Mindfulness-based Virtual Reality Intervention in Hemodialysis Patients: A Pilot Study on End-user Perceptions and Safety

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Abstract

Background Virtual reality (VR) is an evolving technology that is becoming a common treatment for pain management and psychologic phobias. Although nonimmersive devices (e.g., the Nintendo Wii) have been previously tested with patients on hemodialysis, no studies to date have used fully immersive VR as a tool for intervention delivery. This pilot trial tests the initial safety, acceptability, and utility of VR during maintenance hemodialysis treatment sessions—particularly, whether VR triggers motion sickness that mimics or negatively effects treatment-related symptoms (e.g., nausea).

Methods Patients on hemodialysis (n=20) were enrolled in a phase 1 single-arm proof-of-concept trial. While undergoing hemodialysis, participants were exposed to our new Joviality VR program. This 25-minute program delivers mindfulness training and guided meditation using the Oculus Rift head-mounted display. Participants experienced the program on two separate occasions. Before and immediately after exposure, participants recorded motion-related symptoms and related discomfort on the Simulator Sickness Questionnaire. Utility measures included the end-user’s ability to be fully immersed in the virtual space, interact with virtual objects, find hardware user friendly, and easily navigate the Joviality program with the System Usability Scale.

Results Mean age was 55.3 (±13.1) years; 80% male; 60% Black; and mean dialysis vintage was 3.56 (±3.75) years. At the first session, there were significant decreases in treatment and/or motion-related symptoms after VR exposure (22.6 versus 11.2; P=0.03); scores >20 indicate problematic immersion. Hemodialysis end-users reported high levels of immersion in the VR environment and rated the software easy to operate, with average System Usability Scale scores of 82.8 out of 100.

Conclusions Patients on hemodialysis routinely suffer from fatigue, nausea, lightheadedness, and headaches that often manifest during their dialysis sessions. Our Joviality VR program decreased symptom severity without adverse effects. VR programs may be a safe platform to improve the experience of patients on dialysis.

Key Points

- This pilot trial tests the initial safety, acceptability, and utility of virtual reality during hemodialysis treatment sessions.
- Our Joviality program, a fully immersive virtual reality environment, decreased dialysis-related symptom severity without adverse effects.
- Fully immersive virtual reality programs may be a safe platform to improve the experience of patients on dialysis.

Introduction

Virtual reality (VR) is an evolving technology that immerses end users in a digitally fabricated, yet realistic and lifelike environment. End users wear a head-mounted display (HMD) that uses tracking systems and physical motion, such as eye or head movements, to navigate a digitally created virtual world, which can replicate realistic settings (e.g., 360° video of a garden or beach) or complex science-fiction environments (1). VR is most frequently used in video gaming and for simulation training with clinicians and military
VR has also been successfully used in treatment plans for pain management (e.g., burn victims), physical rehabilitation, and psychologic phobias (e.g., acrophobia or fear of heights), with evident improvements in emotional wellbeing and lessening of physical complaints (5–9).

The benefits of chairside exposure to VR remain largely unexplored in patients on hemodialysis (HD). Previous studies on VR-related experiences have focused on non-immersive gaming devices (e.g., Nintendo Wii) (10–12). Therapeutic uses of VR might provide similar benefits to video gaming, including distraction, entertainment, and engagement, which allow patients to feel they can escape the mundane clinical setting, where they spend over ≥9 h/wk (13,14). VR might provide additional benefits through embedding of evidence-based programming (e.g., mindfulness-based stress reduction) (15). Such programming could improve a patient's emotional wellbeing, quality of life, and disease progression.

There might also be negative side effects of using VR that must be explored before widespread use. Most notably, VR can induce cybersickness symptoms of fatigue, nausea, dizziness, and general discomfort. Testing for cybersickness is particularly relevant for this patient population, because cybersickness symptoms are often similar to common symptoms experienced by patients on HD that are related to intradialytic hypotension, osmotic shifts during dialysis, or other causes. Therefore, nausea and other routine discomfort associated with HD therapy might be exacerbated by VR. Another concern is the extended periods of noise experienced during dialysis. Noise creates a unique environmental exposure that might lead to sensory overload and adverse effects when combined with VR (16).

