pain Inventory and Its "Pain At Its Worst in the Last 24 Hours" Item: Clinical Trial Endpoint Considerations. *Pain Med*. 2010;11(3):337-346. doi:10.1111/j.1526-4637.2009.00774.x

89. Mendoza TR, Chen C, Brugger A, et al. The utility and validity of the modified brief pain inventory in a multiple-dose postoperative analgesic trial. *Clin J Pain*. 2004;20(5):357-362. doi:10.1097/00002508-200409000-00011

90. Tittle MB, McMillan SC, Hagan S. Validating the brief pain inventory for use with surgical patients with cancer. *Oncol Nurs Forum*. 2003;30(2):325-330. doi:10.1188/03.ONF.325-330

91. Oxlad M, Wade TD. Longitudinal risk factors for adverse psychological functioning six months after coronary artery bypass graft surgery. *J Health Psychol*. 2008;13(1):79-92. doi:10.1177/1359105307084314

92. Gallagher R, McKinley S, Dracup K. Post discharge problems in women recovering from coronary artery bypass graft surgery. *Aust Crit Care Off J Confed Aust Crit Care Nurses*. 2004;17(4):160-165. doi:10.1016/s1036-7314(04)80021-3

93. Ghoneim MM, O'Hara MW. Depression and postoperative complications: an overview. *BMC Surg*. 2016;16:5. doi:10.1186/s12893-016-0120-y

94. Forsat ND, Palmowski A, Palmowski Y, Boers M, Buttgereit F. Recruitment and Retention of Older People in Clinical Research: A Systematic Literature Review. *J Am Geriatr Soc*. 2020;68(12):2955-2963. doi:10.1111/jgs.16875

95. Khalili-Mahani N, Sawchuk K. Double-Bind of Recruitment of Older Adults Into Studies of Successful Aging via Assistive Information and Communication Technologies: Mapping Review. *JMIR Aging*. 2022;5(4):e43564. doi:10.2196/43564

96. Health And Safety Warnings | Meta Quest | Meta Store. Accessed September 29, 2022. https://www.meta.com/legal/quest/health-and-safety-warnings/

97. Stamm O, Dahms R, Müller-Werdan U. Virtual reality in pain therapy: a requirements analysis for older adults with chronic back pain. *J Neuroengineering Rehabil*. 2020;17(1):129. doi:10.1186/s12984-020-00753-8

98. Hoffman HG, Patterson DR, Carrougher GJ, Sharar SR. Effectiveness of virtual reality-based pain control with multiple treatments. *Clin J Pain*. 2001;17(3):229-235. doi:10.1097/00002508-200109000-00007

99. Oculus Rift S stuck on “Health and Safety Warnings” screen. Published May 31, 2019. Accessed September 29, 2022. https://forums.oculusvr.com/t5/Oculus-Rift-S-and-Rift/Oculus-Rift-S-stuck-on-quot-Health-and-Safety-Warnings-quot/td-p/746333

100. Faber AW, Patterson DR, Bremer M. Repeated use of immersive virtual reality therapy to control pain during wound dressing changes in pediatric and adult burn patients. *J Burn Care Res Off Publ Am Burn Assoc*. 2013;34(5):563-568. doi:10.1097/BCR.0b013e3182777904

101. May A, Hajak G, Gänssbauer S, et al. Structural brain alterations following 5 days of intervention: dynamic aspects of neuroplasticity. *Cereb Cortex N Y N 1991*. 2007;17(1):205-210. doi:10.1093/cercor/bhj138

102. Healy D, Flynn A, Conlan O, McSharry J, Walsh J. Older Adults' Experiences and Perceptions of Immersive Virtual Reality: Systematic Review and Thematic Synthesis. *JMIR Serious Games*. 2022;10(4):e35802. doi:10.2196/35802

103. Brown JA. An Exploration of Virtual Reality Use and Application Among Older Adult Populations. *Gerontol Geriatr Med*. 2019;5:2333721419885287. doi:10.1177/2333721419885287

104. Roberts AR, De Schutter B, Franks K, Radina ME. Older Adults' Experiences with Audiovisual Virtual Reality: Perceived Usefulness and Other Factors Influencing Technology Acceptance. *Clin Gerontol*. 2019;42(1):27-33. doi:10.1080/07317115.2018.1442380

105. Phelan I, Furness PJ, Fehily O, et al. A Mixed-Methods Investigation Into the Acceptability, Usability, and Perceived Effectiveness of Active and Passive Virtual Reality Scenarios in Managing Pain Under Experimental Conditions. *J Burn Care Res Off Publ Am Burn Assoc*. 2019;40(1):85-90. doi:10.1093/jbcr/iry052

106. Nukarinen T, Rantala J, Korpela K, et al. Measures and modalities in restorative virtual natural environments: An integrative narrative review. *Comput Hum Behav*. 2022;126:107008. doi:10.1016/j.chb.2021.107008

107. White MP, Yeo NL, Vassiljev P, et al. A prescription for "nature" - the potential of using virtual nature in therapeutics. *Neuropsychiatr Dis Treat*. 2018;14:3001-3013. doi:10.2147/NDT.S179038

108. Basil MD. Multiple Resource Theory. In: Seel NM, ed. *Encyclopedia of the Sciences of Learning*. Springer US; 2012:2384-2385. doi:10.1007/978-1-4419-1428-6_25

109. Moayedi M, Davis KD. Theories of pain: from specificity to gate control. *J Neurophysiol*. 2013;109(1):5-12. doi:10.1152/jn.00457.2012

110. Ohly H, White MP, Wheeler BW, et al. Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *J Toxicol Environ Health B Crit Rev*. 2016;19(7):305-343. doi:10.1080/10937404.2016.1196155

111. Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M. Stress recovery during exposure to natural and urban environments. *J Environ Psychol*. 1991;11(3):201-230. doi:10.1016/S0272-4944(05)80184-7

112. Gaertner RJ, Kossmann KE, Benz ABE, et al. Relaxing effects of virtual environments on the autonomic nervous system indicated by heart rate variability: A systematic review. *J Environ Psychol*. 2023;88:102035. doi:10.1016/j.jenvp.2023.102035

113. International Society for Presence Research. Accessed March 27, 2024. https://ispr.info/

114. Triberti S, Repetto C, Riva G. Psychological factors influencing the effectiveness of virtual reality-based analgesia: a systematic review. *Cyberpsychology Behav Soc Netw*. 2014;17(6):335-345. doi:10.1089/cyber.2014.0054

115. Martingano AJ, Duane JN, Brown E, Persky S. Demographic differences in presence across seven studies. *Virtual Real*. 2023;27(3):2297-2313. doi:10.1007/s10055-023-00805-z

116. Cummings JJ, Bailenson JN. How Immersive Is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence. *Media Psychol*. 2016;19(2):272-309. doi:10.1080/15213269.2015.

CHAPTER 4

Immersive Virtual Reality for Pain and Relaxation in Older Adults Following Elective Inpatient Abdominal Surgery: A Single-Arm Study Examining Feasibility and Acceptability

ABSTRACT

Background: There is mounting evidence to suggest that immersive virtual reality (IVR) can improve pain in older adults in the community settings, yet aside from total joint arthroplasty, its use postoperatively in the acute postoperative period remains largely underexplored. This single-arm study aimed to assess the feasibility, acceptability, and preliminary impact of IVR on postoperative pain and relaxation levels in older adults following elective inpatient abdominal surgery.

Methods: We recruited individuals aged 55 and older undergoing elective abdominal surgery at an academic medical center in Northern California, from October 2023 to February 2024. We evaluated feasibility through accrual rate, intervention completion, and questionnaire compliance; acceptability via the System Usability Scale (SUS) and a user experience survey; and tolerability by monitoring self-reported side effects. The preliminary impact of IVR on self-reported pain intensity and relaxation levels was assessed in one group through pre-and post-intervention comparisons**.**

Results: A total of 29 participants, with a median age of 73 years (range 55-81), were enrolled and completed one IVR session, with 19 completing a second session. Perceived usability and overall acceptance of IVR was high, with minimal side effects reported. In terms of preliminary impact of IVR, statistically significant

improvements were observed in both pain and relaxation levels from pre- to post-IVR on Day 1 and Day 2.

Conclusion: This study supports the feasibility and acceptability of IVR as a potential tool for postoperative pain management and enhancing relaxation among older adults following elective inpatient abdominal surgery. The positive preliminary results suggest the need for large scale studies across additional complex inpatient abdominal surgeries to confirm acceptance and efficacy of IVR as a postoperative pain management intervention across a wide range of diverse older demographics, including individuals from underrepresented minority groups and those facing physical and cognitive limitations. Future research is critical to evaluating the therapeutic potential of IVR in a variety of surgical and patient-specific contexts.

INTRODUCTION

Nearly 4 million operations are performed annually on individuals aged 65 or older in the United States, a number that is expected to rise significantly as the population continues to age.[1,2] Optimal pain management following major surgery is crucial for older adults who face unique risks associated with uncontrolled postoperative pain, such as delirium, functional decline, and reduced psychosocial well-being.[3–6] Effectively managing pain in older surgical adults is often complicated by challenges stemming from age-related physiological changes, the presence of multiple comorbidities, and the intricacies of polypharmacy.[7,8] Moreover, older adults have an increased risk of developing opioid-related adverse events, addiction, and/or chronic pain following surgery when compared to younger age groups.[9–12] These factors may contribute to the heightened risks associated with traditional pharmacologic pain management in the older adult.[13–15]

Given the complexities and inherent risks in managing acute postoperative pain in this demographic, there is a growing interest to explore innovative nonpharmacological methods for pain.[16–18] Among these emerging solutions, immersive virtual reality (IVR) has garnered significant interest from both the clinical and research communities.[19] IVR, defined by the use of a head-mounted display (HMD) with motion tracking capabilities, effectively provides users with a believable sense of reality while engaged in a virtual environment.[20] This profound sense of 'presence' within the virtual environment often provides positive distraction away from pain stimuli.[21–23]

Research on IVR has shown significant potential in reducing acute pain across various clinical settings, such as burn wound care. [24,25] Recent studies have also

demonstrated that IVR is effective in reducing postoperative pain in pediatric and young to middle-aged adults following various surgical procedures.[25,26] Contrary to the common belief that older adults are hesitant to embrace new technologies, there is mounting evidence to suggest that using IVR for pain management in the older adult demographic is promising.[27–30] Research focused on IVR use for chronic pain management in community dwelling older adults has demonstrated improved pain tolerance with a high degree of acceptance as part of pain management.[31,32] Finally, studies have also indicated acceptability and efficacy of IVR use for postoperative pain among older adults, specifically in elective total knee arthroplasty operations (TKA).[33,34]

It is key to recognize that the user experience of IVR for postoperative pain management may differ across various older adult subgroups and types of surgical procedures.[30,35] Appreciating these distinctions is vital for tailoring IVR applications to effectively manage pain and pain related symptoms in a wide range of surgical scenarios and across different older age demographics. Thus, IVR could serve as a promising alternative or adjunct to traditional pain management techniques. However, the feasibility, acceptability, and tolerability of IVR for postoperative pain among older adults across a spectrum of major surgical procedures, including complex abdominal procedures remains largely underexplored. Therefore, the aim of this single-arm study was to investigate the initial feasibility and acceptability (primary outcome), and the preliminary impact (secondary outcome) of IVR on postoperative pain and relaxation levels in older adults during the initial days following inpatient elective abdominal surgery.

METHODS

Study Design

This study employed a prospective pretest-posttest single-arm study design to ascertain the feasibility, acceptability, and preliminary impact of IVR on pain and relaxation outcomes among older adults following elective major abdominal surgery. Of note, this study did not aim to assess moderators or predictors of IVR acceptability, feasibility, or tolerability. A participant enrollment sample size of 30-40 was set for practical reasons and not driven by power analysis. This study followed the Consolidated Standards of Reporting Trials (CONSORT) extension to pilot and feasibility studies statement,[36] which is recommended for adaption in nonrandomized feasibility studies.[36,37] This study design also aligns with the recommendations and methodological framework proposed by the Virtual Reality Clinical Outcomes Research Experts (VR-CORE) on best practices for the development and testing of IVR treatments in clinical care.[38] The study received approval from the University of California, San Francisco (UCSF) Institutional Review Board (IRB #19-28391) and is registered under clinicaltrials.gov (NCT #0609566).

Participants

We employed purposeful sampling to recruit adults aged ≥55 years undergoing elective inpatient abdominal surgery at the UCSF Colorectal and General Surgery clinics. Those who were potentially eligible for the study and who were interested in participation were screened via telephone. Inclusion criteria were individuals anticipated to have an elective abdominal operation requiring hospitalization for at least 48 hours post-surgery and those who were able to speak and write in English. Exclusion criteria

encompassed individuals with a reported history of self-reported motion sickness, severe cognitive impairment, epilepsy, eye/face/neck injuries, blindness or severe visual impairment, severe hearing loss, or acute illness hindering post-surgery IVR use. Participants with immediate pre-intervention nausea, vomiting, or dizziness were also excluded. All participants continued to receive their usual surgical care as per the recommendations of clinical providers and were not asked to decline or change any adjunct strategies for pain management.

Intervention

This study employed the REAL System i-Series IVR head-mounted display (HMD) from Penumbra, Inc., featuring built-in audio and gaze-controlled navigation.[39] This IVR system, preloaded with various 360-degree immersive environments for positive distraction and relaxation, includes experiences like mindful meditation, travel, nature scenes, and games (Appendix 4.1). The IVR system provides motion tracking through sensors embedded in the headset, capturing all possible participant movements, thus facilitating an extensive immersive experience. The decision to leverage this specific IVR device was two-fold: 1) the HMD unit was preloaded with a built-in library of experiences allowing the user access to a wide variety of IVR environments, and 2) the device offered gaze-controlled navigation, potentially allowing ease of use in the immediate postoperative phase of care following major abdominal surgery.

Procedure

During the preoperative surgery visit, clinical staff provided possible participants with an informational flyer and an email introducing the study. Participant information

was gathered from the electronic medical record, and potential participants were then contacted by phone and screened for eligibility by the research team. Screening included assessment of cognitive function using the Short Portable Mental Status Questionnaire (SPMSQ), self-reported history of motion sickness, epilepsy, blindness, severe hearing deficits, and any current eye, face, or neck injuries. If deemed eligible and interested in study participation following the initial screening, participants electronically received the informed consent form. Once the consent form was signed, participants were asked to electronically complete an online questionnaire for sociodemographic and clinical data prior to their date of surgery. Participants were then sent a video link via email explaining the IVR intervention a week before their hospitalization for surgery.

All participants enrolled in the study were provided with the opportunity to engage in at least one IVR session within their hospital room. These sessions were made available starting from the next day following surgery and could extend up to the second day post-surgery, ensuring a maximum offering of two IVR sessions in total. The IVR intervention was administered to the patient in a seated or lying position by a member of the research team, who was present during and up to 15 minutes after each IVR session. Participants then choose their desired experience within the IVR software library. IVR program preference selection and length of the session was determined by the participant, up to a maximum use of 30 minutes per session.

Immediately before and after the IVR intervention, participants reported their pain intensity level and state of relaxation on an 11-point Numeric Rating Scale (NRS) ranging from '0' representing “no pain” or “not relaxed at all” to '10' representing “pain as

bad as you can imagine" or "as relaxed as possible." Adverse outcomes were assessed up through the first 15 minutes after each IVR session using an adapted 4-item Simulator Sickness Questionnaire (SSQ).[40] All responses were de-identified and entered directly into an electronic tablet that was password protected. A one-time $25 gift card was provided to all participants for their participation in at least one IVR session. A subgroup of participants was additionally offered the option to complete a single user experience survey prior to hospital discharge. Those who opted to participate in the survey received an additional $25 gift card.

Outcome Measures

Acceptability

In the context of this study, acceptability refers to the participants willingness to use IVR in the initial two days of their hospitalization and their ability to tolerate IVR use, with minimal side effects reported. Acceptability was assessed by the System Usability Scale (SUS) in all participants (n=29), with a subgroup of 21 participants also completing a user experience survey. After at least one session of IVR, all participants were asked to complete the SUS once. SUS is considered a valid and reliable instrument for measuring perceived usability of a technology system, and consists of a 10-item questionnaire with five response options, with '1' representing "Strongly disagree" and '5' representing "Strongly Agree."[41] A higher score indicates greater self-reported usability reflecting positive attitude towards using the system.[42] An 8-item user experience survey created by the research team using a 5-point Likert scale, ranging from 1 ('totally disagree') to 5 ('totally agree') was also administered to quantify participant satisfaction with IVR (Appendix 4.2). The scores from the user experience

survey for each sentiment level (Strongly Disagree-1, Disagree-2, Neutral-3, Agree-4, and Strongly Agree-5) are presented as a mean and standard deviation.

Tolerability refers to the evaluation of adverse events that occurred as result of IVR use, related to either the hardware or software components.[43] Adverse outcomes, which include symptoms such as nausea, headache, blurred vision, and dizziness, were assessed using a 4-item adapted questionnaire of the SSQ.[40] This questionnaire was administered immediately after each IVR session, allowing participants to indicate the presence or absence of these symptoms with a 'Yes' or 'No' response. Participants also had the option to type in free text regarding any side effects they felt occurred during or after IVR use.

Feasibility

In this study, feasibility is defined as the extent to which potential eligible participants consented to join the study during the recruitment phase and the degree to which those who were enrolled successfully completed the IVR intervention and all questionnaires. To evaluate feasibility, we measured the rate of participant accrual, reasons for non-participation, the successful completion of the intervention on the first and second days after surgery, and the mean duration time spent using IVR during each session. We also captured reasons for not completing a second IVR session.

We also evaluated feasibility by the rate to which participants completed baseline questionnaires. The baseline characteristics captured through questionnaires were self-reported perceived health status, anxiety, depression, and pain catastrophizing prior to the operation. Perceived health status was measured using the EuroQol 5-Dimension 5-Level questionnaires' Visual Analog Scale (VAS), with scores ranging from 0 to 100,

with a higher score indicating higher perceived health.[44,45] Anxiety was measured using the Generalized Anxiety Disorder 7-item scale (GAD-7),[46] with higher scores indicating higher anxiety levels (total score for GAD is 0-21).[46] Depression was assessed using the Patient Health Questionnaire-8 (PHQ-8), which ranges from 0 to 24, with a higher score indicating higher levels of depression.[47] Finally, we leveraged the Pain Catastrophizing Scale (PCS), where higher scores signify more intense negative thoughts and feelings towards pain.[48]

Preliminary Clinical Impact on Pain and Relaxation

Preliminary clinical impact of IVR on pain intensity levels and state of relaxation were measured through pre-and post-intervention mean differences using independent paired sample t-tests if the data were deemed normal. Non-parametric continuous data were evaluated using Wilcoxon signed-rank test. Pain intensity level was measured on an 11-point Numeric Rating Scale (NRS) and ranged from '0' representing “no pain” to '10' representing extreme pain. State of relaxation is also measured on an 11-point NRS with '0' representing “Not relaxed at all” to '10' representing "As relaxed as one could imagine." Both pain and relaxation were assessed immediately prior to and after each IVR session.

Data Analysis

Acceptability, feasibility, and tolerability are reported as descriptive statistics. User experience surveys for each sentiment level were presented as a mean and standard deviation. Prior to analyzing the preliminary effects of the IVR intervention, we assessed the normality of the distribution of pain and relaxation levels using the Shapiro-Wilk test Normal data were compared as pre-post mean differences with

independent paired 2-sample t-tests. Nonparametric data was reported as a median and compared using Wilcoxon signed-rank test. The significance level was set at $p<0.05$. All statistical analyses were performed using the STATA statistical software,[49] version 18 SE.[49]

RESULTS

Characteristics of Participants

Fifty-five participants scheduled for elective inpatient abdominal surgery were assessed for study eligibility between October 2023 and February 2024 (Figure 1). Among possible participants, 15 in total were excluded due to not meeting the inclusion criteria. A total of 40 participants completed the baseline questionnaires prior to surgery. Of the 40 enrolled participants, 11 dropped out for various reasons as described in Figure 1. A total of 29 enrolled participants were allocated to and completed the first IVR intervention the next day following their surgery, with 19 (65.5%) additionally completing a second intervention the next day. Most participants reported no prior experience with IVR (93.1%, n=27).

