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Case report

Immersive Virtual Reality Used as Adjunct Anesthesia for Conversion Total Hip Arthroplasty in a 100-Year-Old Patient

Cameron K. Ledford, MD [a, *], Michael J. VanWagner, DO [a], Courtney E. Sherman, MD [a], Klaus D. Torp, MD [b]

[a] Department of Orthopedic Surgery, Mayo Clinic, Jacksonville, FL
[b] Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Jacksonville, FL

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ABSTRACT

Immersive virtual reality (IVR) is an adjunctive form of anesthesia intended to distract patients from their intraoperative environment and reduce other side effects of sedating or narcotic agents. While this technology has been applied sparingly in various orthopedic procedural environments, its clinical utility has not been widely evaluated in major, nonelective surgical settings. The use of IVR in the geriatric hip fracture population represents a novel indication with potential benefit to reduced cognitive dysfunction and delirium. We report a case of a 100-year-old patient who received IVR adjunctive to neuraxial anesthesia during conversion total hip arthroplasty via posterolateral approach for treatment of failed peritrochanteric hip fracture fixation.

Introduction

Immersive virtual reality (IVR) is a nonpharmacological form of distraction therapy that may attenuate pain perception, anxiety, and general discomfort during potentially painful medical interventions such as wound care, physical therapy, or pediatric procedures [1-5]. IVR was first introduced into perioperative practice to reduce anxiety and pain related to general anesthesia and associated preoperative interventions [6-8]. More recently, distractive IVR use has been expanded to the operative environments whereby surgical procedures can be performed under regional anesthesia with potential benefits of reducing sedation and patient anxiety [9-12].

The typical IVR experience involves patients wearing a small, comfortable specialized headset and headphones that can project an interactive virtual environment with auditory guidance while surgery is performed under regional or spinal anesthesia. IVR has not been thoroughly investigated in orthopedic surgical applications, and early reports have only provided limited insight into indications, applications, and efficacy, particularly related to its effect on postoperative cognitive function [10-12].

A novel utilization of IVR technology may be within the geriatric hip fracture population, where risk of mortality and morbidity, especially cognitive dysfunction, and delirium is significant postoperatively [13-17]. The pathophysiology of delirium remains multifactorial (electrolyte imbalances, hypotension, hypoxia, metabolic encephalopathy, sleep deprivation, pain, hearing, and/or visual disorders); however, anesthesia type has been implicated as a controversial contributor to its development [18-20]. The use of general anesthetic and sedative medications during the procedure is known to affect cognitive function in the acute postoperative period and sometimes even more long term [21-23]. Nonelective, major lower extremity orthopedic surgery at our institution currently is performed with either general or neuraxial anesthesia, including propofol infusion with intravenous narcotics for sedation and comfort. In addition to optimizing known medical and environmental delirium risks, the use of IVR in the geriatric population could provide further opportunity to minimize the use of sedating anesthetic agents and potentially contribute to a more lucid and favorable postoperative course. Herein, after patient consent was obtained for publication, we report a case of a 100-year-old patient undergoing conversion total hip arthroplasty (THA) after failed

* Corresponding author. 4500 San Pablo Road, Jacksonville, FL 32224, USA. Tel.: (904) 953-2000.
E-mail address: ledford.cameron@mayo.edu

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peritrochanteric hip fracture fixation with the use of neuraxial anesthesia and IVR adjunct.

Case history

A 100-year-old female presented to our institution with a complex peritrochanteric hip fracture after sustaining a ground level fall at home (Fig. 1). At baseline, she functioned independently living in her own home and ambulating approximately one-half mile per day without an assistive device. Her comorbidities included hypertension, chronic right heart failure, and paroxysmal atrial fibrillation not treated with adjunct anticoagulant usage. Upon preoperative medical evaluation, mild thrombocytopenia (platelet count of 95,000 per microliter) was noted, thus the anesthesia team made the decision to forego spinal anesthetic and used general anesthesia after a single-shot femoral nerve block. She underwent closed reduction and cephalomedullary nail fixation of her fracture approximately 36 hours from the time of the fall (Fig. 2a).