This pilot study tests the initial safety, acceptability, and utility of VR during regularly scheduled HD treatment. We employ a 25-minute mindfulness/meditation exercise in a fully immersive VR program delivered through an HMD (see Figure 1). Our central hypothesis is that the VR program will be immersive, cause no adverse effects, and create a positive experience. We specifically expect patients will report high levels of spatial presence, low levels of nausea and discomfort, and describe their experience as enjoyable, understandable and clear, and beneficial. Our primary goal is to determine whether VR exacerbates symptoms routinely experienced during maintenance HD—mainly, headaches, nausea, lightheadedness, or fatigue.

Materials and Methods

Study Population

Data for this phase 1 single-arm proof-of-concept trial were collected from 20 participants between October and November 2019 (Figure 2). Participants were recruited from an HD clinic in Urbana-Champaign, IL, using the following inclusion criteria: (1) recipient of HD treatment for ≥3 months, (2) ≥18 years of age, (3) sufficient visual and audio acuity to navigate the VR world unaided, and (4) English fluency. Exclusion criteria included: (1) unavailability for the entire study period, (2) cognitive impairments suggesting dementia, (3) physical/sensory limitations restricting use of an HMD, and (4) history of epilepsy, seizures, or vertigo. The Institutional Review Board of the University of Illinois at Urbana-Champaign approved the trial (Institutional Review Board number 19190). Written informed consent was obtained for all enrolled participants. The research activities being reported are consistent with Principles of the Declaration of Helsinki.

Recruitment consisted of research staff approaching potentially eligible participants chairside, during regularly scheduled HD treatment sessions. Patients were provided study details and answers to their questions. Patients interested in enrolling underwent screening to determine full eligibility. With the exception of cognitive impairment, which was assessed with the Short Portable Mental Status Questionnaire (17), all eligibility requirements were on the basis of self-reported data. Eligible patients then provided written informed consent and completed several questionnaires (see Measures and Assessment Procedures) immediately before participation.

VR Intervention

We used the Oculus Rift CV1 (1080×1200 resolution per eye, a 90 Hz refresh rate, and a 110° field of view) (Facebook Technologies, LLC) to expose HD participants to Joviality, our newly designed VR mindfulness/meditation program. VR immersion occurred 30 minutes after HD treatment initiation or during the final hour of dialysis. This program was adapted from the Developing Affective Health to Improve Adherence (DAHLIA) positive psychologic curriculum developed by Cohn et al. (2014) (18). Joviality focuses on the DAHLIA module that is readily translatable to a solitary VR experience: techniques of mindful awareness and meditation.

A transdisciplinary team of digital artists, computer programmers, and engineers developed the Joviality program. The textual content of DAHLIA related to mindful
awareness and meditation was adapted for VR, with the agile design principles of brainstorming, storyboarding, testing, and refining (19,20). The finished program places end-users in an armchair within a virtual living room, where they follow visual and auditory stimuli and instructions on a flatscreen television (Figure 3A). The television displays a prerecorded video, where the principal investigator of the trial explains the concept of mindfulness using the DAHLIA curriculum. This explanation focuses on learning and practicing nonjudgmental and intentional awareness of one’s thoughts, feelings, and physical sensations in the present moment. Participants then learn techniques to practice mindfulness in their everyday life outside of the dialysis center. After the delivery of this mindfulness/mediation lesson, participants are teleported to a virtual garden for a 12-minute guided meditation (Figure 3B).

The entire 25-minute intervention was repeated on two separate occasions during consecutive HD treatment sessions (e.g., Monday and Wednesday, or Tuesday and Thursday). Research staff assisted participants in fitting the HMD to ensure a comfortable experience. Given the limited hand mobility of HD end-users, we opted not to use hand controllers; instead, participants navigated the VR environment with head movement (e.g., nod). HMDs were removed from participants by research staff when severe motion sickness was evident or a dialysis-related event interfered with the dialysis session. Staff notified the attending clinician of symptomatology for immediate follow-up.

Measures

Measures consisted of end-users’ subjective ratings on paper-and-pencil questionnaires administered before and after the intervention (Table 1). Research staff were available to assist participants in completing these assessments.