Among 29 participants, the median age was 73.0 years (range 55-81). 79.3%(n=23) identified as White, 62.10% (n=18) were female, and all but two participants reported at least some level of college education (n=27, 93.1%) (Table 1). Nearly half of the participants (n=14, 48.3%) underwent a low anterior resection abdominal operation, with cancer as the most common indication for surgery (65.5%, n=19). Over half of participants reported pain in the two weeks prior to surgery (55.2%, n=16), with few individuals taking opioid medications for pain (n=3). In our evaluation of the baseline characteristics of the study sample, we found that participants typically

described their perceived health status as generally good. Additionally, they reported experiencing mild levels of anxiety and depression, alongside minimal tendencies towards pain catastrophizing, before undergoing surgery and the IVR intervention (Table 1).

Acceptability

The mean duration of IVR use in the initial session for 29 participants was 19.14 minutes (SD 7.67). Moreover, 19 participants additionally completed a second session, during which the mean usage time was 16.78 minutes (SD 6.13) (see Table 2). The most common IVR experiences chosen by study participants were guided travel followed by mindfulness and meditation, with nearly half of participants choosing more than one IVR experience during a single session. The results indicate high perceived usability of IVR in this sample as demonstrated by a high mean SUS score of 88.10 (SD = 6.15). SUS scores above 68 are considered above average and are an indicator of good usability.[41] Individual adjusted raw mean scores for each SUS item were generally > 3, indicating positive usability per each SUS item statement (adjusted items ranged from 0-4, with 4 as more desirable per each item) (Table 3).

Study participants reported an overall positive experience with using IVR as indicated in the survey questionnaire (Figure 2). In this subgroup (n=21), all study participants marked responses of “Agree-4” or “Strongly Agree-5” to the statement “I enjoyed the virtual reality experience.” Majority of the study participants (95.2%, n=20) also marked “Agree-4” or “Strongly Agree-5” that IVR improved their postoperative pain. Furthermore, most participants agreed that they would use IVR again for pain (90.5%,

n=19) or anxiety (85.7%, n=18). Finally, all participants (n=21) marked “Strongly Agree” to the statement, “I would recommend virtual reality to other older surgical patients.”

Nearly all participants (n=28, 96.6%) completed one or more IVR sessions without self-reported side effects (e.g., dizziness, headache, eye strain, and nausea). One participant reported mild face and chest skin redness that occurred nearly 24 hours after the first IVR intervention. Upon further investigation, it was unclear as to the exact cause of the skin irritation, whether due to the IVR headset foam padding or related to recent medications as part of surgical care. There was no skin breakdown noted and the participant was discharged home as expected. Although unlikely related to the use of IVR equipment, the possible adverse event was reported to the UCSF IRB out of an abundance of caution.

Feasibility

To evaluate overall feasibility, we measured the rate of accrual and reasons for non-participation, as well as successful completion of IVR on the first and second day after inpatient abdominal surgery (Figure 1 CONSORT diagram). Of the 55 potential participants assessed for eligibility, 7 individuals did not meet inclusion requirements during telephone screening, 7 declined to participate after learning more about the study, stating extreme anxiety over surgery (n=5) or fear of new technology (n=2) as the main reasons for non-participation, and one individual did not state a reason for declining participation (Figure 1). The remaining participants (n=40) were deemed eligible and agreed to participate. Of the 40 participants, a total of 11 either dropped out or were excluded before the intervention was administered due to the following reasons: did not return the consent (n=2), decided to drop-out of the study prior to the date of

surgery for unspecified reasons (n=3), surgery was cancelled (n=3), ICU admission directly from the operating room (n=1), and Covid-19 related reasons (n=2).

A total of 29 enrolled participants allocated to the intervention on the day following surgery all completed the first IVR session, with 19 additionally completing the second IVR session the next day. The most common reason from not completing a second IVR session the next day was typically due to a change in complexity of care or severe nausea/vomiting (n=5). All participants allocated to the first and second IVR sessions completed all baseline questionnaires as well as all pre- and post-intervention questionnaires, with no missing or unanswered items.

Preliminary Clinical Impact of IVR on Pain and Relaxation

Significant improvements were observed in both pain and relaxation levels from pre- to post-IVR on both Day 1 and Day 2 following surgery (Figure 3 and Table 4). The preliminary impact of IVR on pain levels was analyzed using a paired two-sample t-test. On Day 1 following surgery, post-IVR mean pains levels showed a significant reduction as compared to pre-IVR pain levels, with a mean improvement of 2.66, representing approximately a 50% reduction in pain scores (95% CI, 1.90 to 3.42; $p < 0.001$). Similarly, on Day 2 following surgery, results indicated a significant decrease in pain levels from pre- to post-IVR, with a mean pain level decrease of 2.05 (95% CI, 1.32 to 2.78; $p < 0.001$).

Finally, participants reported a significantly higher level of relaxation immediately following IVR as compared to pre-IVR relaxation levels on both Day 1 and Day 2 following surgery. The Wilcoxon Signed-Rank Test, applied due to the non-normal distribution of relaxation scores, revealed significant findings. One day following

surgery, the median relaxation score prior to using IVR was 3 (IQR 3-6), which increased to a median score of 8 (IQR 7-9) immediately following IVR usage, indicating a statistically significant improvement in relaxation levels from pre- to post-intervention ($Z = -4.6$, $p < 0.01$). On the second day post-surgery, the median score before intervention was 4 (IQR: 4-5), which increased to a median relaxation score of 8 (IQR: 7-9) following the intervention, demonstrating a significant improvement in relaxation scores from pre- to post-IVR use ($Z = -3.85$, $p < 0.01$).

DISCUSSION

Our results indicate that the use of IVR for postoperative pain and relaxation in older adults in the initial days following elective inpatient abdominal surgery is feasible, acceptable, well-tolerated, and contributed to reductions in self-reported pain levels and improvement in state of relaxation. Additionally, most participants expressed a willingness to utilize IVR again for pain management and would recommend IVR to other older surgical adults. In terms of feasibility, participants were likely to complete the IVR sessions post-surgery if medically stable, with about 70% opting for a second IVR session. It is noteworthy that while there is expanding research exploring the efficacy of IVR applications on preoperative anxiety and postoperative exercise among colorectal surgery patients,[50,51] our investigation stands out as one of the select few probing the preliminary impact of IVR as a means of positive distraction to mitigate postoperative pain in older adults following various types of inpatient elective abdominal operations. Finally, our study is among the few specifically examining IVR use for acute pain in the inpatient setting specifically in the older adult demographic. Our results, diverge from the existing literature in that the older adults in our cohort were amenable to

incorporating IVR into their inpatient pain management regimen during the immediate first days following surgery.

Acceptability, Feasibility, and Tolerability

Our research both corroborates and diverges from existing literature on the application IVR for managing pain and facilitating relaxation. Recent meta-analyses have suggested that IVR is efficacious in reducing acute pain following a variety of surgical and medical procedures.[25,52] However, except for TKA, a procedure often categorized as minor outpatient surgery, there is a notable gap in research regarding the acceptability, feasibility, and tolerability of IVR among older surgical adults in the initial days following various types of major elective inpatient surgeries.[53] Some studies suggest that hospitalized older adults over the age of 60 are more likely to decline participation in IVR studies, related to lack of understanding or perceived usefulness of IVR.[54,55] Other research indicates a possibly lower acceptance of IVR among older adults in acute care settings due to negative attitudes and anxiety towards using technology.[53,56]

Furthermore, except for those who developed postoperative clinical complications precluding the use of IVR, the dropout rate among our study participants was notably low at 12.5% (n=5). In both community and residential contexts, as well as within the scope of colorectal cancer care, existing research has indicated that the use of IVR as positive distraction is both feasible and highly accepted among older adults for alleviating chronic pain in non-hospital settings.[57–60] Moreover, studies on the adoption of emerging technologies like IVR suggest that older adults are generally more

receptive to using new technology when they are offered a broad range of choices and the autonomy to select according to their preferences.[61–65]

Regarding the tolerability of IVR use in older adults, there have been minor reports of motion sickness and occasional discomfort with the HMD noted in prior research.[53,66,67] In our study there were no reports of motion sickness after use of IVR. This may have been due to limiting each IVR session to a maximum of 30 minutes. A recent review of IVR use in older adults across a wide spectrum of settings found cybersickness[68] (e.g., dizziness, nausea, eye strain, etc.) to be minimal across 39 studies.[69] Also related to tolerability of IVR, in our study, one participant reported skin irritation, an adverse effect for which, to the best of our knowledge, there is no existing research quantifying its incidence rate. However, it is worth noting that there was a safety recall by the United States Product Safety Commission for an HMD removable foam facial interface, not used in our study, that led to approximately 6,000 reported cases of facial skin irritation among users.[70] Finally, our user experience survey results suggest that while the overall satisfaction with the IVR system was positive, a significant number of participants expressed discomfort with the HMD headset. This reported discomfort is consistent with prior research indicating that while older adults in community settings have found the headsets to be bulky and uncomfortable, their overall experience with IVR was enjoyable.[30]

Preliminary Impact of IVR on Pain Level

Although previous research has suggested that pain sensitivity may be reduced in older adults, more current research shows that the overall perception of pain remains unchanged with age.[71] Across various inpatient abdominal operations in adults 60 years

of age and over, nearly 75% of participants reported moderate to severe pain during hospitalization.[72] These findings highlight that unrelieved pain in older surgical adults remains a significant challenge within the inpatient setting, and may contribute to various adverse events following surgery, including delirium.[73,74]

Prior research has indicated that IVR as a form of positive distraction can be used as an efficacious non-pharmacological tool for reducing acute pain after surgery or a medical procedure, especially in younger adult cohorts.[25,75] In the older adult demographic, the efficacy of IVR on postoperative pain reductions following are especially evident in elective TKA.[33,34,76,77] However, as related to IVR following inpatient complex abdominal surgery few studies exist in the literature examining the impact of IVR on pain. One small-scale feasibility study involving 10 participants revealed that among younger older adults (mean age=61.0 years, SD=10.57) who underwent robotic colorectal surgery, there was a moderate negative correlation between IVR usage and pain scores, suggesting that an increase in the rate of IVR usage could potentially lead to a decrease in postoperative pain scores.[78] Although our study did not measure the correlation between IVR duration or the frequency use and pain scores, we did find statistically significant reductions in immediate post intervention pain scores as compared to pre-IVR pain scores.

Preliminary Impact of IVR on Relaxation

Our study showed significant improvement in relaxation levels following the use of IVR in the postoperative recover phase. Increasing evidence suggests the harmful effects of perioperative distress on quality-of-life and psychosocial well-being following surgery, especially in older adults.[79,80] Enhancing relaxation may offer numerous

physical and psychological benefits, including the reduction of stress and the promotion of a sense of tranquility.[81] Improved relaxation may activate the parasympathetic nervous system, leading to reduced muscle tension, heart rate, and blood pressure.[82] Previous research suggests that various types of IVR environments such as nature-based scenes, guided meditation or mindfulness, and guided tourism may facilitate both self-reported and physiologically induced relaxation, particularly in individuals experiencing high levels of stress, in both the general population as well as in adults with various mental health conditions.[83–86] In the surgical literature self-reported and physiological measures relaxation following use of IVR has been predominantly studied in the pediatric demographics, with promising findings.[87] While emerging research has begun to explore the effects of IVR on mood, anxiety, and well-being among older adults in community dwelling and residential care settings, there is a scarcity of studies investigating the impact of IVR on emotional distress, and state of relaxation in older adults during inpatient surgical hospitalization.[79,88]

Clinical and Research Implications

The integration of IVR into the care of older adults following major abdominal surgery presents a promising avenue for enhancing pain management and relaxation strategies, with the potential to improve patient reported outcomes, patient satisfaction, and the overall recovery experience. The clinical implications of integrating IVR into the care of older adults following elective inpatient abdominal surgery are multifaceted and potentially substantial. First, despite existing concerns about older adults' willingness to engage with new technologies, our study found a high level of acceptability and tolerability of IVR for pain and relaxation. This suggests that with proper introduction

and support, older adults are open to using innovative technology like IVR in the acute care setting as part of their care.[28,89] Second, our results hold particular significance in the surgical care of older adults, where IVR could act as a cost-effective and safe alternative or adjunct to conventional pain management approaches.[9,90,91] Some studies indicate that IVR retains the possibility to lessen opioid medication usage and its associated side effects.[92,93]

In the last decade, government agencies and clinical professional organizations, including the American College of Surgeons' Geriatric Surgery Verification program, have increased emphasis on the importance of incorporating opioid sparing methods into pain treatment strategies, including non-pharmacological interventions, especially in vulnerable groups such as older adults.[16,94] The prominence of this push can also be exemplified through a recent ruling by the Centers for Medicare & Medicaid Services indicating that one type of an integrated software/hardware IVR device may be eligible for Medicare insurance coverage.[95] In the near future, it is expected that increased insurance coverage will greatly increase the accessibility of such technologies for older adults as part of their clinical care.

Introducing IVR into the care of older adults may initially be met with uncertainty, by both clinicians and older adults, due to prevailing beliefs about technological proficiency or appropriateness in this age group. This view may originate from widespread societal perceptions on aging and technology, which commonly depict older adults as less skilled or less inclined to engage with new technology.[96,97] Such perspectives can unintentionally result in exclusion from IVR clinical trials or use in the clinical setting.[98] Thus, we may underestimate the older adults' capacity to accept or

learn new technology such as IVR. Personalized education, tailored training, and sufficient support are essential actions to enhance the adoption of IVR among the older adults.[62] Moreover, aligning IVR content with older adults' personal interests, such as cultural and spiritual practices, as well as hobbies and previous life experiences, is vital for its wider acceptance in this demographic.[30] Future research is needed to investigate whether the level of pain or relaxation correlates with specific types of IVR content or exhibits a dose-response relationship based on duration and frequency of use. Finally, the insights gained from this study could pave the way for more extensive randomized controlled trials aimed at assessing the acceptance and overall efficacy of IVR in older adults undergoing a variety of major elective surgeries.

Limitations

The findings of this study should be considered in view of certain limitations. The study design and limited sample size restrict the generalizability of the findings; therefore, final conclusions about efficacy of IVR to improve pain and relaxation cannot be made. Additionally, the current study was not designed or powered to reliably assess the impact of predictors such as age, gender, specific surgeries, or other baseline characteristics on study outcomes. Moreover, the reliance on self-report introduces a potential for bias and subjectivity in our findings. While our sample reflects the demographic composition of a single academic healthcare system, our findings may not represent the experiences of individuals from non-White cultural or ethnic backgrounds, non-English speakers, those with lower levels of educational attainment, or those with frailty or cognitive limitations. In addition, the IVR intervention in this study was not standardized, allowing variation in both content selection and duration of use. Future

studies should consider controlling for the type of environment, duration, and frequency of use and the impact on acceptability, tolerability, feasibility, and clinical outcomes. Finally, due to the nature of this initial feasibility study, we did not control for opioids or other pain medications.

CONCLUSION

This study supports the feasibility, acceptability, and tolerability of IVR as a potential tool for postoperative pain management and enhancing relaxation among older adults following elective inpatient abdominal surgery. This study contributes to the expanding field of knowledge on the use of non-pharmacological approaches to manage post-surgical pain. The preliminary findings of this study, while promising, suggest the need for large scale studies to confirm acceptance and efficacy of IVR as a postoperative pain management intervention across a wide range of diverse older adult demographics, including individuals from underrepresented minority groups and those facing physical and cognitive limitations. Finally, this study emphasizes the potential of IVR to improve patient-reported outcomes and enrich the perioperative care experience for a demographic that is often considered vulnerable and excluded from technology-based studies.

Source of Support: This work was supported by the National Institute of Nursing Research of the National Institutes of Health (T32NR01692), the University of California, San Francisco (UCSF), School of Nursing Century Research award, the UCSF Graduate Mentorship Fellowship award, the UCSF Phillip R. Lee Health Policy Fellowship award, the UCSF Office of the Executive Vice Chancellor and Provost (EVCP) Social and Population Science Fellowship Research Award, and by the Department of Veterans Affairs, Veterans Health Administration, Office of Academic Affiliations VA Quality Scholars Advanced Fellowship Program (OAA 3Q072019C).

Conflict of Interest: All authors report no conflicts of interest. We also declare that there is no conflict of interest with Penumbra, Inc., regarding this study. Neither Penumbra, Inc., nor any of its representatives had any financial involvement or exerted any undue influence on study findings or development of this manuscript. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