The patient developed acute delirium beginning on postoperative day 1, which gradually improved during her hospital course with the use of limiting sedatives and narcotic medications, sleep enhancement, and continuous reorientation with family. She continued to progress acceptably in her rehabilitation maintaining mobility and weight-bearing as tolerated with the use of a walker. She ultimately demonstrated cognitive, physical, and medical stability for discharge to a skilled nursing facility on postoperative day 3. Unfortunately, she sustained yet another reported fall at the skilled nursing facility 1 week after discharge from the hospital; however, radiographs did not demonstrate any obvious signs of fixation failure at that time (Fig. 2b). At her 6-week postoperative visit, she reported an approximate 8-day history of increasing pain, difficulty with weight-bearing, limited progress with the expected rehabilitation, and radiographs noted failure of the cephalomedullary fixation including screw cutout with penetration and erosion into the acetabulum (Fig. 2c and d). The patient was subsequently readmitted to the hospital and scheduled for conversion to THA with removal of the failed cephalomedullary implant. Upon readmission, the patient was found to have acute, severe hypervolemic hyponatremia (120 mmol/L), which delayed her surgery for 3 days to allow for slow, complete correction of her sodium level through diuresis and electrolyte repletion. The previous mild thrombocytopenia had improved, and no signs of delirium or cognitive dysfunction appeared present, although she was notably fatigued from the problematic postoperative course.

The patient was offered spinal anesthetic and IVR as an adjunct instead of general anesthesia because of her age and desire to reduce the risk of recurrent postoperative delirium. On the day before the operation, the anesthesiologist provided the IVR headset for demonstration and to assess the mental capacity to tolerate the device. The hardware consisted of a PICO G2 4K Enterprise, (PICO, San Francisco, CA) goggles and Bose Quiet Comfort QC 35 noise-canceling headsets (Bose, Framingham, MA). The content used was created by HypnoVR (Strasbourg, France; https://hypnovr.io/en/solutions/softwares/) consisting of a choice of 4 visual environments (field, beach, sea, and space) along with voice-guided relaxation techniques and sounds (https://vimeo.com/373210297). The patient was enthusiastic about the IVR trial experience, and she expressed understanding of the proposed anesthesia, positioning, and surgical procedure to be performed. Informed consent was obtained for the conversion THA surgery to be performed with IVR adjunct to neuraxial anesthesia.

At the time of surgery, the patient underwent a single-shot lumbar plexus block followed by a spinal anesthetic both without sedation. She was then placed in the right lateral position and covered with conductive active heating blankets. The IVR goggles were applied with noise-canceling headsets on the upper ear only, as they were too bulky to fit on the lower ear in the lateral decubitus position (Fig. 3).

A standard posterolateral approach was performed, the cephalomedullary nail was removed, and attention was turned to the acetabular reconstruction. To this point in the procedure, the patient had not demonstrated any signs of discomfort until the noise and movement from impaction of the acetabular component startled her out of her IVR experience, for which she received three 10-mg boluses of propofol followed by a brief infusion (5 mg) until that portion of the procedure was complete. She did not require any narcotics or further sedation throughout the remaining portion of the surgery. After acetabular reconstruction with a highly porous acetabular shell (Zimmer Biomet G7 OsseoTi, Warsaw, IN) and multiple screws, the femur was prepared for a nonmodular tapered fluted stem (Zimmer Biomet Wagner SL Revision) after diaphyseal bone was supportive of reaming and a prophylactic cabling performed in the subtrochanteric region to prevent iatrogenic fracture at the previous lag screw site. After successful trialing and intraoperative radiographs, the final components were placed, which included a constrained (Zimmer Biomet Freedom Constrained) acetabular liner. It is important to note that the decision to use a constrained liner was made not due to intraoperative stability