The main outcome of the trial was the safety of the VR program. This was evaluated with the Simulator Sickness Questionnaire (SSQ). The SSQ is a 16-item questionnaire that measures an end-user’s current feelings of cybersickness and other adverse motion-related symptomatology (21). Items are measured on a four-point Likert scale ranging from 0 (none) to 3 (severe), with higher scores indicating greater cybersickness. In addition to generating a total score, subscales captured domains of symptoms related to oculomotor functioning, nausea, and disorientation. Because items of the SSQ overlap with HD-related symptoms, participants completed the questionnaire both before and after both VR exposures to test for worsening (or improvements) of symptoms.

The subjective ratings of presence and immersion in the VR program was measured with the IGroup Presence Questionnaire (IPQ) (22–24). This 14-item questionnaire includes three subscales: (1) Spatial Presence, which captures the extent to which end-users feel physically present in the space; (2) Involvement, which evaluates the level to which end-users are captivated and estimates their ability to focus on the content presented; and (3) Experienced Realism, which gauges whether the virtual environment mimics real-life objects and interactions. The questionnaire also

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**Figure 2.** Consolidated Standards of Reporting Trials flowchart diagram.
includes a single item outside of the subscales that asks, “In the computer-generated world, I had a sense of ‘being there’.” This item measures the overall level of presence. All items are rated on a seven-point Likert scale, with higher scores indicating greater immersion and felt presence. The mean IPQ score is calculated by averaging across the 14 items, which generates a score ranging from 1 (low level of presence) to 7 (high level of presence). An average score is also calculated for each of the subscales. Presence via the IPQ was measured after both VR experiences.

The subjective ratings of the VR device and software was captured with the System Usability Scale (SUS) (25,26). This ten-item questionnaire includes such items as “I would imagine that most people would learn to use this VR program very quickly.” Items are rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). A total score is computed by adding all items and generating a score ranging from 0 to 100. Higher scores are indicative of greater usability, and scores ≥80 indicate that end-users enjoyed interacting with the system so much they are likely to recommend its use to others (27). Usability via the SUS was measured after the second VR exposure only.

Participants were also asked what they liked and disliked most about the Joviality program, and how they thought the program and VR experience could be improved through qualitative feedback. Medical staff also rated the extent to which VR immersion promoted isolationism, noise pollution affected the clinic space, and VR interfered with normal clinical practices in Clinical Staff Assessments (Supplemental Appendix A). Survey data from clinical staff were anonymous and limited to those on the dialysis floor, including nurses or technicians. All of these measures were collected after the second VR exposure only.

Several other measures were collected through surveys with patients. Sociodemographic characteristics included age (in years), sex, race/ethnicity, marital status, number of years of formal education, annual household income, employment status, health insurance coverage (absent versus present), and place of nativity (US born versus foreign born). Health status included previous history and/or current prevalence of hypertension, high cholesterol, and diabetes mellitus. Last, data on VR past use were collected to control for different effects among first-time VR users and repeat users. To gather these data, we asked participants...
| Surveys and Data Collection Assessments | Exposure 1 | Exposure 2 | Postintervention | Postintervention |
|----------------------------------------|-----------|-----------|-----------------|-----------------|
|                                       | Pre Virtual Reality | VR Session One | Post Virtual Reality | Pre Virtual Reality | VR Session Two | Post Virtual Reality |               |
| VR/HD symptoms (SSQ)                   | X         | X         | X               | X               |                |                  |
| Immersion in VR environment (IPQ)      | X         |           |                 |                 | X               | X                 |
| Usability of VR equipment (SUS)        |           | X         |                 |                 |                 | X                 |
| Feedback from end-users on VR exposure|           |           |                 |                 | X               | X                 |
| Clinical staff assessments of VR treatment |         |           |                 |                 |                 | x                 |

VR, virtual reality; HD, hemodialysis; SSQ, Simulator Sickness Questionnaire; IPQ, IGroup Presence Questionnaire; SUS, System Usability Scale.

Postintervention measures were completed after both exposure sessions.
whether they were familiar with VR technology and whether they previously used an HMD. Items used a dichotomous response (yes, no) (28).