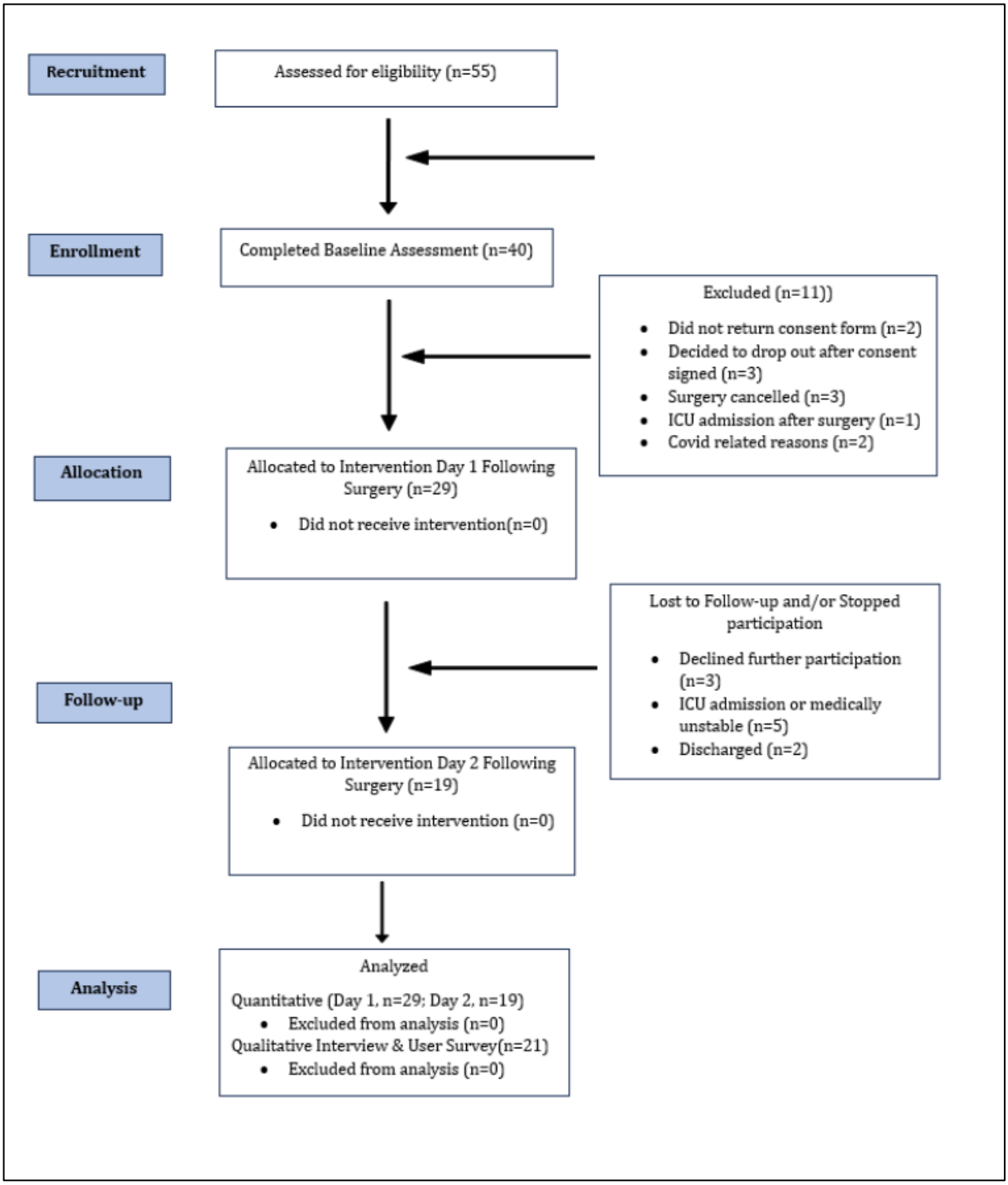

Figure 4.1 CONSORT Flow Diagram

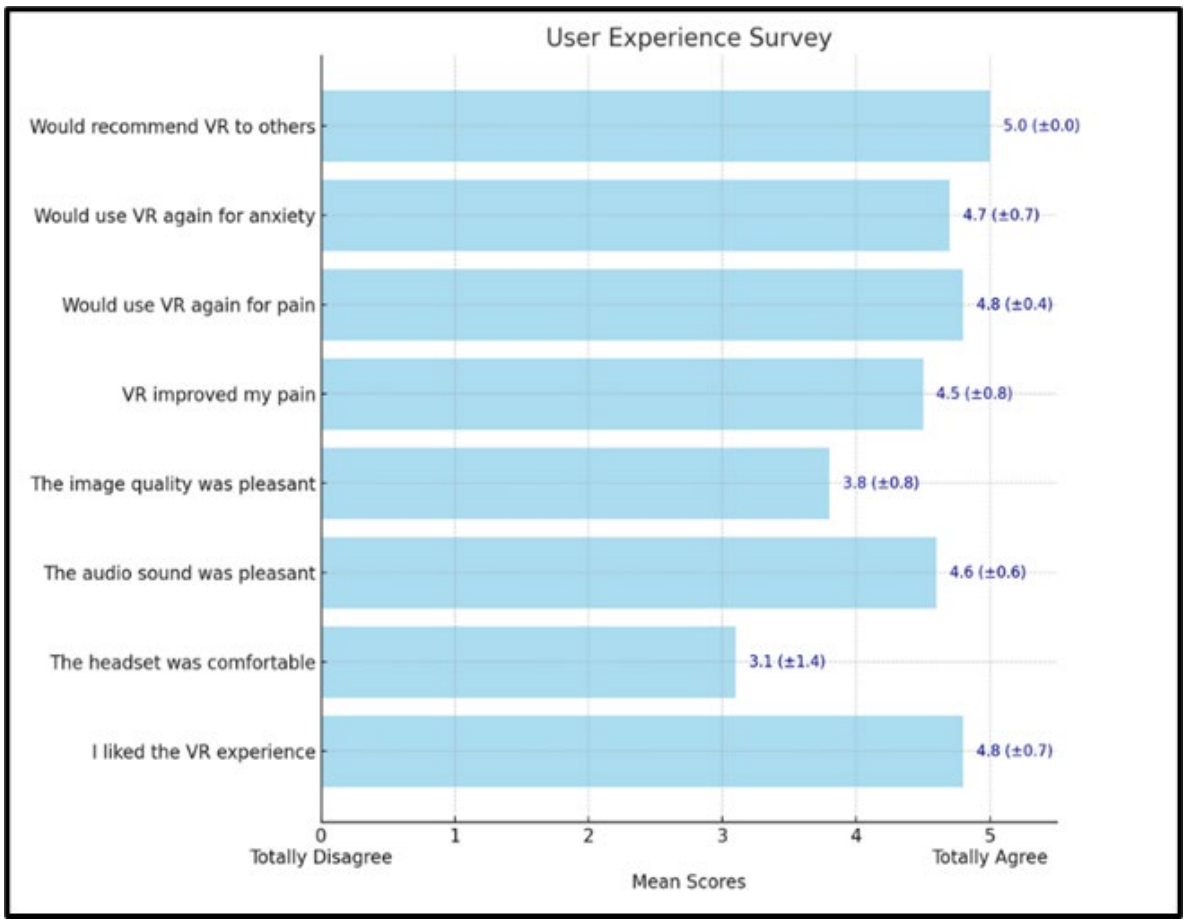

Figure 4.2 User Experience Survey Responses: (a) Participants responded to each user experience statement once on a scale of 1 to 5, with 1=totally disagree, 2 disagree, 3=neutral, 4=agree, and 5=totally agree, following at least one IVR session. Mean (+/-SD) is reported per each survey item.

Table 4.1 Sociodemographic, Baseline Characteristics, and Clinical Descriptives (n=29)

Age, median, years (range)	73.0 (range 55-81)
Gender	
Male	11 (37.9)
Female	18 (62.1)
Race/ethnicity, n (%)	
White/Caucasian	23 (79.3)
Asian	4 (13.8)
Hispanic	2 (6.9)
Black or African American	0 (0)
Relationship Status, n (%)	
Currently Married	14 (48.3)
Divorced	1 (3.4)
Single	13 (44.8)
Widowed	1 (3.4)
Level of Education, n (%)	
High School Diploma	2 (6.9)
Some college, no degree	5 (17.2)
Any college, graduate, or professional degree	22 (75.9)
Primary Indication for Surgery, n (%)	
Cancer	19 (65.5)
Primary Types of Abdominal Procedures, n (%)	
Laparoscopic Low Anterior Resection	11 (37.9)
Robotic Assisted Low Anterior Resection	3 (10.3)
Laparoscopic Colectomy	5 (17.2))
Open Colectomy	2 (6.8)
Open Colostomy Revision or Takedown	3 (10.3)
Ileostomy Takedown	3 (10.3)
Open Abdominal Perineal Resection	1 (3.4)
Robotic Assisted Rectopexy	1 (3.4)
Prior Pain and Virtual Reality Use, n (%)	
Pain In the Past Week Prior to Surgery	16 (55.2)
Current Opioid Use for Pain Prior to Surgery	3 (10.3)
Prior Virtual Reality Use	2 (6.9)
Baseline Scores, mean (SD)	
Pain Catastrophizing Scale (PCS)[1]	14.56 (14.21)
Health State Questionnaire – EQ-5D-5L[2]	71.10 (22.3)
Generalized Anxiety Disorder 7-item (GAD-7)[3]	5.56 (5.9)
PHQ-8 (Patient Health Questionnaire-8)[4]	5.03 (5.5)

[1]Pain Catastrophizing Scale consists of 13 items, with each item on a scale from 0 to 4 based on their thoughts when experiencing pain. The total score can range from 0 to 52, with higher scores indicating greater levels of pain catastrophizing.
[2]The EuroQol 5-Dimension 5-Level questionnaire uses a Visual Analog Scale (VAS), where the endpoints are labeled as the "best imaginable health state" and the "worst imaginable health state." The VAS score ranges from 0 to 100, with the higher score indicating higher perceived health.
[3]Generalized anxiety disorder 7-item scale is a self-reported questionnaire used to assess the severity of anxiety symptoms with each item scored from 0 (not at all) to 3 (nearly every day). The total score ranges from 0 to 21, with higher scores indicating higher anxiety levels.
[4]The Patient Health Questionnaire-8 measures the severity of depressive symptoms. Each item is scored on a scale from 0 to 3. The sum of all items is a range of 0 to 24 Minimum Score, with a higher score indicating greater levels of depressive symptoms.

Table 4.2 Mean Time Spent Using Immersive Virtual Reality and Content Selection

	1 Day After Surgery n=29	**2 Days After Surgery n=19**
Mean Time Spent in IVR (minutes)	19.14 (SD 7.67)	16.78 (SD 6.13)
Range of Time Spent in IVR (minutes)	6-30	3-30
Participant IVR Content Selection[1]	n (%)	n (%)
Guided Travel	20 (68.9)	10 (52.6)
Mindfulness and Meditation	7 (24.1)	5 (26.3)
Artic Cold and/or Underwater	4 (13.7)	3 (15.8)
Forests and/or Wildlife	2 (6.8)	1 (5.3)
Games	1 (3.4)	1 (5.3)

[1] Participants had the option to choose as many experiences as desired, up to a maximum of 30 minutes of use per session, in any of the content categories offered within the preloaded software library.

Table 4.3 System Usability Scale (SUS) Ratings

SUS Adjusted Raw Score Per Item (n=29)[1]	Mean Score	Standard Deviation	Range
1. I think that I would like to use this system frequently	3.5	0.58	2-4
2. I found the system unnecessarily complex.	3.8	0.77	0-4
3. I thought the system was easy to use	3.7	0.47	3-4
4. I think that I would need the support of a technical person to be able to use this system.	3.2	0.85	1-4
5. I found the various functions in this system were well integrated.	2.48	0.87	1-4
6. I thought there was too much inconsistency in this system	3.7	0.66	2-4
7. I would imagine that most people would learn to use this system very quickly	3.6	0.50	3-4
8. I found the system very cumbersome to use.	3.9	0.37	2-4
9. I felt very confident using the system	3.7	0.47	3-4
10. I needed to learn a lot of things before I could get going with this system	3.8	0.41	3-4

[1] The original responses are given on a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree) for each of the 10 items. After adjusting the scale of negatively worded questions (items 2, 4, 6, 8, and 10) by subtracting their scores from 5 and for positively worded questions (items 1, 3, 5, 7, and 9) obtained by subtracted by one, adjusted scores will range from 0 to 4. After adjustment “0” represents a negative usability experience as related to the item statement and “4” represents a positive usability experience for each item. Higher scores after adjustment indicate better usability. The SUS questions are adapted from Brooke J. SUS: a quick and dirty usability scale. ResearchGate. 1995. https://www.researchgate.net/publication/228593520_SUS_A_quick_and_dirty_usability_scale

Table 4.4 Pre-to Post Immersive Virtual Reality Changes in Self-Reported Pain and Relaxation

	Mean (SD)	**95% Confidence Interval**
Pain Level Day 1, n=29		
Pre-IVR	5.17 (2.1)	4.37-5.97
Post-IVR	2.51 (1.5)	1.91-3.16
Change	2.65 (2.0)	1.89-3.41, $p < 0.01$
Pain Level Day 2, n=19		
Pre-IVR	4.84 (1.6)	4.08-5.60
Post-IVR	2.79 (1.5)	2.06-3.51
Change	2.05 (1.5)	1.33-2.78, $p<0.01$
Relaxation Level Day 1, n=29	**Median, IQR**	**Test statistic, p-value**
Pre-IVR	3 (3-6)	
Post-IVR	8 (7-9)	
Change		$Z=-4.6$, $p<0.01$
Relaxation Level Day 2, n=19		
Pre-IVR	4 (4-5)	
Post-IVR	8 (7-9)	
Change		$Z=-3.85$, $p<0.01$

References

1. Schwarze ML, Barnato AE, Rathouz PJ, et al. Development of a List of High-Risk Operations for Patients 65 Years and Older. *JAMA Surg*. 2015;150(4):325-331. doi:10.1001/jamasurg.2014.1819
2. Cheung C, Meissner MA, Garg T. Incorporating Outcomes that Matter to Older Adults into Surgical Research. *J Am Geriatr Soc*. 2021;69(3):618-620. doi:10.1111/jgs.17028
3. Aubrun F, Marmion F. The elderly patient and postoperative pain treatment. *Best Pract Res Clin Anaesthesiol*. 2007;21(1):109-127. doi:10.1016/j.bpa.2006.12.005
4. Hwang SS, Chang VT, Kasimis B. Dynamic cancer pain management outcomes: the relationship between pain severity, pain relief, functional interference, satisfaction and global quality of life over time. *J Pain Symptom Manage*. 2002;23(3):190-200. doi:10.1016/s0885-3924(01)00418-3
5. Apfelbaum JL, Chen C, Mehta SS, Gan TJ. Postoperative pain experience: results from a national survey suggest postoperative pain continues to be undermanaged. *Anesth Analg*. 2003;97(2):534-540, table of contents. doi:10.1213/01.ane.0000068822.10113.9e
6. Borys M, Zyzak K, Hanych A, et al. Survey of postoperative pain control in different types of hospitals: a multicenter observational study. *BMC Anesthesiol*. 2018;18(1):83. doi:10.1186/s12871-018-0551-3
7. Jin F, Chung F. Minimizing perioperative adverse events in the elderly. *Br J Anaesth*. 2001;87(4):608-624. doi:10.1093/bja/87.4.608

8. Falzone E, Hoffmann C, Keita H. Postoperative Analgesia in Elderly Patients. *Drugs Aging*. 2013;30(2):81-90. doi:10.1007/s40266-012-0047-7
9. Kessler ER, Shah M, Gruschkus SK, Raju A. Cost and quality implications of opioid-based postsurgical pain control using administrative claims data from a large health system: opioid-related adverse events and their impact on clinical and economic outcomes. *Pharmacotherapy*. 2013;33(4):383-391. doi:10.1002/phar.1223
10. Baker J, Brovman EY, Rao N, Beutler SS, Urman RD. Potential Opioid-Related Adverse Drug Events Are Associated With Decreased Revenue in Hip Replacement Surgery in the Older Population. *Geriatr Orthop Surg Rehabil*. 2020;11:2151459320915328. doi:10.1177/2151459320915328
11. Huhn AS, Strain EC, Tompkins DA, Dunn KE. A hidden aspect of the U.S. opioid crisis: Rise in first-time treatment admissions for older adults with opioid use disorder. *Drug Alcohol Depend*. 2018;193:142-147. doi:10.1016/j.drugalcdep.2018.10.002
12. Hamilton HJ, Gallagher PF, O'Mahony D. Inappropriate prescribing and adverse drug events in older people. *BMC Geriatr*. 2009;9:5. doi:10.1186/1471-2318-9-5
13. Mangoni AA, Jackson SHD. Age-related changes in pharmacokinetics and pharmacodynamics: basic principles and practical applications. *Br J Clin Pharmacol*. 2004;57(1):6-14. doi:10.1046/j.1365-2125.2003.02007.x
14. McKeown JL. Pain Management Issues for the Geriatric Surgical Patient. *Anesthesiol Clin*. 2015;33(3):563-576. doi:10.1016/j.anclin.2015.05.010

15. Weiss AJ, Heslin KC, Barrett ML, Izar R, Bierman AS. *Opioid-Related Inpatient Stays and Emergency Department Visits Among Patients Aged 65 Years and Older, 2010 and 2015*. Agency for Healthcare Research and Quality (US); 2018. Accessed June 26, 2022. https://www.ncbi.nlm.nih.gov/books/NBK534106/
16. Quick Safety 44: Non-pharmacologic and non-opioid solutions for pain management | The Joint Commission. Accessed October 1, 2022. https://www.jointcommission.org/resources/news-and-multimedia/newsletters/newsletters/quick-safety/quick-safety-44-nonpharmacologic-and-nonopioid-solutions-for-pain-management/#.YzjJV0zMKUk
17. Martinez V, Beloeil H, Marret E, Fletcher D, Ravaud P, Trinquart L. Non-opioid analgesics in adults after major surgery: systematic review with network meta-analysis of randomized trials. *Br J Anaesth*. 2017;118(1):22-31. doi:10.1093/bja/aew391
18. OEI-02-17-00250.pdf. Accessed March 10, 2021. https://oig.hhs.gov/OEI/REPORTS/OEI-02-17-00250.pdf
19. Baker NA, Polhemus AH, Haan Ospina E, et al. The State of Science in the Use of Virtual Reality in the Treatment of Acute and Chronic Pain: A Systematic Scoping Review. *Clin J Pain*. 2022;38(6):424-441. doi:10.1097/AJP.0000000000001029
20. Furht B, ed. Immersive Virtual Reality. In: *Encyclopedia of Multimedia*. Springer US; 2008:345-346. doi:10.1007/978-0-387-78414-4_85

21. Gupta A, Scott K, Dukewich M. Innovative Technology Using Virtual Reality in the Treatment of Pain: Does It Reduce Pain via Distraction, or Is There More to It? *Pain Med Malden Mass*. 2018;19(1):151-159. doi:10.1093/pm/pnx109

22. Malloy KM, Milling LS. The effectiveness of virtual reality distraction for pain reduction: a systematic review. *Clin Psychol Rev*. 2010;30(8):1011-1018. doi:10.1016/j.cpr.2010.07.001

23. Dan A, Reiner M. EEG-based cognitive load of processing events in 3D virtual worlds is lower than processing events in 2D displays. *Int J Psychophysiol Off J Int Organ Psychophysiol*. 2017;122:75-84. doi:10.1016/j.ijpsycho.2016.08.013

24. Chan E, Foster S, Sambell R, Leong P. Clinical efficacy of virtual reality for acute procedural pain management: A systematic review and meta-analysis. *PloS One*. 2018;13(7):e0200987. doi:10.1371/journal.pone.0200987

25. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82:87-94. doi:10.1016/j.ijsu.2020.08.033

26. Iannicelli AM, Vito D, Dodaro CA, et al. Does virtual reality reduce pain in pediatric patients? A systematic review. *Ital J Pediatr*. 2019;45(1):171. doi:10.1186/s13052-019-0757-0

27. Syed-Abdul S, Malwade S, Nursetyo AA, et al. Virtual reality among the elderly: a usefulness and acceptance study from Taiwan. *BMC Geriatr*. 2019;19(1):1-10. doi:10.1186/s12877-019-1218-8

28. Seifert A, Schlomann A. The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges. *Front Virtual Real*. 2021;2. Accessed December 26, 2023. https://www.frontiersin.org/articles/10.3389/frvir.2021.639718

29. Healy D, Carr E, Conlan O, Browne AC, Walsh JC. Exploring the content of the STAND-VR intervention: A qualitative interview study. *PLOS Digit Health*. 2023;2(3):e0000210. doi:10.1371/journal.pdig.0000210

30. Healy D, Flynn A, Conlan O, McSharry J, Walsh J. Older Adults' Experiences and Perceptions of Immersive Virtual Reality: Systematic Review and Thematic Synthesis. *JMIR Serious Games*. 2022;10(4):e35802. doi:10.2196/35802

31. Benham S, Kang M, Grampurohit N. Immersive Virtual Reality for the Management of Pain in Community-Dwelling Older Adults. *OTJR Occup Particip Health*. 2019;39(2):90-96. doi:10.1177/1539449218817291

32. Goudman L, Jansen J, Billot M, et al. Virtual Reality Applications in Chronic Pain Management: Systematic Review and Meta-analysis. *JMIR Serious Games*. 2022;10(2):e34402. doi:10.2196/34402

33. Peng L, Zeng Y, Wu Y, Si H, Shen B. Virtual reality-based rehabilitation in patients following total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. *Chin Med J (Engl)*. 2021;135(2):153-163. doi:10.1097/CM9.0000000000001847

34. Su W, Zhou Y, Qiu H, Wu H. The effects of preoperative rehabilitation on pain and functional outcome after total knee arthroplasty: a meta-analysis of randomized controlled trials. *J Orthop Surg*. 2022;17(1):175. doi:10.1186/s13018-022-03066-9

35. Huang Q, Lin J, Han R, Peng C, Huang A. Using Virtual Reality Exposure Therapy in Pain Management: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Value Health*. 2022;25(2):288-301. doi:10.1016/j.jval.2021.04.1285
36. Eldridge SM, Chan CL, Campbell MJ, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *Pilot Feasibility Stud*. 2016;2(1):64. doi:10.1186/s40814-016-0105-8
37. Lancaster GA, Thabane L. Guidelines for reporting non-randomised pilot and feasibility studies. *Pilot Feasibility Stud*. 2019;5(1):114. doi:10.1186/s40814-019-0499-1
38. Birckhead B, Khalil C, Liu X, et al. Recommendations for Methodology of Virtual Reality Clinical Trials in Health Care by an International Working Group: Iterative Study. *JMIR Ment Health*. 2019;6(1):e11973. doi:10.2196/11973
39. REAL i-Series® – Cognition and Mental Well-being. REAL System. Accessed January 20, 2024. https://www.realsystem.com/iseries/
40. Kennedy RS, Lane NE, Berbaum KS, Lilienthal MG. Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *Int J Aviat Psychol*. 1993;3:203-220. doi:10.1207/s15327108ijap0303_3
41. Bangor A. Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale. 2009;4(3).
42. Brooke J. SUS - A quick and dirty usability scale.