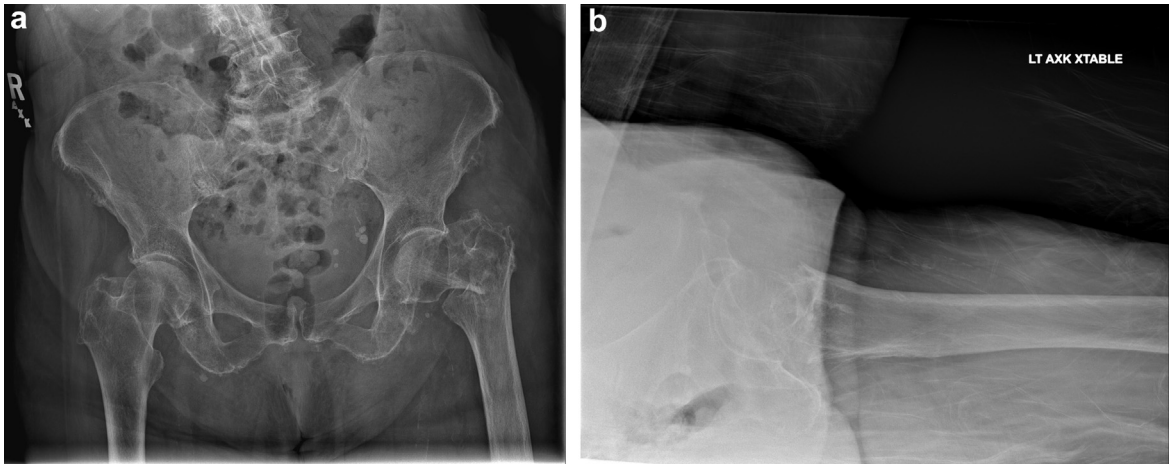

Figure 1. Index anteroposterior pelvis (a) and left lateral hip (b) radiographs presenting the comminuted peritrochanteric hip fracture in a 100-year-old patient.