 Analyses
 Analyses were conducted using SPSS Version 23 (IBM SPSS Statistics 23 for Windows, 2015). Descriptive statistics summarized baseline characteristics of patients. Paired sample t-tests determined the magnitude of pre and post changes in the questionnaire measures collected before and after VR exposure (see Table 1 for sequencing of study measures). To test for effect modifiers, independent sample t-tests were used with SSQ, IPQ, and the SUS scores within treatments. Of the remaining participants, 100% completed both VR exposures.

Recruitment and Feasibility
 Figure 2 provides a Consolidated Standards of Reporting Trials diagram summarizing rates of recruitment, enrollment, and dropout. A total of 29 patients on HD were assessed for eligibility and eight were excluded for the following reasons: (1) self-reported history of epilepsy, seizures, or vertigo (n=3); (2) HD treatment initiated <3 months ago (n=1); and (3) lack of interest in study participation (n=4). Final participant enrollment included 21 patients. However, one participant did not experience the VR program due to the lack of adherence with their scheduled HD treatments. Of the remaining participants, 100% completed both VR exposures.

 VR Program Safety
 Table 3 summarizes cybersickness scores before and after the two exposures to the VR program. Significant decreases were observed during exposure one for fatigue, nausea, oculomotor symptoms, disorientation, and total symptomology before versus after VR, P<0.05. No statistically significant differences in scores were observed during exposure two.

 VR Program Presence and Utility
 Table 4 shows the degree to which participants were immersed in the two VR program exposures. Overall presence scores were moderate for both exposures with means around 4.0 (ranging from 1=low to 7=high). Levels varied between more specific measures. Scores were highest for the single measure of presence (“sense of being there”) and lowest for involvement and experience. No scores showed statistically significant differences between exposures one and two, P>0.05. The VR device and software had moderately high levels of usability (see Table 3). The average usability score was 82.74±21.85, and the range was 15–100.

 Qualitative Feedback and Clinical Assessments
 HD end-users judged the program as fun and easy to use. Specific themes in their responses involved the relaxing/calming environment, effective tool for active distraction, pleasant scenery, and valuable mindfulness education. In terms of recommended improvements, end-users wanted multiple destinations of travel during curricular content and meditation practice, and graphics that more realistically mimic the real world, such as 360° videos of actual locations in the United States and abroad. Staff members reported that the VR program did not interfere with their typical duties (n=8, 100%), did not lead to social isolationism for HD end users (n=8, 100%), and was well received by both patients and clinical staff (n=8, 100%) (Supplemental Appendix A and B).

 Effect Modifiers
 Table 5 presents the results of stratified analyses by participant subgroups. Mean changes in cybersickness scores did not show significant differences by sex, age, race/ethnicity, or previous VR experience. However, we did observe trends suggesting greater symptom declines in females, Black patients, younger adults (<55), and those with previous VR experience; these differences were most prominent at exposure one. No statistically significant differences were

| Table 2. Description of participants who completed the Joviality trial (n=20) |
|-----------------------------|-----------------------------|
| Characteristics             | Result                      |
| Age, yr, mean (SD)          | 55.25 (13.12)               |
| Male, n (%)                 | 16 (80)                     |
| Race/ethnicity, n (%)       |                             |
| Black                       | 12 (60)                     |
| Non-Hispanic White          | 8 (40)                      |
| Married, n (%)              | 8 (40)                      |
| Dialysis vintage, yr, mean (SD) | 3.56 (3.75)             |
| Retired or unable to work, n (%) | 9 (45)                |
| Schooling, yr, mean (SD)    | 13.50 (3.38)                |
| Income <$20,000, n (%)      | 7 (35)                      |
| US born, n (%)              | 20 (100)                    |
| Health insurance coverage, n (%) | 20 (100)             |
| Body mass index, yr, mean (SD) | 32.25 (6.77)              |
| Hypertension, n (%)         | 17 (85)                     |
| Hypercholesterolemia, n (%) | 5 (25)                      |
| Diabetes mellitus, n (%)    | 10 (50)                     |
| VR familiarity, n (%)       | 13 (65)                     |
| VR experience, n (%)        | 6 (30)                      |

VR, virtual reality.

| Table 3. Summary of cybersickness scores across HD end-users | |
|------------------------------------------------------------|
| Measure                                                      | Pre VR Exposure | Post VR Exposure |
| Sickness                                                     | 2.67            | 2.34             |
| Oculomotor symptoms                                          | 1.41            | 1.28             |
| Disorientation                                               | 1.54            | 1.28             |
| Total symptomatology                                         | 4.62            | 4.22             |