43. Birckhead B, Khalil C, Liu X, et al. Recommendations for Methodology of Virtual Reality Clinical Trials in Health Care by an International Working Group: Iterative Study. *JMIR Ment Health*. 2019;6(1):e11973. doi:10.2196/11973
44. Brooks R. EuroQol: the current state of play. *Health Policy Amst Neth*. 1996;37(1):53-72. doi:10.1016/0168-8510(96)00822-6
45. Herdman M, Gudex C, Lloyd A, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual Life Res Int J Qual Life Asp Treat Care Rehabil*. 2011;20(10):1727-1736. doi:10.1007/s11136-011-9903-x
46. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006;166(10):1092-1097. doi:10.1001/archinte.166.10.1092
47. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9. *J Gen Intern Med*. 2001;16(9):606-613. doi:10.1046/j.1525-1497.2001.016009606.x
48. Sullivan MJL, Bishop SR, Pivik J. The Pain Catastrophizing Scale: Development and validation. *Psychol Assess*. 1995;7:524-532. doi:10.1037/1040-3590.7.4.524
49. Stata: Software for Statistics and Data Science. Accessed March 10, 2021. https://www.stata.com/
50. Schrempf MC, Zanker J, Arndt TT, et al. Immersive Virtual Reality Fitness Games to Improve Recovery After Colorectal Surgery: A Randomized Single Blind Controlled Pilot Trial. *Games Health J*. 2023;12(6):450-458. doi:10.1089/g4h.2023.0004
51. Ugras GA, Kanat C, Yaman Z, Yilmaz M, Turkmenoglu MO. The Effects of Virtual Reality on Preoperative Anxiety in Patients Undergoing Colorectal and

Abdominal Wall Surgery: A Randomized Controlled Trial. *J Perianesthesia Nurs Off J Am Soc PeriAnesthesia Nurses*. 2023;38(2):277-283. doi:10.1016/j.jopan.2022.07.005

52. Smith RC. Making the biopsychosocial model more scientific—its general and specific models. *Soc Sci Med*. 2021;272:113568. doi:10.1016/j.socscimed.2020.113568

53. Wang S, Lim SH, Aloweni FBAB. Virtual reality interventions and the outcome measures of adult patients in acute care settings undergoing surgical procedures: An integrative review. *J Adv Nurs*. 2022;78(3):645-665. doi:10.1111/jan.15065

54. Mosadeghi S, Reid MW, Martinez B, Rosen BT, Spiegel BMR. Feasibility of an Immersive Virtual Reality Intervention for Hospitalized Patients: An Observational Cohort Study. *JMIR Ment Health*. 2016;3(2):e28. doi:10.2196/mental.5801

55. Tashjian VC, Mosadeghi S, Howard AR, et al. Virtual Reality for Management of Pain in Hospitalized Patients: Results of a Controlled Trial. *JMIR Ment Health*. 2017;4(1):e7387. doi:10.2196/mental.7387

56. Hauk N, Hüffmeier J, Krumm S. Ready to be a Silver Surfer? A Meta-analysis on the Relationship Between Chronological Age and Technology Acceptance. *Comput Hum Behav*. 2018;84:304-319. doi:10.1016/j.chb.2018.01.020

57. Benham S, Kang M, Grampurohit N. Immersive Virtual Reality for the Management of Pain in Community-Dwelling Older Adults. *OTJR Occup Particip Health*. 2019;39(2):90-96. doi:10.1177/1539449218817291

58. Dermody G, Whitehead L, Wilson G, Glass C. The Role of Virtual Reality in Improving Health Outcomes for Community-Dwelling Older Adults: Systematic Review. *J Med Internet Res*. 2020;22(6):e17331. doi:10.2196/17331

59. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. *Cyberpsychology Behav Soc Netw*. 2023;26(12):886-895. doi:10.1089/cyber.2023.0188

60. Kelleher SA, Fisher HM, Winger JG, et al. Virtual reality for improving pain and pain-related symptoms in patients with advanced stage colorectal cancer: A pilot trial to test feasibility and acceptability. *Palliat Support Care*. 2022;20(4):471-481. doi:10.1017/S1478951521002017

61. Hawley-Hague H, Boulton E, Hall A, Pfeiffer K, Todd C. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: A systematic review. *Int J Med Inf*. 2014;83(6):416-426. doi:10.1016/j.ijmedinf.2014.03.002

62. Roberts AR, De Schutter B, Franks K, Radina ME. Older Adults' Experiences with Audiovisual Virtual Reality: Perceived Usefulness and Other Factors Influencing Technology Acceptance. *Clin Gerontol*. 2019;42(1):27-33. doi:10.1080/07317115.2018.1442380

63. Mitzner TL, Boron JB, Fausset CB, et al. Older Adults Talk Technology: Technology Usage and Attitudes. *Comput Hum Behav*. 2010;26(6):1710-1721. doi:10.1016/j.chb.2010.06.020

64. Lee LN, Kim MJ, Hwang WJ. Potential of Augmented Reality and Virtual Reality Technologies to Promote Wellbeing in Older Adults. *Appl Sci*. 2019;9(17):3556. doi:10.3390/app9173556

65. Rawlins CR, Veigulis Z, Hebert C, Curtin C, Osborne TF. Effect of Immersive Virtual Reality on Pain and Anxiety at a Veterans Affairs Health Care Facility. *Front Virtual Real*. 2021;2. Accessed February 6, 2023. https://www.frontiersin.org/articles/10.3389/frvir.2021.719681

66. Bekelis K, Calnan D, Simmons N, MacKenzie TA, Kakoulides G. Effect of an Immersive Preoperative Virtual Reality Experience on Patient Reported Outcomes: A Randomized Controlled Trial. *Ann Surg*. 2017;265(6):1068-1073. doi:10.1097/SLA.0000000000002094

67. Huang MY, Scharf S, Chan PY. Effects of immersive virtual reality therapy on intravenous patient-controlled sedation during orthopaedic surgery under regional anesthesia: A randomized controlled trial. *PloS One*. 2020;15(2):e0229320. doi:10.1371/journal.pone.0229320

68. Tian N, Lopes P, Boulic R. A review of cybersickness in head-mounted displays: raising attention to individual susceptibility. *Virtual Real*. 2022;26(4):1409-1441. doi:10.1007/s10055-022-00638-2

69. Drazich BF, McPherson R, Gorman EF, et al. In too deep? A systematic literature review of fully-immersive virtual reality and cybersickness among older adults. *J Am Geriatr Soc*. 2023;71(12):3906-3915. doi:10.1111/jgs.18553

70. Facebook Technologies Recalls Removable Foam Facial Interfaces for Oculus Quest 2 Virtual Reality Headsets Due to Skin Irritation Hazard (Recall Alert).

U.S. Consumer Product Safety Commission. Accessed April 1, 2024. https://www.cpsc.gov/Recalls/2021/Facebook-Technologies-Recalls-Removable-Foam-Facial-Interfaces-for-Oculus-Quest-2-Virtual-Reality-Headsets-Due-to-Skin-Irritation-Hazard-Recall-Alert

71. Lautenbacher S, Peters JH, Heesen M, Scheel J, Kunz M. Age changes in pain perception: A systematic-review and meta-analysis of age effects on pain and tolerance thresholds. *Neurosci Biobehav Rev*. 2017;75:104-113. doi:10.1016/j.neubiorev.2017.01.039
72. Zalon ML. Mild, moderate, and severe pain in patients recovering from major abdominal surgery. *Pain Manag Nurs Off J Am Soc Pain Manag Nurses*. 2014;15(2):e1-12. doi:10.1016/j.pmn.2012.03.006
73. Robinson TN, Eiseman B. Postoperative delirium in the elderly: diagnosis and management. *Clin Interv Aging*. 2008;3(2):351-355.
74. Schenning KJ, Deiner SG. Postoperative Delirium in the Geriatric Patient. *Anesthesiol Clin*. 2015;33(3):505-516. doi:10.1016/j.anclin.2015.05.007
75. Smith V, Warty RR, Sursas JA, et al. The Effectiveness of Virtual Reality in Managing Acute Pain and Anxiety for Medical Inpatients: Systematic Review. *J Med Internet Res*. 2020;22(11):e17980. doi:10.2196/17980
76. Barrington JW, Lovald ST, Ong KL, Watson HN, Emerson RH. Postoperative Pain After Primary Total Knee Arthroplasty: Comparison of Local Injection Analgesic Cocktails and the Role of Demographic and Surgical Factors. *J Arthroplasty*. 2016;31(9 Suppl):288-292. doi:10.1016/j.arth.2016.05.002

77. Blasco J, Igual-Camacho C, Blasco M, Antón-Antón V, Ortiz-Llueca Ivaro, Roig-Casasús S. The efficacy of virtual reality tools for total knee replacement rehabilitation: A systematic review. *Physiother Theory Pract*. 2021;37(6):682-692. doi:10.1080/09593985.2019.1641865

78. Cockerham M, Eakins J, Hsu E, Tran A, Adjei NB, Guerrero K. Virtual reality in post-operative robotic colorectal procedures: An innovation study. *J Nurs Educ Pract*. 2023;13(6):1. doi:10.5430/jnep.v13n6p1

79. Schrempf MC, Petzold JQ, Vachon H, et al. Virtual reality-based relaxation for enhancement of perioperative well-being and quality of life: protocol for a randomised pilot trial. *BMJ Open*. 2021;11(4):e044193. doi:10.1136/bmjopen-2020-044193

80. Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. "It's Incapacitated me in so Many Ways": Older Adults' Lived Experience with Postoperative Symptoms at Home Following Major Elective Surgery. *Ann Surg*. Published online December 5, 2023. doi:10.1097/SLA.0000000000006170

81. DeMarco-Sinatra J. Relaxation training as a holistic nursing intervention. *Holist Nurs Pract*. 2000;14(3):30-39. doi:10.1097/00004650-200004000-00007

82. Friedman R, Myers P, Benson H. 19 - Meditation and the Relaxation Response. In: Friedman HS, ed. *Assessment and Therapy*. Academic Press; 2001:227-234. doi:10.1016/B978-012267806-6/50053-6

83. Riches S, Jeyarajaguru P, Taylor L, et al. Virtual reality relaxation for people with mental health conditions: a systematic review. *Soc Psychiatry Psychiatr Epidemiol*. 2023;58(7):989-1007. doi:10.1007/s00127-022-02417-5

84. Riches S, Azevedo L, Bird L, Pisani S, Valmaggia L. Virtual reality relaxation for the general population: a systematic review. *Soc Psychiatry Psychiatr Epidemiol*. 2021;56(10):1707-1727. doi:10.1007/s00127-021-02110-z

85. Shah LBI, Klainin-Yobas P, Torres S, Kannusamy P. Efficacy of psychoeducation and relaxation interventions on stress-related variables in people with mental disorders: a literature review. *Arch Psychiatr Nurs*. 2014;28(2):94-101. doi:10.1016/j.apnu.2013.11.004

86. Fiocco AJ, Millett G, D'Amico D, et al. Virtual tourism for older adults living in residential care: A mixed-methods study. *PLOS ONE*. 2021;16(5):e0250761. doi:10.1371/journal.pone.0250761

87. Bernaerts S, Bonroy B, Daems J, et al. Virtual Reality for Distraction and Relaxation in a Pediatric Hospital Setting: An Interventional Study With a Mixed-Methods Design. *Front Digit Health*. 2022;4:866119. doi:10.3389/fdgth.2022.866119

88. Montana JI, Matamala-Gomez M, Maisto M, et al. The Benefits of emotion Regulation Interventions in Virtual Reality for the Improvement of Wellbeing in Adults and Older Adults: A Systematic Review. *J Clin Med*. 2020;9(2):500. doi:10.3390/jcm9020500

89. Høeg ER, Andersen NB, Malmkjær N, Vaaben AH, Uth J. Hospitalized older adults' experiences of virtual reality-based group exercise therapy with cycle ergometers: An early feasibility study. *Comput Hum Behav Rep*. 2023;11:100301. doi:10.1016/j.chbr.2023.100301

90. Delshad SD, Almario CV, Fuller G, Luong D, Spiegel BMR. Economic analysis of implementing virtual reality therapy for pain among hospitalized patients. *Npj Digit Med*. 2018;1(1):1-8. doi:10.1038/s41746-018-0026-4

91. Florence CS, Zhou C, Luo F, Xu L. The Economic Burden of Prescription Opioid Overdose, Abuse, and Dependence in the United States, 2013. *Med Care*. 2016;54(10):901-906. doi:10.1097/MLR.0000000000000625

92. Pandrangi V, Shah S, Bruening J, et al. Effect of Virtual Reality on Pain Management and Opioid Use Among Hospitalized Patients After Head and Neck Surgery A Randomized Clinical Trial. *JAMA Otolaryngol-HEAD NECK Surg*. 2022;148(8):724-730. doi:10.1001/jamaoto.2022.1121

93. Slomski A. Virtual Reality Lessens Postoperative Pain. *JAMA J Am Med Assoc*. 2022;328(7):610-610. doi:10.1001/jama.2022.13772

94. Geriatric Surgery Verification. ACS. Accessed September 16, 2022. https://www.facs.org/quality-programs/accreditation-and-verification/geriatric-surgery-verification/

95. CMS issues first HCPCS code and Medicare DME benefit category determination for therapeutic Virtual Reality Device | DLA Piper. Accessed February 24, 2024. https://www.dlapiper.com/en-us/insights/publications/2023/04/cms-issues-first-hcpcs-code-and-medicare-dme-benefit-category-determination

96. Heinz M, Martin P, Margrett JA, et al. Perceptions of technology among older adults. *J Gerontol Nurs*. 2013;39(1):42-51. doi:10.3928/00989134-20121204-04

97. Vaportzis E, Giatsi Clausen M, Gow AJ. Older Adults Perceptions of Technology and Barriers to Interacting with Tablet Computers: A Focus Group Study. *Front Psychol*. 2017;8:1687. doi:10.3389/fpsyg.2017.01687

98. Mace RA, Mattos MK, Vranceanu AM. Older adults can use technology: why healthcare professionals must overcome ageism in digital health. *Transl Behav Med*. doi:10.1093/tbm/ibac070

CHAPTER 5

"It helped with my pain and so much more”: Older Adults' Immersive Virtual Reality Experience Following Inpatient Elective Abdominal Surgery

ABSTRACT

Background: Immersive Virtual Reality (IVR) for postoperative pain in older adults beyond minor elective total joint surgeries, remains underexplored. This qualitative study aimed to describe the older adults' lived experience with using IVR for pain during the initial days following inpatient elective abdominal surgery.

Methods: We employed purposeful sampling to recruit adults aged ≥55 years undergoing inpatient elective abdominal surgery at an academic medical center in Northern California. Semi-structured interviews, aimed at capturing the user experience, were conducted within two days after surgery following at least one IVR session. An inductive qualitative approach was used to identify themes.

Results: Twenty-one participants completed one IVR session the day following surgery, and 17 additionally completed a second session the next day. Semi-structed interviews revealed four prominent themes: 1) IVR was a positive distraction from variety postoperative symptoms; 2) IVR provided a sense of escape from the hospital environment or worrisome medical conditions; 3) There is a need to tailor virtual reality content and equipment specifically for older surgical adults; and 4) Older adults endorsed the possibility of IVR use throughout perioperative care. None of the participants who partook in the qualitative interviews reported any adverse side effects because of IVR use.

Conclusions: Despite minor critiques of the technology, participants overall enjoyed the experience and expressed that IVR following surgery helped to divert their attention away from pain and other symptoms. IVR also offered a temporary escape from hospitalization and concerns about underlying health issues like cancer. This highlights the multifaceted potential of IVR in addressing a broad spectrum of postoperative symptoms, including pain, underscoring its value as a comprehensive tool as part of the care of older adults during the perioperative journey. Thus, further tailoring IVR to the specific needs of older surgical patients could potentially improve overall well-being, suggesting a novel approach to enhancing patient-centered care and promoting improved patient reported outcomes.

INTRODUCTION

The World Health Organization (WHO) estimates a significant increase in the population aged 60 and over, from 900 million in 2015 to approximately 2 billion by 2050, constituting approximately 20% of the global population.[1] In the United States, older adults represent the fastest growing segment of the population.[2] This rising trend highlights the need for innovative healthcare solutions designed specifically for the unique needs of older adults in today's digital era.[3] Immersive Virtual Reality (IVR) stands out as a significant technological advancement, attracting considerable attention for its potential to enhance the overall health of older adults.[4,5] IVR offers a wide range of support options for older adults in the outpatient, residential care, and community settings including mitigating feelings of social isolation and loneliness,[6] boosting cognitive abilities,[7] providing psychological support,[7,8] chronic pain management,[9,10] physical rehabilitation,[11] and improved overall well-being.[7]

Contrary to prevalent misconceptions about older adults' reluctance towards technology, recent studies have demonstrated that older adults in the community setting exhibit high levels of IVR acceptance, even when cognitive or functional limitations are present.[12,13] A recent review also demonstrated that IVR was generally tolerated in older adults across various settings with minimal side effects reported.[14]

Immersive Virtual Reality, characterized by the use of a head-mounted display (HMD) equipped with motion tracking, engenders a compelling sense of 'presence' and immersion in the virtual environment.[15] This believable perception of ‘being there’ plays a pivotal role in the beneficial impact of IVR on a wide array of outcomes.[16] The primary mechanism of action for most IVR applications in clinical care is positive distraction,

especially as related to pain and anxiety reduction;[17] however, IVR is increasingly being leveraged as a clinical tool to deliver various types of psychological therapies, such as cognitive behavioral therapy,[18] rehabilitation,[19,20] and patient education.[21]

With roughly 4 million major operations occurring each year among individuals aged 65 and older in the United States,[22] understanding the role, acceptance, and impact of innovative technology such as IVR within geriatric surgical care is essential. In the surgical setting, a multitude of studies have demonstrated the efficacy of IVR in mitigating pain and anxiety in children and adults less than 65 years of age.[23–25] Regarding older adults undergoing surgery, aside from Total Joint Arthroplasty (TJA),[26–29] there is limited research exploring the user experience or efficacy of IVR across a range of major elective surgeries requiring inpatient care. Moreover, studies that investigating the use of IVR, specifically in abdominal and gastrointestinal surgery in the older adults are remarkably limited.[30–32]

It is important to recognize that older adults may experience and recover from surgery differently than younger adults due to various geriatric vulnerabilities, such as frailty and cognitive impairment.[33,34] Older adults also often prioritize the impact of surgery on quality of life, autonomy, and the ability to participate in meaningful activities to evaluate the success of their surgery.[35–37] Given these considerations, it is advantageous to delve deeper into the perceptions, attitudes, beliefs, and experiences of older adults using IVR as part of their surgical care.[12,13] Despite the promising potential of IVR, its acceptance, and overall user experience, in older adults undergoing major inpatient abdominal surgery, remains largely unexamined. Thus, this study aimed

to qualitatively explore and describe the experiences of older adults who use IVR in the initial days following inpatient elective abdominal surgery.

METHODS

Study Design

A qualitative thematic analysis study design was employed to discern key themes related to the immersive virtual reality user experience. This qualitative thematic analysis study was founded on a constructivist approach, which posits that reality is subjective and shaped by individual perspectives.[38] A 4-item survey was also used to assess for side effects not verbally reported during interviews. Qualitative methods are reported following the Consolidated Criteria for Reporting Qualitative Research (COREQ).[39] The study received approval from University of California, San Francisco (UCSF) Institutional Review Board (IRB #19-28391) and is registered as part of a parent feasibility study under Clinicaltrials.gov (NCT06095661).

Setting and Participants

English-speaking adults aged 55 years of age or older having elective inpatient abdominal surgery at UCSF Medical Center were recruited from the Colorectal and General Surgery Clinics, if anticipated to be hospitalized for at least 48 hours following surgery. Exclusion criteria encompassed individuals with a reported history of conditions hindering post-surgery IVR use such as motion sickness, severe cognitive impairment, epilepsy, eye/face/neck injuries, blindness or severe visual impairment, or severe hearing loss. Enrolled participants were also excluded if severe nausea, vomiting, or dizziness were present just prior to administration of IVR.