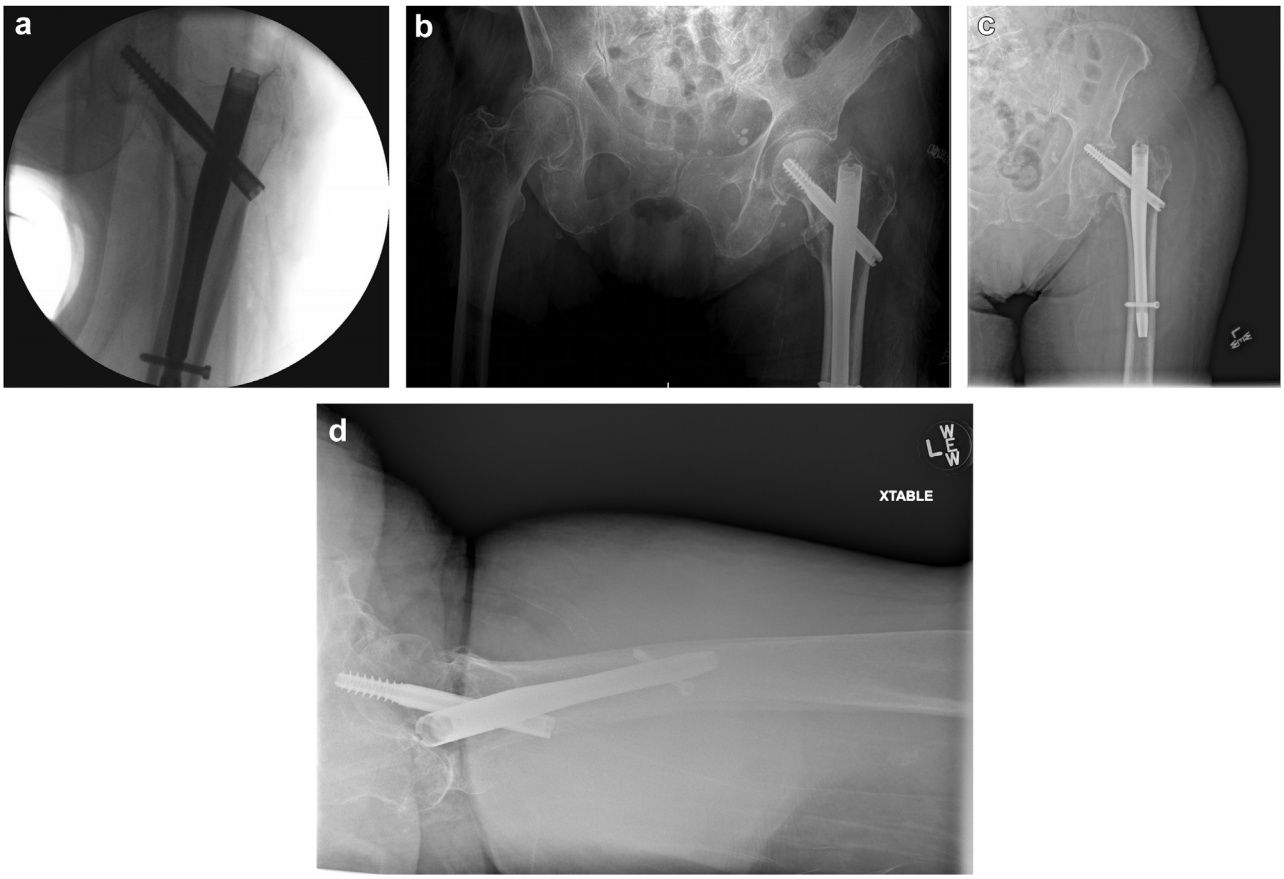

Figure 2. Closed reduction and internal fixation were performed with cephalomedullary nail fixation as shown on fluoroscopic imaging (a). Anteroposterior pelvis radiograph after fall at extended care facility confirming maintenance of initial fixation (b). Six-week radiographs demonstrating varus collapse of the fracture and screw cutout into the acetabulum on left hip anteroposterior (c) and lateral (d) images.

concerns, rather to prophylactically avoid the most common complication of dislocation given the baseline fall risk and potential recurrent cognitive dysfunction. The surgery was completed uneventfully, and the patient did not complain of any pain during the procedure or in the immediate postoperative period, nor did she have any recollection of the procedure or the noise generated from the impaction of the acetabular component. During bed transfer and in the postanesthesia care unit, she remained fully awake, alert, and comfortable.

She continued to recover well from surgery and was ambulatory with physical therapy on postoperative day 1 with no mental status change concerns. On postoperative day 3, she developed a less than 24-hour episode of delirium secondary to recurrent hyponatremia (126 mmol/L), which resolved readily with temporary fluid restriction and diuresis. She was discharged on postoperative day 5 to a skilled nursing facility and continued rehabilitation progress. At her 6-week postoperative clinic visit, radiographs demonstrated stable THA component fixation and acceptable position (Fig. 4). She was ambulatory with a rolling walker and had returned home living independently with local family support. She reported that her experience with IVR was extremely positive and favorable compared with prior surgical experiences. Clinical follow-up remains ongoing per routinely scheduled postoperative outpatient visits.

Discussion

As our population continues to age, the incidence of geriatric hip fractures is projected to increase to 6.3 million yearly by 2050 [24]. These patients remain at significant risk of postoperative complications and mortality. Delirium is one of the most frequent complication with rates between 4% and 53% and is associated with longer hospital stays, increased medical complications, and poorer functional outcomes [17,25]. In addition, patients who develop postoperative delirium are at increased risk for cognitive decline beyond the acute phase [25]. While the exact pathophysiology of postoperative delirium in geriatric patients is poorly understood, reducing (or even avoiding) intraoperative sedating agents can significantly decrease the risk of delirium occurrence. In a double-blind, randomized controlled trial of patients undergoing nonelective hip fracture surgery, Sieber et al. reported that lighter propofol sedation decreased the prevalence of postoperative delirium by 50% than deep sedation [26].

IVR represents an adjunct that can potentially further aid in the reduction of anesthetic agents and the associated side effect of cognitive dysfunction, although complete elimination of sedative medications may not be fully obtainable. According to a randomized controlled trial with primary elective total joint arthroplasty, Huang et al. showed similar sedation (propofol) requirements between IVR and controls during the procedure [11]. The 100-year-old patient reported in this case also required minimal propofol sedation during acetabular component impaction secondary to the noise and movement of impaction overwhelming her IVR experience. The amount of propofol sedation required for this case was much less than typically administered (35 mg vs 500-700 mg during routine THA cases without IVR adjunct), and no additional sedation or narcotics were required during the remainder of the surgery. While our patient did experience a short episode of

Figure 3. The immersive virtual reality (IVR) experience created through PICO G2 4K Enterprise goggles and Bose Quiet Comfort QC 35 noise headphones (a). The patient prepped in right lateral decubitus position (b) with IVR goggles and headset placed comfortably (c) as an adjunct to neuraxial anesthesia.

delirium possibly related to hyponatremia, propofol sedation, and/or surgical pain itself, her overall cognitive function was reported to be significantly improved after the IVR adjunct than previous procedural anesthetic events.