SSQ scores above 3.5 were indicative of severe cybersickness symptoms. DISQ scores greater than 4.0 were suggestive of high levels of disorientation. Total symptomatology scores greater than 7 were indicative of high levels of symptomology.
| Symptomatology                  | Exposure One                                      | Exposure Two                                      |  |
|--------------------------------|--------------------------------------------------|--------------------------------------------------|---|
|                                | Pre Virtual Reality, Mean (SD) | Post Virtual Reality, Mean (SD) | \(P\) | Pre Virtual Reality, Mean (SD) | Post Virtual Reality, Mean (SD) | \(P\) |
| General discomfort             | 7.70 (10.35)                                   | 4.28 (7.61)                                      | 0.16 | 5.99 (11.48)                  | 3.32 (8.60)                  | 0.24 |
| Fatigue                        | 5.31 (6.07)                                    | 1.14 (2.78)                                      | 0.002 | 3.41 (5.75)                  | 2.65 (5.08)                  | 0.43 |
| Headache                       | 1.52 (3.97)                                    | 0.38 (1.69)                                      | 0.27 | 0.76 (2.33)                  | 0.38 (1.69)                  | 0.33 |
| Eye strain                     | 2.27 (4.33)                                    | 2.27 (4.98)                                      | 1.0 | 1.90 (4.17)                  | 1.14 (2.78)                  | 0.43 |
| Difficulty focusing            | 6.45 (12.28)                                   | 7.53 (12.62)                                     | 0.58 | 5.38 (11.83)                 | 2.15 (6.62)                 | 0.27 |
| Salivation increasing          | 0.95 (4.27)                                    | 0.95 (4.27)                                      | 0.48 (2.13) | 0.95 (2.94)                 | 0.95 (4.27)                 | 1.0  |
| Sweating                       | 2.39 (5.23)                                    | 0.48 (2.13)                                      | 0.10 | 0.95 (2.94)                  | 0.95 (4.27)                 | 0.33 |
| Nausea                         | 8.21 (15.74)                                   | 1.17 (5.25)                                      | 0.09 | 2.35 (7.22)                  | 0.95 (4.27)                 | 0.25 |
| Difficulty concentrating       | 5.14 (9.78)                                    | 0.86 (3.83)                                      | 0.06 | 2.57 (6.27)                  | 0.86 (3.83)                 | 0.16 |
| Fullness of the head           | 2.78 (7.28)                                    | 0.70 (3.11)                                      | 0.19 | 1.38 (4.28)                  | 0.00 (0.00)                 | 0.16 |
| Blurred vision                 | 6.45 (12.28)                                   | 6.45 (12.28)                                     | 1.0 | 3.23 (7.88)                  | 3.23 (7.88)                 | 1.0  |
| Dizziness w/eyes open          | 2.09 (6.82)                                    | 1.39 (6.23)                                      | 0.33 | 0.00 (0.00)                  | 0.00 (0.00)                 | 0.00 |
| Dizziness w/eyes closed        | 1.39 (6.23)                                    | 1.39 (6.23)                                      | 0.00 (0.00) | 0.00 (0.00)                 | 0.00 (0.00)                 | 1.0  |
| Vertigo\(^a\)                  | 2.09 (6.81)                                    | 0.00 (0.00)                                      | 0.19 | 0.70 (3.11)                  | 0.00 (0.00)                 | 0.33 |
| Stomach awareness\(^c\)        | 2.86 (5.45)                                    | 0.95 (2.94)                                      | 0.10 | 0.48 (2.13)                  | 0.00 (0.00)                 | 0.33 |
| Burping                        | 1.91 (4.99)                                    | 0.00 (0.00)                                      | 0.10 | 0.48 (2.13)                  | 0.00 (0.00)                 | 0.33 |
| **Subscales and total score**  | **18.60 (30.71)**                              | **5.72 (8.42)**                                  | **0.04** | **8.12 (12.49)** | **5.25 (15.31)** | **0.37** |
| Nausea                         | 19.33 (25.38)                                  | 10.99 (13.35)                                    | 0.03 | 12.89 (20.44)                | 7.96 (14.85)                | 0.18 |
| Oculomotor                     | 21.58 (44.36)                                  | 13.22 (26.13)                                    | 0.10 | 9.05 (15.16)                 | 4.87 (11.31)                | 0.21 |
| Disorientation                 | **22.63 (34.71)**                              | **11.22 (15.16)**                               | **0.03** | **11.97 (17.61)** | **7.29 (15.28)** | **0.18** |

\(^a\)Results of paired sample \(t\) tests between pre- and postexposure, \(P\) values <0.05, and associated exposure values displayed in bold.