Virtual Reality Intervention

Participants received an email video link explaining the IVR intervention a week before their surgery. This study employed the REAL System i-Series virtual reality HMD from Penumbra, Inc., featuring built-in audio and gaze-controlled navigation.[40] This IVR system, preloaded with various 360-degree immersive environments for distraction and relaxation, includes experiences like mindful meditation, travel, nature scenes, and games (Appendix 1). This IVR system provides six degrees of freedom, broadly defined as motion tracking through the ability of sensors embedded in the HMD unit to detect and respond to participants' movements in every possible direction.[41,42] This responsiveness translates participant movement into movement displayed within the virtual environment, facilitating a high-fidelity immersive experience.[43]

All enrolled participants were offered at least one IVR session in their hospital room, starting as early as the first day following surgery up to the second day post-surgery. Participants chose their desired experience within the preloaded IVR software library. IVR program preference selection and length of the session were recorded by the research team. The length of each session was determined by the participant but limited to 30 minutes. A member of the research team was present during and up to 15 minutes after each IVR session to assess for side effects. Participants were offered the option to use IVR again the following day. A one-time $50 gift card was provided to all individuals for their participation in the study.

Data Collection

Following informed consent, participants completed a sociodemographic questionnaire. Study participant interviews and survey responses were de-identified using an assigned study identification number. A 15-minute in-person one-to-one audio-

recorded interview was conducted following the IVR session, typically between the first and second day after the operation. The semi-structured interviews, conducted by interviewer CK occurred between October 2023 and February 2024. The interview questions were designed to gather insights into the overall user experience, participants' views on how IVR could be applied in perioperative care or at home, and the usability of the IVR software and hardware during postoperative recovery (Appendix 2). Adverse outcomes, which include symptoms such as nausea, headache, blurred vision, and dizziness, were assessed using a 4-item adapted version of the Simulator Sickness Questionnaire (SSQ).[44] This questionnaire was administered 15 minutes after each IVR session, allowing participants to indicate the presence or absence of side effects with a 'Yes' or 'No' response. Participants also had the option report any side effects they felt occurred during or after IVR to the research team or the clinical team. Each interview was audio recorded, transcribed verbatim, and uploaded into Atlas.ti, a qualitative data analysis software program.[45]

Data Analysis

The data analysis process involved two coders (CK and SS), who leveraged an inductive approach to identify prevalent themes through line-by-line coding of interview transcripts. One coder independently read through five transcripts to identify emerging codes and themes. A standardized codebook was then created from these preliminary themes. The codebook served as a guide for a more comprehensive first pass coding of the remaining transcripts. Both coders independently conducted an initial first pass reading of all interview transcripts. During a second round of coding, each coder reviewed and verified agreement of the codes contained within the transcripts. The

coding team discussed any discrepancies during collaborative meetings to reach a final consensus.

The research team iteratively discussed and refined the categorization of identified codes into broader themes until data saturation was achieved, with no new themes emerging. Final themes were shared with the surgery and geriatric clinical providers on the research team for their input. The team selected exemplar quotes from the transcribed interviews to accompany the identified themes. Field notes from the interviews were captured and discussed with research team as part of assessing for researcher reflexivity (subjective perspective).[46]

RESULTS

Twenty-one participants (median age 72.5 years, range 55-81) completed the IVR intervention at least once, with 17 additionally completing a second IVR session the next day (Tables 1 and 2). Among them, 57.1% (n=12) were female, 81.0% (n=17) identified as White, and all study participants (n=21) reported receiving at least some level of college education. Participants primarily underwent colorectal surgery, with cancer as the most common indication for surgery (81.0%, n=17), followed by inflammatory bowel disease (n=4). Nearly all participants reported no prior experience with IVR (95.2%, n=20). The most frequently selected IVR experiences by participants were guided travel, followed by mindfulness and meditation (Table 2). Mean overall time spent using IVR was 18.4 (SD 8.6) minutes on the day following surgery, and 12.4 (SD 6.8) minutes on the second day. None of the participants who partook in the qualitative interviews reported any adverse side effects. However, within the broader context of the parent feasibility study, there was a single report of minor skin irritation on the face and

chest that occurred nearly 24 hours following a single IVR session (this individual did not participate in the qualitative interview due to an earlier than expected hospital discharge). The connection between the skin redness and the use of the IVR system remains uncertain, with the likely possibility that the irritation was attributed to an unrelated cause.

Semi-structed interviews revealed four prominent themes: 1) IVR was as a positive distraction from variety postoperative symptoms; 2) IVR provided a sense of escape from the hospital environment or worrisome medical conditions; 3) There is a need to tailor virtual reality content and equipment for older surgical adults; and 4) Older adults endorsed the possibility of IVR use throughout perioperative care.

Theme 1: Immersive Virtual Reality Was a Positive Distraction from Postoperative Symptoms

Study participants spoke at length about how they felt that IVR acted as a positive distraction, effectively diverting attention from both physical and emotional postoperative symptoms (Table 3). Pain was the most reported symptom that was alleviated immediately following the IVR intervention. As one participant stated, *"I was distracted and it [IVR] took my mind off of the pain as your focus goes to the experience."* While study participants felt that IVR was helpful in distracting them away from their postoperative pain, only one participant mentioned that they felt IVR was a preferred alternative to pain medication. This participant stated, *"I don't want to take pain pills. Having that alternative [VR] for pain is good. I think I'll do the virtual reality for light to moderate pain instead of [pain] pills."* A few participants also stated that they felt IVR was more advantageous than traditional distraction methods commonly available

during hospitalization, such as television (TV). One participant stated, *"It [IVR] definitely adds more distraction from pain than watching TV or reading a book."* Another physical symptom that seemed to be alleviated by IVR was fatigue. One participant stated, *"I just was completely blown away on how much this helped distract me from fatigue [after surgery]*

Participants also mentioned that they felt the IVR experience was a distraction from psychological symptoms that they were experiencing during the initial postoperative period. One patient stated, *"It [IVR] made me think of different things other than my anxiety."* Another participant stated, *"Surgery has been making me feel a little down; the programs that I picked really boosted my mood. It helped me focus on something uplifting."*

Theme 2: Escape From the Hospital Environment and Worrisome Medical Conditions

Numerous participants reported experiencing a 'sense of escape' from the confines of the hospital setting and, in certain instances, temporary relief from thoughts linked to their medical conditions while engaged with IVR (Table 4). In many instances, this feeling of escape was characterized as a profound sense of presence within the IVR environment, realistically transporting patients away from the immediate realities of hospitalization or disease. Regarding, escape from the hospital setting, one participant stated, *"It was so easy to escape from the reality of being in this hospital room. It didn't even seem like virtual, it seemed like my reality."* Other participants felt that the IVR experience provided escape from their thoughts about their cancer diagnosis. As one participant stated, "*It [virtual reality] was an escape from thinking about my cancer. I*

liked watching the nature scenes as I felt like I was there." Apart from cancer, a handful of participants indicated that the immersive experience in IVR offered a respite from the reality of their existing health conditions, although they did not detail any specific illnesses other than cancer. Finally, several participants felt that the IVR helped them to avert the boredom from hospitalization in a manner that was more effective than traditional methods such as TV.

Theme 3: Tailoring Virtual Reality for Older Surgical Adults

While all participants were satisfied with the IVR experience overall, most universally emphasized the necessity of tailoring IVR content and equipment to better meet the specific needs of older surgical adults, especially during hospitalization (Table 5). Recommendations included designing content that resonates more closely with personal interests and life experiences, encompassing cultural and spiritual preferences. Additionally, there was a consensus on the need to modify IVR software and hardware, to better accommodate the physical limitations often associated with aging or recent surgery.

Participants suggested many enhancements to make IVR more suitable for older adults undergoing surgery (Table 6). Regarding the need for more cognitive stimulating content, one participant remarked, *"It [the IVR content] needs to do more to stimulate your mind. The travel guided tour was perfect as it was the right amount of mental engagement after surgery, but many of the other programs did not offer enough mental interaction as I like to keep my mind sharp."* Additionally, many participants felt that more cultural and spiritual activities and environments were needed. As one participant stated, *"If you're going to show this [IVR] to people of different races and backgrounds, I*

think it would be good to have things [content] that they can also relate to." Many participants also expressed a strong desire for more IVR content focused on spiritual and religious landmarks and practices, emphasizing its importance during recovery.

One participant stated, *"More content on spiritual meditations, such as Tibetan monks, music, or Christian chants would be good for many older people."* Aside from cultural and spiritual practices, many participants also suggested a variety of IVR content that spanned from interactive card games and math to gardening and more guided travel. Furthermore, participants suggested that more IVR content with storytelling and voice guidance as part of the virtual scenes would be favorable. One participant stated, *"I really enjoy gardening and it would be nice to have voice like guided tour to talk to you about various items in the garden."*

Finally, most participants felt that to optimize the IVR user experience as part of surgical care, both the software and hardware needed to be adapted to better accommodate the physical limitations frequently associated with aging or recent surgery. Nearly all participants remarked that the IVR headset was too heavy for use given age related limitations and recent surgery. One participant stated, *"You know I'm an older petite woman. I don't really have a lot of fat in my cheekbones, and I felt that it [HMD]] kept sliding down and it didn't matter how much we tightened it."* Other participants felt that the headset was not necessarily compatible with the hospital bed or their physical limitations and needed improvement if it were to be used regularly. One participant stated, *"I think that being in a hospital bed, the headset could be a little bit lighter and easier to move around, so I wasn't hitting the guardrails of the bed."* Finally, many participants felt that the IVR headset field of vision for most programs should be

more compatible with declining eyesight, limited mobility, and neck range of motion issues. As another participant remarked, *"Both the headset and the programs need to reflect the world of older adulthood, keeping in mind limitations like eyesight and arthritis [neck stiffness and pain]."*

Theme 4: Older Adults Endorsed the Possibility of IVR Use Throughout Perioperative Care

Many participants shared valuable insights on the potential utility of IVR across different phases of the perioperative pathway, highlighting its possible usefulness from pre-surgery, through the duration of surgical hospitalization, to postoperative recovery at home (Table 6). Although IVR was only offered to study participants during the first two days following their inpatient surgery, most participants felt that IVR would have additionally been helpful before surgery, when anxiety levels were typically elevated. As one participant stated, *"I think it'd be a value for people preoperatively where they can tune into that healing and relaxation through the virtual reality experience."* Several participants felt that IVR could also be used as a vehicle to deliver preoperative education and preparation on what to expect prior to surgery, *"There could be programs to help prepare for surgery. Maybe like a tour of the operating room or the hospital room. Most of us are nervous. It'd be nice to see [VR] programs on what to expect."* Participants also spoke at length about the possibility of having unlimited access to IVR throughout their hospitalization or at home following discharge. Regarding the availability of IVR in the hospital, one participant stated, *"I think it [IVR] should be available [in the hospital]. Half the time we lay in bed and that's all we do is lay in bed, so if we keep our mind active, I think that's a great thing [after surgery]."* Other

participants felt that using IVR at home following surgical discharge would also be of great benefit. As one participant stated, *"It [virtual reality] could be helpful after I go home from this surgery for relaxing and to take my mind off of the pain."*

Finally, when generally asked about the types of support and resources needed to use IVR again, many participants stated that they would need instructions beforehand, as well as ongoing technical support. As mentioned by one participant, "*I think for anybody using it at home, having someone to show them ahead of time and explain the device would be greatly helpful."* Finally, a few participants (n=3) expressed great interest in using IVR at home for postoperative pain but were concerned about the cost of the device. As one participant stated, *"I think I could consider using it regularly at home for pain after surgery if the equipment was paid for by my insurance."*

DISCUSSION

This qualitative study evaluated the experiences of older adults using IVR technology during the initial days after elective inpatient abdominal surgery. Participants predominantly described their experience as positive, despite minor issues with the hardware. They emphasized the value of IVR in diverting attention from postoperative pain and other symptoms, and in offering a temporary escape and respite from the stressors of hospitalization and ongoing health conditions. Participants expressed that IVR could be a valuable addition to the surgical care of older adults, especially if more age-friendly improvements were integrated into the content and hardware. This study not only contributes to the growing body of knowledge regarding IVR use in older surgical adults, but it also emphasizes the potential of IVR as a multifaceted tool in promoting a comprehensive patient centered approach to the surgical care of older

adults.[47,48] Our findings both align with and diverge from the existing literature on IVR use in the older adult.

IVR for Postoperative Symptoms

Our study supports previous findings that suggest IVR is effective in reducing postoperative pain in older adults, consistent with research in Total Knee Arthroplasty.[26,49,50] Many participants in our study additionally reported that IVR distracted them from other symptoms beyond pain. This novel finding in our research highlights the potential broader benefit of IVR use as tool in symptom management in older adults following major abdominal surgery. Prior results suggests that postoperative symptoms in older adults following elective major surgery often negatively impact psychosocial well-being and the ability to engage in meaningful activities.[51] Although not reflected robustly in the surgical literature, previous research within the palliative care and oncology settings suggests the benefit of IVR in mitigating a wide range of symptoms.[52,53] Thus, to examine the full scope of the impact of IVR across a variety of postoperative symptoms in the older surgical adult, utilization of a systematic validated questionnaires are necessary in future research.

IVR as an Escape from Hospitalization and Health Concerns

Previous research highlights the negative psychological impact of the hospital environment on older adults, often inducing feelings of fear or a lack of control.[54,55] The stress associated with surgery can compound these feelings, with patients additionally worrying about unknown surgical outcomes or disease progression, potentially leading to a slower recovery.[56–58] Research has indicated that IVR may offer a respite from negative feelings by transporting patients to virtual settings that may foster positive

emotions and thoughts.[30,59,60] A recent review indicates that IVR may improve the overall well-being and psychological functioning of hospitalized patients dealing with serious illnesses.[61] Our study corroborates these findings, with participants reporting temporary relief from the stressors of their hospital stay and health concerns as a result of IVR use.

Moreover, IVR presents an opportunity for older adults to engage in activities or explore environments that would otherwise be inaccessible due to surgical hospitalization, disease, or age-related limitations.[62] This temporary escape into a virtual environment offers a lifelike simulated experience, enabling older adults to engage in meaningful activities that could enrich their overall well-being and surgical recovery experience. Furthermore, several participants also reported that IVR averted their sense of boredom from hospitalization. There is evidence, albeit limited, that indicates that avoidance of boredom contributes to improved quality of life and hope among hospitalized patients.[63,64] The ability of IVR to impact boredom in the context of the healthcare setting remains in the early stages of research; however, one preliminary study demonstrates the promise of IVR in reducing boredom as compared to other methods, such as TV.[65]

Participants Recommendations for Enhancing IVR

Our study revealed that to improve the usability of IVR for older adult surgical patients, enhancements are needed, echoing previous research on non-surgical older adults struggling with the HMD unit due to weight or eyeglass compatibility issues.[62,66,67] Some participants in our study criticized the visual resolution of IVR, attributing difficulties primarily to age-related visual impairments rather than headset fit. This aligns

with findings from previous research on the visual quality of IVR in older adults in the community setting.[62,67] Uniquely, our research emphasized the practical challenges of using IVR during hospitalization for surgical recovery, underscoring the importance of adapting devices for bedridden users or those with physical limitations due to recent abdominal surgery or chronic disease.

Our findings also suggest a demand for a more diverse range of content within the IVR platform, echoing a general preference for personalization that better reflects users' life experiences and interests. This aligns with existing research on the desire for personalization of IVR content in community dwelling and residential care older adults.[6,62] Notably, our study contributes new insights to the existing research in two key areas as related to software content. First, there was significant interest among participants in integrating spiritual, religious, and cultural content into the IVR offerings. There is a growing body of evidence suggesting a positive correlation between religious beliefs and practices and enhanced mental health during adjustment to illness, disability, or surgery.[68–72] The concept of Whole Person Health, grounded in the biopsychosocial model, has expanded to include spirituality.[73,74] This holistic perspective highlights the interconnection of an individual's biological, social, psychological, and spiritual dimensions as integral to overall health and well-being.[48,75,76] This viewpoint is crucial for promoting a more comprehensive approach to age-friendly surgical care, with IVR emerging as potential tool to support this goal.

The request for culturally diverse content in IVR from older surgical adults also brings several considerations to light. First, there is a notable scarcity of research on how cultural or racial differences impact experiences, preferences, or outcomes as a

result of IVR use in the older adult, likely a reflection of the lack of diversity among study participants.[16,77,78] Second, despite many of our participants being highly educated and White, their interest in accessing more culturally diverse content suggests a possible dual motivation: 1) the eagerness to virtually explore new cultural experiences within a simulated setting that would otherwise be inaccessible, and 2) the desire to learn more about groups and cultures different from their own. Research has indicated that experiences in IVR can serve as a powerful tool for promoting awareness, empathy, and understanding towards individuals with differing life experiences and cultures.[79–81] IVR has the potential to create an authentic cultural experience for people from different backgrounds, transcending the confines of physical geographic barriers.[62,82] Nonetheless, there is a significant gap in insights regarding older adults' interest in IVR cultural experiences and the impact on their overall well-being following surgery, indicating a need for further investigation.

Finally, contrary to other studies that noted older adults' preference for stationary or IVR content,[83] our study participants expressed a desire for more cognitively engaging material, including the integration of storytelling or activities with problem solving, critiquing many of the available programs for being too passive. Current research does indicate that cognitive and emotional declines in older adults following surgery can impede recovery.[84,85] While direct mentions of cognitive changes were absent in the study, many participants noted emotional challenges during recovery. Prior research suggests various types of cognitive stimulation post-surgery can boost mood and maintain cognitive health.[85–87] More recent research has indicated that specific types of IVR applications can enhance cognitive function in older adults,

including those with mild cognitive impairment (MCI), highlighting the possibility of IVR as a tool to support cognitive and emotional stability following surgery.[88,89]

Potential Integration of IVR Into Older Adult Surgical Care Pathway

Although the participants in our study only encountered IVR in the initial days following surgery, most suggested that they would have found IVR useful in many other aspects of surgical care. A recent review demonstrated that IVR has been leveraged as a beneficial tool for delivering preoperative education, reducing preoperative surgical anxiety, mitigation of postoperative pain, and promotion of pre- and postoperative physical activity;[90] albeit this has not been specifically evaluated in the older surgical adult. Research highlights that pre-operative IVR tours of environments, such as the operating room and nursing unit, may offer patients a better sense of preparedness for surgery, decreasing overall anxiety.[91] Additionally, several studies have indicated that patients may prefer IVR-based education, as related to discussions about their anatomy or the procedure, over traditional learning methods.[92,93] Finally, our study uniquely highlights a strong preference among participants to access IVR on-demand during their inpatient stay or post-discharge at home. This contrasts with the limited research on the feasibility and acceptability of IVR applications in surgical older adults, as existing studies primarily focus on the community-dwelling or residential care demographics. This gap emphasizes a need for further exploration into on-demand IVR use in the hospital.

Implications for Geriatric Surgical Care

Our study highlights the promising role of IVR in improving care for older adults, particularly following elective inpatient abdominal surgeries. First, IVR may serve as an

effective distraction, offering a cost-efficient adjunct or alternative to conventional pain management strategies.[94] Managing pain in older adults postoperatively presents unique challenges due to heightened sensitivity to opioids and often inadequate pain control, which can lead to complications such as cognitive decline, constipation, and delirium.[95–97] Evidence suggests that IVR not only aids in pain relief but also may reduce opioid dependence post-surgery, thereby potentially decreasing the incidence of opioid-related adverse effects.[98] One study suggested that incorporating IVR into an inpatient pain management program could result in cost savings through reduced hospital length of stay.[94] Adopting non-pharmacological pain management methods like IVR aligns with the quality care standards endorsed by programs like the American College of Surgeons' Geriatric Surgery Verification program.[99]

Moreover, IVR offers unlimited possibilities to develop more age-appropriate virtual activities, practices, and environments. This technology enables older adults to overcome physical constraints related to aging, surgery, or illness, immersing them in experiences they might otherwise be unable to enjoy. Such innovation is consistent with the World Health Organization's (WHO) age-friendly initiatives, fostering supportive spaces that enhance older adults' lives.[100] IVR can act as a virtual extension of the environment, providing diverse age-friendly content that supports a more holistic biopsychosocial approach to surgical care. The use of IVR could potentially allow older adults greater autonomy in their surgical journey, likely leading to improved outcomes, such as enhanced overall well-being.