Perhaps most encouraging, our elderly patient reported excitement to use the IVR technology and a fulfilled expectation of less anxiety and satisfaction after surgery. In another prospective, randomized study of patients undergoing routine wide-awake hand operations under local anesthesia, IVR patients exhibited lower anxiety and more fun during surgery as measured with a Likert scale at several time points [12]. In addition, these patients also reported greater relaxation throughout the procedure than those not using IVR. Such results are difficult to extrapolate to the geriatric orthopedic trauma population; however, improving anxiety through a calm, virtual environment could undoubtedly be only beneficial to these cognitively at-risk patients.

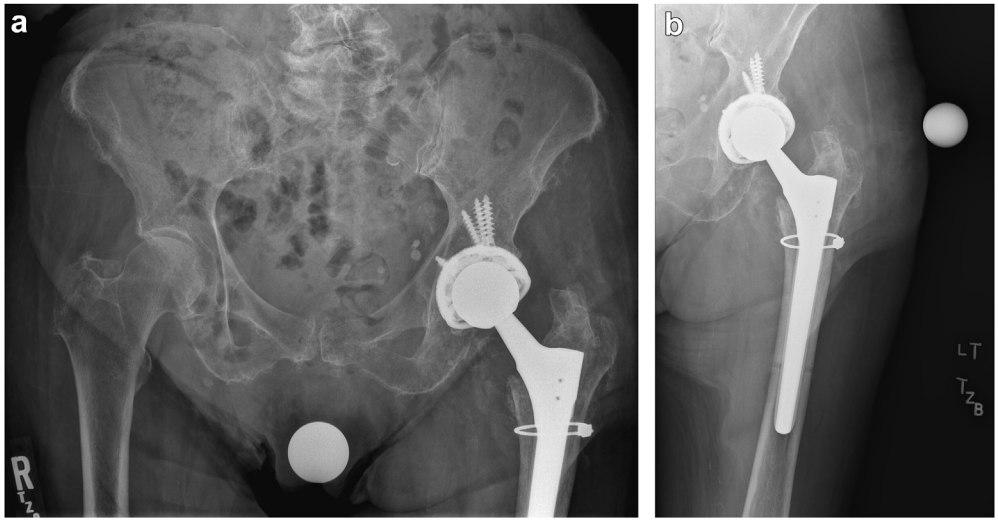

Figure 4. Postoperative anteroposterior pelvis (a) and left femur (b) radiographs displaying final total hip arthroplasty components.

The presented case experience provided a variety of lessons and modifications to our IVR adjunct anesthesia process. First and foremost, patient selection remains critical as one must not only be willing but also have the capacity to tolerate acute awareness of the operating room, positioning, and procedure despite the distraction of IVR. Preoperative demonstration of the IVR headset and headphones is recommended, and patients must be informed of expected sounds, vibrations, or smells of the surgical procedure. Although a trial with the IVR experience was performed with the 100-year-old patient before surgery in this case, we believe the IVR disruption (and subsequent required sedation) during component impaction could have been avoided with improved preoperative expectation setting and intraoperative notice of the upcoming sensory disturbance. Patients should be informed that their IVR environment is easily controllable with anesthesia providers having the ability to change their visual universe, language, voice, or music experience at any time. Several auditory options have also been trialed including lower profile earbuds (for supine positioning) or placing the combination of earplugs and bone-conducting headsets (for lateral decubitus positioning), thereby sounds bypass the eardrum to the inner ear. Alternatives such as noise-canceling headphones alone may provide another form of distraction; however, the immersive experience is truly created by the headset, audio cues, and IVR software. We believe using the IVR technology to the fullest is key to keeping the patient calm and "away" from the surgical environment. Perhaps most importantly, intraoperative communication between the patient, anesthesia providers, and surgical team must remain constant throughout the surgical process, including abandoning the IVR experience with the use of sedation or emergent intubation if needed. These tactics have been implemented in interval primary THA and total knee arthroplasty cases with anecdotal success and often complete elimination of sedative or narcotic medication during the surgery.

Summary

The use of IVR adjunctive anesthesia is a novel technology with the potential to reduce the use of sedating agents during anesthesia and subsequent side effects. Geriatric patients with hip fracture may be an ideal group for IVR utilization to improve the high rate of postoperative cognitive dysfunction and delirium. While this case describes the successful use of IVR in a 100-year-old patient who underwent conversion total hip arthroplasty, randomized controlled trials are needed to better examine the benefits of IVR adjunct anesthesia during major orthopedic operations.

Conflicts of interest

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

Informed patient consent

The author(s) confirm that informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

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