\(^c\)Vertigo is experienced as loss of orientation with respect to vertical upright.

\(^c\)Stomach awareness is usually used to indicate a feeling of discomfort that is just short of nausea.
evident in presence and usability by sex, age, or previous VR experience. Nevertheless, trends suggest greater immersion in males and older adults (≥55 years) and greater system usability in non-Hispanic Whites.

**Discussion**

We present the first safety test of VR in patients on HD. Our new 25-minute VR program, Joviality, was both safe and enjoyable among HD end-users when delivered chair-side. As such, VR may offer a viable high-tech platform to deliver therapies to patients on HD as they attend regularly scheduled dialysis treatment. Further, this VR program decreased HD patient-related symptomatology (e.g., nausea) and elicited high levels of immersion with technology that was easy to operate. These results promote larger trials that focus on the additional benefits of VR for patients on HD including effects on quality of life, dietary adherence, morbidity, and longevity.

The mechanism through which chairside VR exposure might ameliorate HD-related side effects remains unclear. Researchers in the field of pain management suggest two plausible mechanisms are involved: (1) active distraction or attentional diversion, and/or (2) physiologic changes (29). Through its high-definition graphics and interaction with virtual objects, VR can be an effective tool in distracting patients on HD from uncomfortable medical procedures occurring chairside. The stimulus diverts focus away from usual side effects, thereby making symptoms such as nausea and lightheadedness less intense. Alternatively, VR may reduce brain activity in regions where pain responses have been recorded.

If the therapeutic use of VR becomes adopted in HD settings, important questions remain to be answered for optimal efficacy. For example, when is VR exposure most effective during dialysis sessions—the beginning, middle, or toward the end? Also, what types of environmental simulations are most aesthetically pleasing and result in greatest immersion and engagement (e.g., 360° videos or three-dimensional computer animations)? The VR content should also be carefully considered. In its current iteration, our Joviality program is geared toward teaching skills of mindfulness to improve emotional wellbeing, but health

### Table 4. Level of presence during the virtual reality program (n=20)

| Survey Measures | Exposure One, Mean (SD) | Exposure Two, Mean (SD) |
|-----------------|-------------------------|-------------------------|
| IPQ             |                         |                         |
| Overall IPQ Score | 4.13 (1.19)         | 3.94 (1.15)         |
| General “sense of being there” | 5.60 (1.76)         | 4.65 (2.11)         |
| Spatial presence   | 5.03 (1.53)         | 4.57 (1.39)         |
| Involvement        | 3.30 (1.18)         | 3.51 (1.23)         |
| Experienced realism| 3.48 (1.62)         | 3.39 (1.33)         |
| SUS              |                         |                         |
| Total score       | 82.75 (21.85)       |                         |

IPQ, iGroup Presence Questionnaire; SUS, System Usability Scale.