Despite the potential benefits of IVR, obstacles to its widespread clinical adoption remain, including cost and technology acceptance.[101] While our study's participants

positively received IVR postoperatively, broader implementation in older adult surgical care will depend on patient characteristics, technology acceptance, and perceived usefulness.[62,67] Moreover, the acceptance and adoption of IVR by clinicians and healthcare systems into routine surgical care requires further evaluation.[101]

Nonetheless, recent policy developments indicate a shift towards insurance coverage for IVR therapies in older adults under The Centers for Medicare & Medicaid Services Healthcare Common Procedure Coding System for certain IVR devices.[102] Future research should concentrate on the effective implementation of IVR into a geriatric virtual care ecosystem, considering the cost-benefit implications and the varied needs of different older adult populations.

Limitations

There are several limitations of this study that warrant acknowledgment. First, while the sample mirrors the patient demographic of one academic healthcare system, it may not encapsulate the experiences of individuals from diverse cultural or ethnic backgrounds, non-English speakers, or those with lower educational attainment. Furthermore, although nearly all participants reported no prior experience using IVR, there is the possibility for selection bias to the intervention, possible skewing the user experience. Additionally, the IVR intervention was not standardized and was limited to the content offerings provided by a single company specializing in IVR technology. Participants, did however, have the option of viewing various genres of environments and for varying lengths of time up to a maximum of 30 minutes per their preference within the preloaded content library. Furthermore, the total duration of IVR usage demonstrated variation between postoperative day one and day two. Future studies

should consider controlling for the type of environment and genre, as well as the duration and frequency of use and the impact on the user experience.

This study also exclusively examined participants who had planned elective inpatient surgery, were medically and cognitively stable, and had received preoperative IVR information prior to the intervention. The IVR user experience of individuals undergoing emergency surgeries, or those with cognitive or functional limitations could potentially differ significantly from our sample. Lastly, the reliance on interviews may not capture the full extent of older adults' experiences with IVR, as it hinges on their willingness to verbally convey their experiences during interviews.

CONCLUSION

In conclusion, despite minor criticisms of the technology, older adults valued the use of IVR after abdominal surgery for its usefulness in diverting attention away from symptoms and offering respite from the realities of hospitalization and underlying health concerns. These findings highlight the potential role of IVR as a versatile tool in managing a variety of postoperative symptoms and in enhancing the overall well-being of older adults during recovery. Further customizing IVR to meet the unique needs of older surgical patients could enhance their acceptance and perceived usefulness of this emerging technology, marking an innovative step towards more patient-centered surgical care. Our study paves the way for future research, including randomized controlled trial pilot studies targeting a more diverse older adult sample, evaluating the acceptance and feasibility of IVR application throughout the surgical care continuum, and delving into older adults' experiences with different types of IVR equipment.

Source of Support: This work was supported by the National Institute of Nursing Research of the National Institutes of Health (T32NR01692), the University of California, San Francisco (UCSF) Century Nursing Research award, the UCSF Graduate Mentorship Fellowship award, the UCSF Phillip R. Lee Health Policy Fellowship award, the UCSF Office of the Executive Vice Chancellor and Provost (EVCP) Social and Population Science Fellowship Research Award, and by the Department of Veterans Affairs, Veterans Health Administration, Office of Academic Affiliations VA Quality Scholars Advanced Fellowship Program (OAA 3Q072019C).

Conflict of Interest: All authors report no conflicts of interest. I also declare that there is no conflict of interest with Penumbra, Inc., regarding this study. Neither Penumbra, Inc., nor any of its representatives had any financial involvement or exerted any undue influence on study findings or development of this manuscript. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

Table 5.1 Sociodemographic and Clinical Characteristics (n=21)

Patient Characteristics	
Age, median, years (range)	73.0 (55-81)
Gender, n (%)	
Male	9 (42.9)
Female	12 (57.1)
Race/ethnicity, n (%)	
White/Caucasian	17 (81.0)
Asian	4 (19.0)
Hispanic	0 (0)
Black or African American	0 (0)
Relationship Status, n (%)	
Currently Married	10 (47.6)
Divorced	1 (4.8)
Single	10 (47.6)
Level of Education, n (%)	
Some college, no degree	10 (47.6)
Any college, graduate, or professional degree	11 (52.4)
Primary Types of Abdominal Procedure, n (%)	
Laparoscopic Low Anterior Resection	11 (52.4)
Laparoscopic Total Colectomy	4 (19.0)
Open Colostomy Takedown	3 (14.3)
Open End Ileostomy Takedown	1 (4.8)
Open Abdominal Perineal Resection	1 (4.8)
Robotic Assisted Rectopexy	1 (4.8)
Primary Indication for Surgery, n (%)	
Cancer	17 (81.0)

Table 5.2 Mean Time Spent Using IVR and Content Selection Among Participants Who Completed Interviews

	1 Day After Surgery n=21	**2 Days After Surgery n=18**
Mean Time Spent in IVR (minutes)	18.4 (SD 8.6)	12.4 (SD 6.8)
Range of Time Spent in IVR (minutes)	6-30	3-30
Participant IVR Content Selection[1]	n (%)	n (%)
Guided Travel	16 (76.2)	11 (55.0)
Mindfulness and Meditation	6 (28.6)	4 (19.0)
Artic Cold and/or Underwater	4 (19.0)	3 (14.3)
Forests and/or Wildlife	2 (9.5)	1 (4.8)
Games	1 (4.8)	1 (4.8)

[1] Participants had the option to choose as many experiences as desired, up to a maximum of 30 minutes of use per session, in any of the content categories offered within the preloaded software library.

Table 5.3 Immersive Virtual Reality as Positive Distraction from Postoperative Symptoms during Hospitalization

Types of Symptoms	Exemplar Quotes
Pain	“It [IVR] takes away some of the pain because you're not concentrating on pain, but instead you're focusing more on the game and the virtual reality environment.” (66 y/o Male, Laparoscopic sigmoid colectomy)
Fatigue	“I think it's good for you to get your mind off what is going on in your body. It will distract you from the pain or extreme tiredness after surgery.” (69 y/o Female, Laparoscopic sigmoid colectomy)
Anxiety/Stress	“If you're anxious, after surgery, it [IVR] is a good way to just kind of relax.” (77 y/o Female, Robotic low anterior colorectal resection)
Depression	“It [IVR] distracted me away from what I am feeling right now. I’m feeling a little sad, so the experience helped to get my mind off feeling a little down and depressed. I felt like it lifted my mood during the time I used the machine [virtual reality].” (74 y/o Female)

Table 5.4 A Sense of Escape from the Hospital Environment and Worrisome Medical Conditions

Types of Escape	Exemplar Quotes
Hospital	“My activity was feeding the squirrels [in a virtual reality game]. It was a sense of escape from the hospital room, at least temporarily.” (57 y/o Female, Laparoscopic Sigmoid colectomy)
Cancer	“It’s a great way to get my mind off my cancer and my disease and just escape in the moment during the experience.” (73 y/o Female, Laparoscopic total colectomy)
Other Health Issues	“I have some illnesses that I'm dealing with too. I would think that it would help with those illnesses by escaping from the reality for a moment.” (68 y/o Female, Laparoscopic sigmoid colectomy)

Table 5.5 Participant Suggestions for Tailoring Virtual Reality for Older Surgical Adults

Theme	Subtheme	Exemplar Quote
Content/Experiences	More Cognitively Engaging	"Many of the programs needed more mental stimulation. The meditation experience was kind of boring. So, the choice of interactive or education content was rather limited for older adults." (56 y/o Male)
	Spiritual and Cultural Options	"There are many of us who are Christian or Catholic and there's so many others that practice other religions. So there needs to be more of those programs in virtual reality as it is supportive during hard times." (76 y/o Female)
	Personal Interests and Previous Life Experiences	"I love to travel, and I can't right now. It was good to see Istanbul [in virtual reality] as I have been there before, and it brought back good memories. So that was kind of enjoyable and fun. There needs to be more options for interests that appeal to older people in the virtual reality headset" (56 y/o Male)
Hardware/Equipment	Headset	"For older adults, I think that it [the headset] is little heavy. It needs to be more compatible with eyeglass wearers and with the hospital bed." (57 y/o Male)
	Visual Display	"I found that for people who have visual problems like cataract surgery in the past like me and it will be hard to figure out how to get the lenses in just the right spot to focus. So, I think there were some issues with image as blurry and this needs to be fixed for older people." (76 y/o Female)

Table 5.6 Older Adults Endorsed the Possibility of IVR Use Throughout Perioperative Care

Theme	Exemplar Quotes
Useful During the Preoperative and Postoperative Phases of Care	"I think people might want to use it [IVR] the day of surgery as well as during their hospital." (74 y/o Female) "You could use virtual reality before surgery to help calm people's anxiety and of course it could be used after surgery for pain distraction or distraction from other bothersome symptoms." (56 y/o Male)
More availability During Hospital Stay	"It [IVR] should be like a service or option, a service like physical therapy, where they come in, evaluate you and offer it to you in the hospital room." (76 y/o Female)
Useful at Home After Surgical Discharge	"If older adults like me had the option it might be useful at home to help relax or for additional education on recovery at home." (73 y/o Male)
Types of Supported Needed to Use IVR Again	"You would need to have somebody to show you how to use this [IVR] the first time. A video and handout were sent before I used the headset on what to expect and what to do. That made it so much easier, and it was a lot less intimidating. I think for anybody using it at home, having someone to show them ahead of time and explain the device would be greatly helpful." (73 y/o Male)

References

1. Organization WH. *World Report on Ageing and Health*. World Health Organization; 2015. Accessed February 17, 2024. https://iris.who.int/handle/10665/186463
2. Fact Sheet: Aging in the United States. PRB. Accessed February 17, 2024. https://www.prb.org/resources/fact-sheet-aging-in-the-united-states/
3. Seifert A, Schlomann A. The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges. *Front Virtual Real*. 2021;2. Accessed December 26, 2023. https://www.frontiersin.org/articles/10.3389/frvir.2021.639718
4. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. *Cyberpsychology Behav Soc Netw*. 2023;26(12):886-895. doi:10.1089/cyber.2023.0188
5. Tuena C, Pedroli E, Trimarchi PD, et al. Usability Issues of Clinical and Research Applications of Virtual Reality in Older People: A Systematic Review. *Front Hum Neurosci*. 2020;14:93. doi:10.3389/fnhum.2020.00093
6. Baker S, Waycott J, Robertson E, et al. Evaluating the use of interactive virtual reality technology with older adults living in residential aged care. *Inf Process Manag*. 2020;57(3):102105. doi:10.1016/j.ipm.2019.102105
7. Chaze F, Hayden L, Azevedo A, et al. Virtual reality and well-being in older adults: Results from a pilot implementation of virtual reality in long-term care. *J Rehabil Assist Technol Eng*. 2022;9:20556683211072384. doi:10.1177/20556683211072384

8. Cieślik B, Juszko K, Kiper P, Szczepańska-Gieracha J. Immersive virtual reality as support for the mental health of elderly women: a randomized controlled trial. *Virtual Real*. 2023;27(3):2227-2235. doi:10.1007/s10055-023-00797-w
9. Benham S, Kang M, Grampurohit N. Immersive Virtual Reality for the Management of Pain in Community-Dwelling Older Adults. *OTJR Occup Particip Health*. 2019;39(2):90-96. doi:10.1177/1539449218817291
10. Stamm O, Dahms R, Müller-Werdan U. Virtual reality in pain therapy: a requirements analysis for older adults with chronic back pain. *J Neuroengineering Rehabil*. 2020;17(1):129. doi:10.1186/s12984-020-00753-8
11. Cieślik B, Mazurek J, Wrzeciono A, et al. Examining technology-assisted rehabilitation for older adults' functional mobility: a network meta-analysis on efficacy and acceptability. *Npj Digit Med*. 2023;6(1):1-10. doi:10.1038/s41746-023-00907-7
12. Appel L, Appel E, Bogler O, et al. Older Adults With Cognitive and/or Physical Impairments Can Benefit From Immersive Virtual Reality Experiences: A Feasibility Study. *Front Med*. 2019;6:329. doi:10.3389/fmed.2019.00329
13. Kim A, Darakjian N, Finley JM. Walking in fully immersive virtual environments: an evaluation of potential adverse effects in older adults and individuals with Parkinson's disease. *J Neuroengineering Rehabil*. 2017;14(1):16. doi:10.1186/s12984-017-0225-2
14. Drazich BF, McPherson R, Gorman EF, et al. In too deep? A systematic literature review of fully-immersive virtual reality and cybersickness among older adults. *J Am Geriatr Soc*. 2023;71(12):3906-3915. doi:10.1111/jgs.18553

15. Furht B, ed. Immersive Virtual Reality. In: *Encyclopedia of Multimedia*. Springer US; 2008:345-346. doi:10.1007/978-0-387-78414-4_85

16. Martingano AJ, Duane JN, Brown E, Persky S. Demographic differences in presence across seven studies. *Virtual Real*. 2023;27(3):2297-2313. doi:10.1007/s10055-023-00805-z

17. Indovina P, Barone D, Gallo L, Chirico A, De Pietro G, Giordano A. Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review. *Clin J Pain*. 2018;34(9):858-877. doi:10.1097/AJP.0000000000000599

18. Wu J, Sun Y, Zhang G, Zhou Z, Ren Z. Virtual Reality-Assisted Cognitive Behavioral Therapy for Anxiety Disorders: A Systematic Review and Meta-Analysis. *Front Psychiatry*. 2021;12. Accessed February 18, 2024. https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2021.575094

19. Montalbán MA, Arrogante O. Rehabilitation through virtual reality therapy after a stroke: A literature review. *Rev Científica Soc Enferm Neurológica Engl Ed*. 2020;52:19-27. doi:10.1016/j.sedeng.2020.01.001

20. Elor A, Kurniawan S. The Ultimate Display for Physical Rehabilitation: A Bridging Review on Immersive Virtual Reality. *Front Virtual Real*. 2020;1. Accessed February 18, 2024. https://www.frontiersin.org/articles/10.3389/frvir.2020.585993

21. van der Kruk SR, Zielinski R, MacDougall H, Hughes-Barton D, Gunn KM. Virtual reality as a patient education tool in healthcare: A scoping review. *Patient Educ Couns*. 2022;105(7):1928-1942. doi:10.1016/j.pec.2022.02.005

22. Schwarze ML, Barnato AE, Rathouz PJ, et al. Development of a List of High-Risk Operations for Patients 65 Years and Older. *JAMA Surg*. 2015;150(4):325-331. doi:10.1001/jamasurg.2014.1819

23. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82:87-94. doi:10.1016/j.ijsu.2020.08.033

24. Specht BJ, Buse CR, Phelps JR, et al. Virtual Reality after Surgery—A Method to Decrease Pain After Surgery in Pediatric Patients. *Am Surg*. Published online July 17, 2021:00031348211032204. doi:10.1177/00031348211032204

25. Chiu PL, Li H, Yap KYL, Lam KMC, Yip PLR, Wong CL. Virtual Reality-Based Intervention to Reduce Preoperative Anxiety in Adults Undergoing Elective Surgery: A Randomized Clinical Trial. *JAMA Netw Open*. 2023;6(10):e2340588. doi:10.1001/jamanetworkopen.2023.40588

26. Fuchs L, Kluska A, Novak D, Kosashvili Y. The influence of early virtual reality intervention on pain, anxiety, and function following primary total knee arthroplasty. *Complement Ther Clin Pract*. 2022;49:101687. doi:10.1016/j.ctcp.2022.101687

27. Koo KI, Park DK, Youm YS, Cho SD, Hwang CH. Enhanced Reality Showing Long-Lasting Analgesia after Total Knee Arthroplasty: Prospective, Randomized Clinical Trial. *Sci Rep*. 2018;8(1):2343. doi:10.1038/s41598-018-20260-0

28. Gianola S, Stucovitz E, Castellini G, et al. Effects of early virtual reality-based rehabilitation in patients with total knee arthroplasty: A randomized controlled trial. *Medicine (Baltimore)*. 2020;99(7):1-8. doi:10.1097/MD.0000000000019136

29. Jin C, Feng Y, Ni Y, Shan Z. Virtual reality intervention in postoperative rehabilitation after total knee arthroplasty: a prospective and randomized controlled clinical trial. *Int J Clin Exp Med*. 2018;11(6):6119-6124.

30. Schrempf MC, Zanker J, Arndt TT, et al. Immersive Virtual Reality Fitness Games to Improve Recovery After Colorectal Surgery: A Randomized Single Blind Controlled Pilot Trial. *Games Health J*. Published online December 4, 2023. doi:10.1089/g4h.2023.0004

31. Cockerham M, Eakins J, Hsu E, Tran A, Adjei NB, Guerrero K. Virtual reality in post-operative robotic colorectal procedures: An innovation study. *J Nurs Educ Pract*. 2023;13(6):1. doi:10.5430/jnep.v13n6p1

32. Shepherd T, Trinder M, Theophilus M. Does virtual reality in the perioperative setting for patient education improve understanding? A scoping review. *Surg Pract Sci*. 2022;10:100101. doi:10.1016/j.sipas.2022.100101

33. Jin F, Chung F. Minimizing perioperative adverse events in the elderly. *Br J Anaesth*. 2001;87(4):608-624. doi:10.1093/bja/87.4.608

34. Cheung C, Meissner MA, Garg T. Incorporating Outcomes that Matter to Older Adults into Surgical Research. *J Am Geriatr Soc*. 2021;69(3):618-620. doi:10.1111/jgs.17028

35. Berian JR, Mohanty S, Ko CY, Rosenthal RA, Robinson TN. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients

After Surgical Procedures. *JAMA Surg*. 2016;151(9):e161689. doi:10.1001/jamasurg.2016.1689

36. Fried TR, Bradley EH, Towle VR, Allore H. Understanding the treatment preferences of seriously ill patients. *N Engl J Med*. 2002;346(14):1061-1066. doi:10.1056/NEJMsa012528

37. Kata A, Dutt M, Sudore RL, Finlayson E, Broering JM, Tang VL. What Matters? The Valued Life Activities of Older Adults Undergoing Elective Surgery. *J Am Geriatr Soc*. 2019;67(11):2305-2310. doi:10.1111/jgs.16102

38. Appleton JV, King L. Journeying from the philosophical contemplation of constructivism to the methodological pragmatics of health services research. *J Adv Nurs*. 2002;40(6):641-648. doi:10.1046/j.1365-2648.2002.02424.x

39. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health Care J Int Soc Qual Health Care*. 2007;19(6):349-357. doi:10.1093/intqhc/mzm042

40. REAL i-Series® – Cognition and Mental Well-being. REAL System. Accessed January 20, 2024. https://www.realsystem.com/iseries/

41. Niehorster DC, Li L, Lappe M. The Accuracy and Precision of Position and Orientation Tracking in the HTC Vive Virtual Reality System for Scientific Research. *-Percept*. 2017;8(3):2041669517708205. doi:10.1177/2041669517708205

42. Venkatesan M, Mohan H, Ryan JR, et al. Virtual and augmented reality for biomedical applications. *Cell Rep Med*. 2021;2(7):100348. doi:10.1016/j.xcrm.2021.100348

43. The Differences between 3DoF and 6DoF, and Why - IEEE Digital Reality. Accessed March 30, 2024. https://digitalreality.ieee.org/publications/degrees-of-freedom

44. Kennedy RS, Lane NE, Berbaum KS, Lilienthal MG. Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *Int J Aviat Psychol*. 1993;3:203-220. doi:10.1207/s15327108ijap0303_3

45. ATLAS.ti: The Qualitative Data Analysis & Research Software. ATLAS.ti. Accessed January 10, 2022. https://atlasti.com/

46. Olmos-Vega FM, Stalmeijer RE, Varpio L, Kahlke R. A practical guide to reflexivity in qualitative research: AMEE Guide No. 149. *Med Teach*. 2022;0(0):1-11. doi:10.1080/0142159X.2022.2057287