### Table 5. Virtual reality assessments stratified by sex, age, and previous virtual reality experience

| Individual-level Characteristics | Simulator Sickness Questionnaire | iGroup Presence Questionnaire | System Usability Scale |
|----------------------------------|----------------------------------|-------------------------------|------------------------|
|                                  | Exposure One Δμ (SD) | Exposure Two Δμ (SD) | Exposure One Mean (SD) | Exposure Two Mean (SD) | Postintervention Mean (SD) |
| Sex                              |                       |                             |                        |                        |                           |
| Male                             | −8.64 (21.06)         | −4.91 (11.96)             | 4.31 (1.11)            | 3.94 (1.14)            | 82.81 (22.89)             |
| Female                           | −22.44 (21.81)        | −3.74 (27.14)             | 3.43 (1.39)            | 3.92 (1.39)            | 82.50 (20.10)             |
| P value                          | 0.56                 | 0.90                        |                       |                       |                           |
| Race/ethnicity                   |                       |                             |                        |                        |                           |
| Non-Hispanic White               | −7.48 (9.38)          | −2.34 (14.27)             | 4.36 (1.10)            | 3.73 (1.14)            | 90.31 (13.66)             |
| Black                            | −14.03 (26.74)        | −6.23 (16.13)             | 3.98 (1.26)            | 4.07 (1.19)            | 77.71 (25.24)             |
| P value                          | 0.52                 | 0.58                        |                       |                       |                           |
| Age                              |                       |                             |                        |                        |                           |
| <55                              | −16.21 (27.55)        | −6.23 (16.09)             | 3.67 (1.45)            | 3.75 (1.48)            | 83.89 (17.90)             |
| ≥55                              | −7.48 (14.96)         | −3.40 (15.0)              | 4.51 (0.81)            | 4.01 (0.85)            | 81.82 (25.47)             |
| P value                          | 0.38                 | 0.69                        |                       |                       |                           |
| Previous VR experience           |                       |                             |                        |                        |                           |
| Yes                              | −16.83 (32.15)        | −5.61 (16.00)             | 3.80 (0.87)            | 3.83 (0.76)            | 83.33 (21.72)             |
| No                               | −9.08 (15.85)         | −4.27 (15.38)             | 4.28 (1.30)            | 4.0 (1.31)             | 82.50 (22.72)             |
| P value                          | 0.47                 | 0.86                        |                       |                       |                           |

Δμ, mean change before versus after virtual reality exposure; VR, virtual reality.
education and other public health content could be similarly disseminated. For instance, our group is designing a three-dimensional grocery store tour where patients on HD engage in virtual shopping to identify the types of food that are healthiest to purchase and consume.

Ethical considerations must also be at the forefront of therapeutic uses of VR in HD settings. Kellmeyer et al. (30) provide an insightful commentary on ethical priorities to consider when including VR as a medical technology in therapy. One such ethical dilemma involves the concept of “persuasive technology.” This occurs when VR is the only viable option to escape one’s immediate physical surroundings and when it becomes the main tool to socialize and communicate with others. This is particularly true for patients with paralysis who are “locked in” and their autonomy stripped, thus making human-to-human contact unlikely. For patients on HD, a patient-centered design (31) could be used, whereby VR exposure does not promote social isolation, and sedentarism is not heightened to overcome this dilemma. Results of this study should be interpreted in light of existing limitations. First, we had a limited sample size, with recruitment from a single clinic site in a small college town in the Midwestern United States. Future studies should be conducted in metropolitan cities, with greater diversity in race/ethnicity, place of nativity status, and sex. Second, given the pilot nature of our trial, we did not include a control arm. This precludes us from making causal inferences because improvements in symptoms may have been a result of confounding factors, such as social contact with research staff. A randomized trial that includes an adequate control arm would more clearly elucidate the benefits reported here. Future trials should also adhere to more stringent standardization protocols when timing VR exposure during maintenance HD to test for moderation by dialyzing time. Further, we did not assess for long-term effects of VR exposure on HD-related symptoms. Future trials will want to include multiple prospective waves of data collection. Medical history should also be ascertained through more objective methods in the future, such as adjudication of medical records to avoid recall bias from self-reported data.

This study also had several strengths. This trial was the first to test whether VR is safe for chairside use with patients on HD. We did not use commercialized VR content but instead designed a new program tailored for HD end-users. The VR program content was adapted from the evidenced-based positive psychologic intervention DAHLIA (18). And we limited VR intractability to head movement, given limited hand mobility of patients on HD during dialysis. Commercial VR programs often utilize remote controllers to move within a virtual space, which would not have been practical for many HD end-users. In light of these strengths, we hope to conduct additional trials with adapted versions of Joviality in the near future. End-users will encounter a different setting and curricular module at each immersion. New weekly content will counter study findings where improvements were most prominent at exposure one. (It is possible that end-users became familiar with the content when an identical lesson was delivered in the same location.) As in the gaming industry, creation of new content will likely prove critical. We will also test whether VR exposure leads to carryover effects where symptom improvement is sustained, and whether timing of VR exposure serves as an effect modifier.