47. Krist AH, South-Paul JE, Meisnere M. Achieving Whole Health for Veterans and the Nation: A National Academies of Sciences, Engineering, and Medicine Report. *JAMA Health Forum*. 2023;4(5):e230874. doi:10.1001/jamahealthforum.2023.0874

48. Powers JS, Penaranda N. Creation of a Whole Health Age-Friendly Template and Dashboard Facilitates Implementation of 4Ms into Primary Care. *Geriatrics*. 2022;7(5):109. doi:10.3390/geriatrics7050109

49. Prabhu V, Stanley L, Morgan R. A Biofeedback Enhanced Adaptive Virtual Reality Environment for Managing Surgical Pain and Anxiety. *Int J SEMANTIC Comput*. 2020;14(3):375-393. doi:10.1142/S1793351X20400152

50. Güneş H, Sarıtaş S. The Effects of Virtual Reality Intervention Before Total Knee Arthroplasty on Pain, Anxiety, and Vital Signs. *Clin Simul Nurs*. 2024;87. doi:10.1016/j.ecns.2023.03.003

51. Keny C, Dillon EC, Russell MM, Colley A, Yank V, Tang V. "It's Incapacitated me in so Many Ways": Older Adults' Lived Experience with Postoperative Symptoms at Home Following Major Elective Surgery. *Ann Surg*. Published online December 5, 2023. doi:10.1097/SLA.0000000000006170

52. Johnson T, Bauler L, Vos D, et al. Virtual Reality Use for Symptom Management in Palliative Care: A Pilot Study to Assess User Perceptions. *J Palliat Med*. 2020;23(9):1233-1238. doi:10.1089/jpm.2019.0411

53. Wu Y, Wang N, Zhang H, Sun X, Wang Y, Zhang Y. Effectiveness of Virtual Reality in Symptom Management of Cancer Patients: A Systematic Review and Meta-Analysis. *J Pain Symptom Manage*. 2023;65(5):e467-e482. doi:10.1016/j.jpainsymman.2023.01.023

54. Bridges J, Flatley M, Meyer J. Older people's and relatives' experiences in acute care settings: systematic review and synthesis of qualitative studies. *Int J Nurs Stud*. 2010;47(1):89-107. doi:10.1016/j.ijnurstu.2009.09.009

55. Admi H, Shadmi E, Baruch H, Zisberg A. From Research to Reality: Minimizing the Effects of Hospitalization on Older Adults. *Rambam Maimonides Med J*. 2015;6(2):e0017. doi:10.5041/RMMJ.10201

56. Pritchard MJ. Identifying and assessing anxiety in pre-operative patients. *Nurs Stand R Coll Nurs G B 1987*. 2009;23(51):35-40. doi:10.7748/ns2009.08.23.51.35.c7222

57. Kiecolt-Glaser JK, Page GG, Marucha PT, MacCallum RC, Glaser R. Psychological influences on surgical recovery. Perspectives from psychoneuroimmunology. *Am Psychol*. 1998;53(11):1209-1218. doi:10.1037//0003-066x.53.11.1209

58. Vayssiere P, Constanthin PE, Baticam NS, et al. Use of Virtual Reality to Improve the Quality of the Hospital Stay for Patients in Neurosurgery. *Front Virtual Real*. 2021;2. Accessed February 20, 2024. https://www.frontiersin.org/articles/10.3389/frvir.2021.736122

59. Di Pompeo I, D'Aurizio G, Burattini C, Bisegna F, Curcio G. Positive mood induction to promote well-being and health: A systematic review from real settings to virtual reality. *J Environ Psychol*. 2023;91:102095. doi:10.1016/j.jenvp.2023.102095

60. Montana JI, Matamala-Gomez M, Maisto M, et al. The Benefits of emotion Regulation Interventions in Virtual Reality for the Improvement of Wellbeing in Adults and Older Adults: A Systematic Review. *J Clin Med*. 2020;9(2):500. doi:10.3390/jcm9020500

61. du Plessis J, Jordaan J. The impact of virtual reality on the psychological well-being of hospitalised patients: A critical review. *Heliyon*. 2024;10(2):e24831. doi:10.1016/j.heliyon.2024.e24831

62. Healy D, Flynn A, Conlan O, McSharry J, Walsh J. Older Adults' Experiences and Perceptions of Immersive Virtual Reality: Systematic Review and Thematic Synthesis. *JMIR Serious Games*. 2022;10(4):e35802. doi:10.2196/35802

63. Steele R, Linsley K. Relieving in-patient boredom in general hospitals: the evidence for intervention and practical ideas. *BJPsych Adv*. 2015;21(1):63-70. doi:10.1192/apt.bp.113.011908

64. Inman A, Kirsh KL, Passik SD. A pilot study to examine the relationship between boredom and spirituality in cancer patients. *Palliat Support Care*. 2003;1(2):143-151. doi:10.1017/s1478951503030165

65. Yeo NL, White MP, Alcock I, et al. What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360° video, and computer generated virtual reality. *J Environ Psychol*. 2020;72:101500. doi:10.1016/j.jenvp.2020.101500

66. Brown JA. An Exploration of Virtual Reality Use and Application Among Older Adult Populations. *Gerontol Geriatr Med*. 2019;5:2333721419885287. doi:10.1177/2333721419885287

67. Roberts AR, De Schutter B, Franks K, Radina ME. Older Adults' Experiences with Audiovisual Virtual Reality: Perceived Usefulness and Other Factors Influencing Technology Acceptance. *Clin Gerontol*. 2019;42(1):27-33. doi:10.1080/07317115.2018.1442380

68. Koenig HG. SPIRITUAL ASPECTS OF SURGERY. *Ophthalmol Clin*. 2000;13(1):71-83. doi:10.1016/S0896-1549(05)70167-X

69. Ai AL, Park CL, Huang B, Rodgers W, Tice TN. Psychosocial mediation of religious coping styles: a study of short-term psychological distress following cardiac surgery. *Pers Soc Psychol Bull*. 2007;33(6):867-882. doi:10.1177/0146167207301008

70. Ai AL, Hopp F, Tice TN, Koenig H. Existential relatedness in light of eudemonic well-being and religious coping among middle-aged and older cardiac patients. *J Health Psychol*. 2013;18(3):368-382. doi:10.1177/1359105311434754

71. Ai AL, Pargament K, Kronfol Z, Tice TN, Appel H. Pathways to postoperative hostility in cardiac patients: mediation of coping, spiritual struggle and interleukin-6. *J Health Psychol*. 2010;15(2):186-195. doi:10.1177/1359105309345556

72. Divaasini Devaraj, Zhooriyati Sehu Mohammad. Psychological effects and coping strategies after major surgery in adults. *J Psikol Malays*. 2019;33(2):33-44. doi:10/1/470-1949-1-PB.pdf

73. Thomas H, Mitchell G, Rich J, Best M. Definition of whole person care in general practice in the English language literature: a systematic review. *BMJ Open*. 2018;8(12):e023758. doi:10.1136/bmjopen-2018-023758

74. Saad M, de Medeiros R, Mosini AC. Are We Ready for a True Biopsychosocial–Spiritual Model? The Many Meanings of “Spiritual.” *Medicines*. 2017;4(4):79. doi:10.3390/medicines4040079

75. Sulmasy DP. A biopsychosocial-spiritual model for the care of patients at the end of life. *The Gerontologist*. 2002;42 Spec No 3:24-33. doi:10.1093/geront/42.suppl_3.24

76. Brault M, Laudermith A. Implementing the Whole Health System in a Geriatric Veteran Population: A Person-Centered Approach to Health Care. *Am J Geriatr Psychiatry*. 2023;31(3, Supplement):S113. doi:10.1016/j.jagp.2022.12.161

77. Parsons TD, Rizzo AA. Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *J Behav Ther Exp Psychiatry*. 2008;39(3):250-261. doi:10.1016/j.jbtep.2007.07.007

78. Taylor VJ, Valladares JJ, Siepser C, Yantis C. Interracial Contact in Virtual Reality: Best Practices. *Policy Insights Behav Brain Sci*. 2020;7(2):132-140. doi:10.1177/2372732220943638

79. Chae D, Yoo JY, Kim J, Ryu J. Effectiveness of Virtual Simulation to Enhance Cultural Competence in Pre-licensure and Licensed Health Professionals: A Systematic Review. *Clin Simul Nurs*. 2021;56:137-154. doi:10.1016/j.ecns.2021.04.013

80. Theodoropoulos A, Antoniou A. VR Games in Cultural Heritage: A Systematic Review of the Emerging Fields of Virtual Reality and Culture Games. *Appl Sci*. 2022;12(17):8476. doi:10.3390/app12178476

81. Škola F, Rizvić S, Cozza M, et al. Virtual Reality with 360-Video Storytelling in Cultural Heritage: Study of Presence, Engagement, and Immersion. *Sensors*. 2020;20(20):5851. doi:10.3390/s20205851

82. Rauscher M, Humpe A. Traveling the Past: Raising Awareness of Cultural Heritage through Virtual Reality. *J Promot Manag*. 2022;28(2):128-143. doi:10.1080/10496491.2021.1987958

83. Srifar D. 360 Virtual Reality Travel Media for Elderly. *Int J Multimed Its Appl*. 2018;10(1/2/3):45-52. doi:10.5121/ijma.2018.10304

84. Pedone C, Ercolani S, Catani M, et al. Elderly patients with cognitive impairment have a high risk for functional decline during hospitalization: The GIFA Study. *J Gerontol A Biol Sci Med Sci*. 2005;60(12):1576-1580. doi:10.1093/gerona/60.12.1576

85. Carbone E, Vianello E, Carretti B, Borella E. Working Memory Training for Older Adults After Major Surgery: Benefits to Cognitive and Emotional Functioning. *Am J Geriatr Psychiatry*. 2019;27(11):1219-1227. doi:10.1016/j.jagp.2019.05.023

86. Kulason K, Nouchi R, Hoshikawa Y, Noda M, Okada Y, Kawashima R. The Beneficial Effects of Cognitive Training With Simple Calculation and Reading Aloud (SCRA) in the Elderly Postoperative Population: A Pilot Randomized Controlled Trial. *Front Aging Neurosci*. 2018;10. Accessed February 22, 2024. https://www.frontiersin.org/articles/10.3389/fnagi.2018.00068

87. Cheng CM, Chiu MJ, Wang JH, et al. Cognitive stimulation during hospitalization improves global cognition of older Taiwanese undergoing elective total knee and hip replacement surgery. *J Adv Nurs*. 2012;68(6):1322-1329. doi:10.1111/j.1365-2648.2011.05842.x

88. Maeng S, Hong JP, Kim WH, et al. Effects of Virtual Reality-Based Cognitive Training in the Elderly with and without Mild Cognitive Impairment. *Psychiatry Investig*. 2021;18(7):619-627. doi:10.30773/pi.2020.0446

89. Kruse CS, Sen K, Armenta V, Hubbard N, Brooks R. Leveraging mHealth and Virtual Reality to Improve Cognition for Alzheimer's Patients: A Systematic Review. *Healthcare*. 2022;10(10):1845. doi:10.3390/healthcare10101845

90. Gendia A, Rottenburg H, Tam A, Cota A, Clark J. Virtual Reality can be a Part of The Surgical Journey from The Preoperative Period until Home Recovery: A Concept to be Applied in The Future. *Surg Endosc*. 2022;36(2):S437. doi:10.1007/s00464-022-09337-0

91. Yu Y, Zhou X, Zeng G, Hou Y. Impact of Virtual Operating Room Tours on Relieving Perioperative Anxiety in Adult Patients: A Systematic Review. *J Perianesth Nurs*. 2023;38(4):657-663.e7. doi:10.1016/j.jopan.2022.11.013

92. Pandrangi VC, Gaston B, Appelbaum NP, Albuquerque FC, Levy MM, Larson RA. The Application of Virtual Reality in Patient Education. *Ann Vasc Surg*. 2019;59:184-189. doi:10.1016/j.avsg.2019.01.015

93. Gao J, Liu S, Zhang S, et al. Pilot Study of a Virtual Reality Educational Intervention for Radiotherapy Patients Prior to Initiating Treatment. *J Cancer Educ Off J Am Assoc Cancer Educ*. 2022;37(3):578-585. doi:10.1007/s13187-020-01848-5

94. Delshad SD, Almario CV, Fuller G, Luong D, Spiegel BMR. Economic analysis of implementing virtual reality therapy for pain among hospitalized patients. *NPJ Digit Med*. 2018;1:22. doi:10.1038/s41746-018-0026-4

95. Mangoni AA, Jackson SHD. Age-related changes in pharmacokinetics and pharmacodynamics: basic principles and practical applications. *Br J Clin Pharmacol*. 2004;57(1):6-14. doi:10.1046/j.1365-2125.2003.02007.x

96. McKeown JL. Pain Management Issues for the Geriatric Surgical Patient. *Anesthesiol Clin*. 2015;33(3):563-576. doi:10.1016/j.anclin.2015.05.010

97. Weiss AJ, Barrett ML, Steiner A. Patient Characteristics of Opioid-Related Inpatient Stays and Emergency Department Visits Nationally and by State, 2014. :19.

98. Pandrangi V, Shah S, Bruening J, et al. Effect of Virtual Reality on Pain Management and Opioid Use Among Hospitalized Patients After Head and Neck Surgery A Randomized Clinical Trial. *JAMA Otolaryngol-HEAD NECK Surg*. 2022;148(8):724-730. doi:10.1001/jamaoto.2022.1121

99. Geriatric Surgery Verification. ACS. Accessed September 16, 2022. https://www.facs.org/quality-programs/accreditation-and-verification/geriatric-surgery-verification/

100. Age-friendly Environments. Accessed February 24, 2024. https://www.who.int/teams/social-determinants-of-health/demographic-change-and-healthy-ageing/age-friendly-environments

101. Kouijzer MMTE, Kip H, Bouman YHA, Kelders SM. Implementation of virtual reality in healthcare: a scoping review on the implementation process of virtual reality in various healthcare settings. *Implement Sci Commun*. 2023;4:67. doi:10.1186/s43058-023-00442-2

102. CMS issues first HCPCS code and Medicare DME benefit category determination for therapeutic Virtual Reality Device | DLA Piper. Accessed February 24, 2024. https://www.dlapiper.com/en-us/insights/publications/2023/04/cms-issues-first-hcpcs-code-and-medicare-dme-benefit-category-determination

CHAPTER 6

CONCLUSION

Objective of Dissertation

The overall objective of this dissertation was to determine the feasibility and acceptability of immersive virtual reality (IVR) for postoperative pain management among older adults following inpatient elective abdominal surgery. The first chapter of this dissertation provided an overview of the significance of postoperative pain in the older adult and the complexities of pain management in this demographic following major surgery. In this first chapter, a general summary of IVR as a positive distraction method for acute pain was also discussed. Chapter two aimed to explore the older adults' lived experience with postoperative symptoms, in particular pain, up through three months following various major elective surgeries. Study participants described how various postoperative symptoms negatively impacted their psychosocial well-being. Participants offered various suggestions to improve symptom management following surgery, including the use of technology to deliver more education, resources, and support on managing and coping with challenging symptoms, such as postoperative pain. Chapter three presented a comprehensive scoping review of the literature on the use of IVR for managing postoperative pain in adults aged 65 years and older. This review identified gaps in the research literature and offered recommendations for future studies. Chapters two and three informed the foundational basis for this dissertation, which were discussed in chapters four and five. Chapter four is the crux of the dissertation study, which presented a feasibility and acceptability study, with findings on the use of IVR for pain management in the initial two days following elective inpatient

abdominal surgery among older adults. The findings of this dissertation study contribute to the growing body of literature on employing IVR as part of acute pain management, particularly among hospitalized older adults. Chapter five described qualitative interview findings on the user experience of IVR for pain management in a subgroup of study participants from the parent feasibility and acceptability study described previously in chapter four.

Review of Findings

Chapter two highlighted that various postoperative symptoms, including pain, may have a more significant impact on older adults' psychosocial well-being than clinicians realize, making it a crucial patient-reported outcome. Furthermore, this study emphasized the need to develop and test interventions aimed at providing better management of postoperative symptoms, especially pain, in the older surgical adult. The findings in chapter three indicated that literature is sparse and heterogenous on the use of IVR for postoperative pain in older adults who have non-total joint surgery. Therefore, conclusions about acceptability, feasibility, and efficacy are not possible.

The review in chapter three emphasized both the promise and the need for more rigorous randomized clinical trials on the efficacy of IVR in older adults across a spectrum of surgical procedures, and older adult subgroups. In chapter four, the main study of this dissertation, the findings showed that the use of IVR in older adults in the initial days following elective inpatient abdominal surgery was feasible, acceptable, well-tolerated, and contributed to reductions in self-reported postoperative pain levels and improvement in state of relaxation. Finally, in chapter five, semi-structured interviews revealed four prominent user experience themes: 1) IVR was a positive distraction from

variety postoperative symptoms; 2) IVR provided a sense of escape from the hospital environment or worrisome medical conditions; 3) There is a need to tailor virtual reality content and equipment specifically for older surgical adults; and 4) Older adults endorsed the possibility of IVR use throughout perioperative care.

Implications

In the United States, the older adult demographic is experiencing a substantial expansion.[1] Projections from the Centers for Disease Control and Prevention suggest that by the year 2060, nearly 25% of the U.S. population will be aged 65 and above.[2] This significant rise in the older population is anticipated to lead to a corresponding surge in the number of surgeries conducted, thereby escalating the demands for post-surgical care.[3] This rising trend in an aging population suggests the need for more innovative technology based solutions specifically designed for the unique needs of older adults.[4]

Immersive virtual reality stands out as a significant technological advancement, with a recent exponential growth in health care use, attracting considerable attention for its potential to enhance various aspects of health in older adults, especially in community and residential settings.[5,6] In the surgical setting, however, there is limited research exploring the acceptability or efficacy of IVR across a range of major elective surgeries requiring inpatient care.[7] It is important to recognize that older adults may experience and recover from surgery differently than younger adults due to various geriatric vulnerabilities.[8–11] Our study highlights the promising role of IVR in improving care, particularly for pain reduction, for older adults following elective inpatient abdominal surgeries. As IVR technology continues to rapidly advance, it is crucial to

highlight its potential implications for research, clinical care, policy, the future direction of healthcare, and ethical considerations.

Research Implications

Future studies are needed to not only evaluate the efficacy of IVR for pain management in the older adult population across a broader spectrum of clinical scenarios, but additionally to determine individual and IVR characteristics associated with pain and pain-related outcomes. Older adults are not a homogeneous group. As such, various geriatric specific factors, such as frailty and cognitive decline, should be more closely examined in relation to overall acceptance and efficacy of IVR use in the inpatient setting. Of paramount importance is also evaluating if various older adult age subgroups, including different age ranges (e.g., ages 65 to 75, 75 and older), various sociodemographic factors, and clinical characteristics are associated with improved pain outcomes. Furthermore, research based on human-centered design frameworks are needed to better inform the older adults' user experience, such as types of IVR content and equipment deemed most acceptable in the older adult demographic. Finally, future research should concentrate on leveraging implementation frameworks to evaluate the barriers and facilitators of IVR integration into a geriatric clinical care.

Clinical Care Implications

While current research is promising on the use of IVR for pain, clinical implementation remains in the early stages.[12,13] Given the exponential growth in the number of research studies demonstrating the potential of IVR for pain management and other clinical outcomes, discussion about IVR integration into patient care is critical. Several aspects of adoption of IVR into patient care must be considered. First, the

introduction of evidence-based practices, particularly those involving technological interventions, into any care setting necessitates strategies aimed at identifying and eliminating barriers, while simultaneously promoting factors that facilitate the adoption and integration into routine care.[12,14] Adoption of new technology into clinical care typically also requires extensive clinical provider training and standardization into care.[12] Furthermore, beyond the logistics of implementation, assessment of adoption readiness of all key stakeholders is equally as important. This can be evaluated through tools such as a stakeholder analysis.[15] This includes not only clinical providers, but organizational leadership, as well as patients. According to a recent review, recommendations for implementation of IVR into patient care should include evaluation of the following domains: clinical provider awareness of patient suitability of IVR use, training and enhanced knowledge of IVR, added support staff during the adoption phase (e.g., mentors and champions), and clear treatment indications for various use cases of IVR (e.g., types of software for pain).[12]

Additionally, as related to operational leaders, demonstrated economic value in terms of both hard and soft cost savings of IVR, as well as demonstration of improved patient outcomes is key to adoption across an organization.[16] Finally, from a patient perspective, especially as related to the older adult, providing increased support and education on IVR use is critical for increased acceptance as part of care.[17]

Policy Implications

There are several aspects of policy that should be considered regarding the use of IVR for patient care. First, managing pain in older adults postoperatively presents unique challenges due to heightened sensitivity to opioids and often inadequate pain

control, both of which can lead to considerable negative outcomes such as cognitive decline, constipation, and delirium.[18–23] Adopting non-pharmacological pain management methods like IVR aligns not only with the push to curb the current opioid epidemic, but also to promote better quality of care for surgical older adults. Quality care standards endorsed by national programs like the American College of Surgeons' Geriatric Surgery Verification program and government sponsored organizations such as the Joint Commission encourage use of nonpharmacological pain management strategies in older adults.[24,25]

Moreover, beyond a therapeutic pain intervention, IVR technology can additionally serve as a tool to enable older adults to overcome physical constraints related to aging, surgery, or illness, by immersing them in experiences they might otherwise be unable to enjoy. Such innovation is consistent with the World Health Organization's (WHO) age-friendly initiative, which encourages environments and spaces that enhance older adults' lives.[26] Immersive Virtual Reality has the potential to deliver support, leisurely activities, and entertainment through virtual environments. Furthermore, IVR has the potential to align with other various age-friendly initiatives which are aimed at reducing feelings of social isolation and promoting physical exercise as well as cognitive stimulation.

Additionally, recent policy developments indicate a shift towards insurance coverage for IVR therapies in older adults under the Centers for Medicare & Medicaid Services (CMS) Healthcare Common Procedure Coding System for certain IVR devices.[27] This recent ruling by CMS will likely pave the pathway for Medicare and commercial payer insurance coverage of IVR use in older adults.

Finally, the Food and Drug Administration (FDA) has started to provide increased

review and guidance on a growing number of IVR devices through premarket approval as a medical device classification.[28] Up until recently IVR was not considered a medical device, and therefore, was not regulated as such by the FDA. It is expected that the FDA will increasingly provide more regulatory oversight and guidance on IVR use in clinical care.

Future Considerations for Implementation of IVR

As the era of digital healthcare continues to unfold in transforming the landscape of the medical industry, virtual reality emerges as a paramount element in this forthcoming evolution of patient care. Although IVR has been successfully adopted for use in commercial settings for entertainment, such a gaming, it is expected that IVR has the potential to positively impact patient care. The exponential growth of IVR use for patient care can best be illustrated by the substantial increase in the number of published research articles and emerging medical IVR and augmented reality companies over the last five years.

Although still in its infancy, several aspects of virtual reality are expected to shape the future of patient care. First, it is projected that artificial intelligence (AI) will greatly influence the ways by which patients interact within virtual reality environments.[29–31] Artificial intelligence and machine learning can create interactive avatars. These “coaches” or virtual assistants can understand a patient’s natural conversation and respond accordingly with highly customized feedback and assistance.[30] In leveraging AI enhanced IVR, this type of technology will be able to deliver customizable virtual reality experiences specific to each patient and according to individual preferences across a variety of clinical settings and use cases.[32] Additionally, although very much in the early stages of research, preliminary research on the use of

AI, specifically Large Language Models (LLMs), combined with a virtual avatar in a virtual reality environment, has highlighted the potential of delivering interactive mental health coaching through naturalistic conversations.[30] The use cases in the clinical settings for this type of AI enhanced virtual reality are almost limitless, yet are promising.

A second area, closely tied to AI enhanced virtual reality, is the potential use of biosensing data to capture not only physiological measures (e.g., heart rate, respiratory rate, etc.), but also emotional response to customize real-time interaction in the virtual reality environment.[33] For example, one study demonstrated that electroencephalography data could be used to inform customizable biofeedback training to reduce anxiety.[34] In another study, a surface electromyography was used to measure facial muscle contractions as a proxy of emotional state, while engaged in a virtual environment, by attaching the sensors directly to the HMD unit.[35]

Ethical Considerations

A final area of discussion as related to IVR use in patient care is emerging ethical considerations. Although regulatory acts such as the Health Information Portability and Accountability Act (HIPAA) provide a strong foundation for patient privacy, privacy oversight of IVR platforms remains limited.[36–38] Many IVR platforms have the capability to record patient interactions and responses during IVR sessions, with the potential to store this information in third-party databases.[37] This lack of stringent regulation presents a potential patient privacy risk, underscoring the need for more comprehensive oversight in this area. Beyond the legal implications of patient privacy, remains the overarching issue of IVR data ownership. There remains ambiguity around this topic as many ethical considerations continue to arise. It is unclear if the company, the

healthcare organization, or the patient owns the IVR data. Second, also closely tied to the regulatory and legal components, is the topic of ownership for adverse reporting of IVR related events and negative outcomes, given that many IVR devices are not technically cleared as a medical device. Currently, FDA regulatory oversight and guidance on ownership of adverse events and reporting considerations are limited.[37]

Another ethical consideration is equitable access to IVR delivered treatments to ensure such technology does not widen health care disparities as the benefits of technology integration into clinical care rise.[31,39,40] Finally, as IVR technology advances to incorporate more sophisticated technologies, such as AI, it will be imperative to continuously assess any biases embedded within these algorithms. Such biases could potentially lead to discrimination against vulnerable social groups, including older adults and underrepresented minorities.[41,42]

Summary

The primary objective of this dissertation was to evaluate the acceptability and feasibility of an IVR intervention for pain management among older adults during the early inpatient recovery period following elective abdominal surgery. The findings from this dissertation enrich our understanding of how IVR can be utilized in the immediate postoperative inpatient context for older patients undergoing complex abdominal operations.

Moreover, this research contributes to the expanding research on IVR as a possible non-pharmacological option for acute pain management and underscores the potential of leveraging technology to enhance patient outcomes and surgical recovery in the older adult population. Finally, this study broadens the research on IVR applications to include a wider variety of surgical operations, presenting a promising safe and viable

option for acute pain management in a population that is typically considered vulnerable and at high risk for adverse effects from postoperative pain and pain medications.

References

1. Fact Sheet: Aging in the United States. PRB. Accessed October 1, 2022. https://www.prb.org/resources/fact-sheet-aging-in-the-united-states/
2. Indicator Definitions - Older Adults | CDI | DPH | CDC. Published March 4, 2024. Accessed April 8, 2024. https://www.cdc.gov/cdi/definitions/older-adults.html
3. Etzioni DA, Liu JH, Maggard MA, Ko CY. The aging population and its impact on the surgery workforce. *Ann Surg*. 2003;238(2):170-177. doi:10.1097/01.SLA.0000081085.98792.3d
4. Seifert A, Schlomann A. The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges. *Front Virtual Real*. 2021;2. Accessed December 26, 2023. https://www.frontiersin.org/articles/10.3389/frvir.2021.639718
5. Moore RC, Hancock JT, Bailenson JN. From 65 to 103, Older Adults Experience Virtual Reality Differently Depending on Their Age: Evidence from a Large-Scale Field Study in Nursing Homes and Assisted Living Facilities. *Cyberpsychology Behav Soc Netw*. 2023;26(12):886-895. doi:10.1089/cyber.2023.0188
6. Tuena C, Pedroli E, Trimarchi PD, et al. Usability Issues of Clinical and Research Applications of Virtual Reality in Older People: A Systematic Review. *Front Hum Neurosci*. 2020;14:93. doi:10.3389/fnhum.2020.00093
7. Ding L, Hua H, Zhu H, et al. Effects of virtual reality on relieving postoperative pain in surgical patients: A systematic review and meta-analysis. *Int J Surg*. 2020;82:87-94. doi:10.1016/j.ijsu.2020.08.033

8. Jin F, Chung F. Minimizing perioperative adverse events in the elderly. *Br J Anaesth*. 2001;87(4):608-624. doi:10.1093/bja/87.4.608
9. Cheung C, Meissner MA, Garg T. Incorporating Outcomes that Matter to Older Adults into Surgical Research. *J Am Geriatr Soc*. 2021;69(3):618-620. doi:10.1111/jgs.17028
10. Berian JR, Mohanty S, Ko CY, Rosenthal RA, Robinson TN. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg*. 2016;151(9):e161689. doi:10.1001/jamasurg.2016.1689
11. Fried TR, Bradley EH, Towle VR, Allore H. Understanding the treatment preferences of seriously ill patients. *N Engl J Med*. 2002;346(14):1061-1066. doi:10.1056/NEJMsa012528
12. Kouijzer MMTE, Kip H, Bouman YHA, Kelders SM. Implementation of virtual reality in healthcare: a scoping review on the implementation process of virtual reality in various healthcare settings. *Implement Sci Commun*. 2023;4:67. doi:10.1186/s43058-023-00442-2
13. Smith V, Warty RR, Sursas JA, et al. The Effectiveness of Virtual Reality in Managing Acute Pain and Anxiety for Medical Inpatients: Systematic Review. *J Med Internet Res*. 2020;22(11):e17980. doi:10.2196/17980
14. Berardi C, Antonini M, Jordan Z, Wechtler H, Paolucci F, Hinwood M. Barriers and facilitators to the implementation of digital technologies in mental health systems: a qualitative systematic review to inform a policy framework. *BMC Health Serv Res*. 2024;24(1):243. doi:10.1186/s12913-023-10536-1

15. Kamal M, Weerakkody V, Irani Z. Analyzing the role of stakeholders in the adoption of technology integration solutions in UK local government: An exploratory study. *Gov Inf Q*. 2011;28(2):200-210. doi:10.1016/j.giq.2010.08.003

16. Delshad SD, Almario CV, Fuller G, Luong D, Spiegel BMR. Economic analysis of implementing virtual reality therapy for pain among hospitalized patients. *Npj Digit Med*. 2018;1(1):1-8. doi:10.1038/s41746-018-0026-4

17. Roberts AR, De Schutter B, Franks K, Radina ME. Older Adults' Experiences with Audiovisual Virtual Reality: Perceived Usefulness and Other Factors Influencing Technology Acceptance. *Clin Gerontol*. 2019;42(1):27-33. doi:10.1080/07317115.2018.1442380

18. Aalami OO, Fang TD, Song HM, Nacamuli RP. Physiological features of aging persons. *Arch Surg Chic Ill 1960*. 2003;138(10):1068-1076. doi:10.1001/archsurg.138.10.1068

19. Shellito AD, Dworsky JQ, Kirkland PJ, et al. Perioperative Pain Management Issues Unique to Older Adults Undergoing Surgery: A Narrative Review. *Ann Surg Open*. 2021;2(3):e072. doi:10.1097/AS9.0000000000000072

20. Schenning KJ, Deiner SG. Postoperative Delirium in the Geriatric Patient. *Anesthesiol Clin*. 2015;33(3):505-516. doi:10.1016/j.anclin.2015.05.007

21. Apfelbaum JL, Chen C, Mehta SS, Gan TJ. Postoperative pain experience: results from a national survey suggest postoperative pain continues to be undermanaged. *Anesth Analg*. 2003;97(2):534-540, table of contents. doi:10.1213/01.ane.0000068822.10113.9e

22. Gan TJ. Poorly controlled postoperative pain: prevalence, consequences, and prevention. *J Pain Res*. 2017;10:2287-2298. doi:10.2147/JPR.S144066

23. Hah JM, Bateman BT, Ratliff J, Curtin C, Sun E. Chronic Opioid Use After Surgery: Implications for Perioperative Management in the Face of the Opioid Epidemic. *Anesth Analg*. 2017;125(5):1733-1740. doi:10.1213/ANE.0000000000002458

24. Geriatric Surgery Verification. ACS. Accessed September 16, 2022. https://www.facs.org/quality-programs/accreditation-and-verification/geriatric-surgery-verification/

25. Quick Safety 44: Non-pharmacologic and non-opioid solutions for pain management | The Joint Commission. Accessed October 1, 2022. https://www.jointcommission.org/resources/news-and-multimedia/newsletters/newsletters/quick-safety/quick-safety-44-nonpharmacologic-and-nonopioid-solutions-for-pain-management/#.YzjJV0zMKUk

26. Age-friendly Environments. Accessed February 24, 2024. https://www.who.int/teams/social-determinants-of-health/demographic-change-and-healthy-ageing/age-friendly-environments

27. CMS issues first HCPCS code and Medicare DME benefit category determination for therapeutic Virtual Reality Device | DLA Piper. Accessed February 24, 2024. https://www.dlapiper.com/en-us/insights/publications/2023/04/cms-issues-first-hcpcs-code-and-medicare-dme-benefit-category-determination

28. Health C for D and R. Augmented Reality and Virtual Reality in Medical Devices. *FDA*. Published online November 22, 2023. Accessed April 9, 2024.

https://www.fda.gov/medical-devices/digital-health-center-excellence/augmented-reality-and-virtual-reality-medical-devices

29. Greenleaf W. How Virtual and Augmented Reality Will Transform Healthcare.
30. Spiegel BMR, Liran O, Clark A, et al. Feasibility of combining spatial computing and AI for mental health support in anxiety and depression. *Npj Digit Med*. 2024;7(1):1-5. doi:10.1038/s41746-024-01011-0
31. Spiegel BMR, Rizzo A, Persky S, et al. What Is Medical Extended Reality? A Taxonomy Defining the Current Breadth and Depth of an Evolving Field. *J Med Ext Real*. 2024;1(1):4-12. doi:10.1089/jmxr.2023.0012
32. Antel R, Abbasgholizadeh-Rahimi S, Guadagno E, Harley JM, Poenaru D. The use of artificial intelligence and virtual reality in doctor-patient risk communication: A scoping review. *Patient Educ Couns*. 2022;105(10):3038-3050. doi:10.1016/j.pec.2022.06.006
33. Guillen-Sanz H, Checa D, Miguel-Alonso I, Bustillo A. A systematic review of wearable biosensor usage in immersive virtual reality experiences. *Virtual Real*. 2024;28(2):74. doi:10.1007/s10055-024-00970-9
34. Arsalan A, Majid M. A study on multi-class anxiety detection using wearable EEG headband. *J Ambient Intell Humaniz Comput*. 2022;13(12):5739-5749. doi:10.1007/s12652-021-03249-y
35. Gjoreski M, Kiprijanovska I, Stankoski S, et al. Facial EMG sensing for monitoring affect using a wearable device. *Sci Rep*. 2022;12(1):16876. doi:10.1038/s41598-022-21456-1

36. Lin J, Latoschik ME. Digital body, identity and privacy in social virtual reality: A systematic review. *Front Virtual Real*. 2022;3. doi:10.3389/frvir.2022.974652

37. Salisbury JP. Using Medical Device Standards for Design and Risk Management of Immersive Virtual Reality for At-Home Therapy and Remote Patient Monitoring. *JMIR Biomed Eng*. 2021;6(2):e26942. doi:10.2196/26942

38. Rights (OCR) O for C. Health Information Privacy. Published June 9, 2021. Accessed April 9, 2024. https://www.hhs.gov/hipaa/index.html

39. Obermeyer Z, Powers B, Vogeli C, Mullainathan S. Dissecting racial bias in an algorithm used to manage the health of populations. *Science*. 2019;366(6464):447-453. doi:10.1126/science.aax2342

40. Thomasian NM, Eickhoff C, Adashi EY. Advancing health equity with artificial intelligence. *J Public Health Policy*. 2021;42(4):602-611. doi:10.1057/s41271-021-00319-5

41. Rudschies C, Schneider I. Ethical, legal, and social implications (ELSI) of virtual agents and virtual reality in healthcare. *Soc Sci Med*. 2024;340:116483. doi:10.1016/j.socscimed.2023.116483

42. Ruane E, Birhane A, Ventresque A. Conversational AI: Social and Ethical Considerations. In: AICS. 2019:104-115. Accessed April 18, 2024. https://ceur-ws.org/Vol-2563/aics_12.pdf

APPENDIX

Appendix 2.1 Participant Interview Guide

TOPIC	QUESTIONS
Rapport/updates	• How did your surgery go?
Resources that helped or is needed for recovery	Now I'd like to talk about how you are recovering and what has helped or has not helped with your recovery. • [PHYSICAL] How are you physically recovering? • [EMOTIONAL] How has your mood been after surgery? - How has that affected your recovery? • [SOCIAL] How has the surgery affected your social life? - Have you had people in your life help you with recovery? - How have they helped you recover? • [SERVICES] - Are there people or services or support that you feel you needed for recovery that you did not get?
Expectations	• What part of your recovery after surgery was surprising or unexpected for you?
Concerns/worries	• What are you worried about after surgery?
Wrapping up	• Is there anything else you would like to add? • Do you have any questions for me?
Ending on a good note	• What are you hopeful for in the upcoming months?

Appendix 4.1 List of Immersive Virtual Reality Experiences

Beach Retreats™

Enhance™

Forests & Fields™

Guided Mindfulness™

Into The Cold™

Intro to i-Series™

Lost in the Desert™

Serene Lake™

Skies & Auroras™

Underwater Adventures™

Wildlife Encounters™

World Traveler™

Appendix 4.2 User Experience Survey

On a scale of 1 to 5, with Strongly Disagree=1, Disagree=2, Neutral=3, Agree=4, and Strongly Agree=5, please mark your response regarding your virtual reality experience.

1. **I liked the virtual reality experience** 1 2 3 4 5
2. **The headset was comfortable** 1 2 3 4 5
3. **The audio sound was pleasant** 1 2 3 4 5
4. **The image quality was pleasant** 1 2 3 4 5
5. **The virtual reality simulation improved my discomfort** 1 2 3 4 5
6. **I would use virtual reality again for pain** 1 2 3 4 5
7. **I would use virtual reality again for anxiety** 1 2 3 4 5
8. **I would recommend virtual reality to others** 1 2 3 4 5

Appendix 5.1 List of Immersive Virtual Reality Experiences

Beach Retreats™

Enhance™

Forests & Fields™

Guided Mindfulness™

Into The Cold™

Intro to i-Series™

Lost in the Desert™

Serene Lake™

Skies & Auroras™

Underwater Adventures™

Wildlife Encounters™

World Traveler™

Appendix 5.2 Interview Semi-Structured Question Guide

1. Tell us about your overall experience with using virtual reality during your hospital stay.
2. What did you like or find helpful about using virtual reality?
3. Did you have any problems or issues with using virtual reality programs or headset? If so, please feel free to share your concerns with us.
4. Tell us about your preferences for the type of VR experiences or environments that you liked or would like to see in the future.
5. Tell what you think about the age and/or cultural appropriateness of the VR content and programs? Is there anything you would like to see more of less of in terms of the types of environments as related to age or culture?
6. Would you consider using virtual reality again for your healthcare? If so, how do you think it would be useful?
7. Would you recommend VR for other older patients? Tell us more about how you think others may use virtual reality during surgery.
8. What are your suggestions for the healthcare team regarding using virtual reality for pain and/or anxiety or any other use?
9. If offered, what are your thoughts on using virtual reality at home after surgery?
10. What type of support do you think would be needed at home to use virtual reality?
11. Is there anything that we could have done differently to enhance or improve your virtual reality experience?

Publishing Agreement

It is the policy of the University to encourage open access and broad distribution of all theses, dissertations, and manuscripts. The Graduate Division will facilitate the distribution of UCSF theses, dissertations, and manuscripts to the UCSF Library for open access and distribution. UCSF will make such theses, dissertations, and manuscripts accessible to the public and will take reasonable steps to preserve these works in perpetuity.

I hereby grant the non-exclusive, perpetual right to The Regents of the University of California to reproduce, publicly display, distribute, preserve, and publish copies of my thesis, dissertation, or manuscript in any form or media, now existing or later derived, including access online for teaching, research, and public service purposes.

DocuSigned by:
Christina Kenny
A0304D1CE1544D9...
Author Signature

5/28/2024
Date