In conclusion, this pilot trial provides promising findings regarding the safety and benefit of VR for patients on HD. Future trials to more robustly test efficacy are now called for, and are indeed underway.

Disclosures
K.R. Wilund reports receiving honoraria from the Greenfield Health Systems, National Kidney Foundation, and Renal Research Institute, Inc.; reports being a scientific advisor or member of the Journal of Renal Nutrition; and reports having other interests/relationships in the Kidney Health Initiative. R. Hernandez reports being a scientific advisor or member of the American Heart Association, Nazareth Academy. All remaining authors have nothing to declare.

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Author Contributions
B. Burrows was responsible for project administration; B. Burrows and R. Hernandez were responsible for formal analysis; M. Browning, D. Fast, R. Hernandez, N. Litbarg, J. Moskowitz, K. Solai, and K. Wilund were responsible for methodology; D. Fast, N. Litbarg, J. Moskowitz, K. Solai, and K. Wilund were responsible for resources; R. Hernandez, J. Moskowitz, and K. Wilund conceptualized the study and were responsible for funding acquisition; R. Hernandez, N. Litbarg, and J. Moskowitz were responsible for investigation; R. Hernandez, K. Solai, and K. Wilund provided supervision; M. Browning and R. Hernandez wrote the original draft; and all authors reviewed and edited the manuscript. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

Supplemental Material
This article contains supplemental material online at http://kidney360.asnjournals.org/lookup/suppl?doi:10.34067/KID.0005522020/-/DCSupplemental.
Supplemental Appendix A. Postintervention clinical staff feedback (n=8).
Supplemental Appendix B. Simulator Sickness Questionnaire (SSQ).
References

1. LaValle SM: Virtual Reality. Cambridge, Cambridge University Press, 2017, 418.
2. Ghanbarzadeh R, Ghapanchi AH, Blumenstein M, Talaei-Khoei A: A decade of research on the use of three-dimensional virtual worlds in health care: A systematic literature review. J Med Internet Res 16: e47, 2014 https://doi.org/10.2196/jmir.3097
3. Lindner P, Miloif A, Zetterlund E, Reuterskiöld L, Andersson G, Carlbring P: Attitudes toward and familiarity with virtual reality therapy among practicing cognitive behavior therapists: A cross-sectional survey study in the era of consumer VR platforms. Front Psychol 10: 176, 2019 https://doi.org/10.3389/fpsyg.2019.01716
4. Motraghi TE, Seim RW, Meyer EC, Morissette SB: Virtual reality exposure therapy for the treatment of posttraumatic stress disorder: A methodological review using CONSORT guidelines. J Clin Psychol 70: 197–208, 2014 https://doi.org/10.1002/jclp.22051
5. Indovina P, Barone D, Gallo L, Chirico A, Di Pietro G, Giordano M: Virtual reality as a distraction intervention to relieve pain and distress during medical procedures: A comprehensive literature review. Clin J Pain 34: 858–877, 2018 https://doi.org/10.1097/AJP.0000000000000599
6. Jordan SW, Grindle M, van Woerden HC, Kamel Boulos MN: Head-mounted virtual reality and mental health: Critical review of current research. JMIR Serious Games 6: e14, 2018 https://doi.org/10.2196/games.9226
7. Mishkind MC, Norr AM, Katz AC, Reger GM: Review of virtual reality treatment in psychiatry: Evidence versus current diffusion of current research. Head-mounted virtual reality and mental health: Critical review of current research. JMIR Serious Games 6: e14, 2018 https://doi.org/10.2196/games.9226
8. Dascal J, Reid M, IsHak WW, Spiegel B, Recacho J, Rosen B, van Woerden HC, Kamel Boulos MN: Head-mounted virtual reality and mental health: Critical review of current research. JMIR Serious Games 6: e14, 2018 https://doi.org/10.2196/games.9226
9. Malloy KM, Milling LS: The effectiveness of virtual reality distraction for pain reduction: A systematic review. Clin Psychol Rev 34: 858–877, 2018 https://doi.org/10.1097/AJP.0000000000000599
10. Cho H, SohngK-Y: The effect of a virtual reality exercise program on physical fitness, body composition, and fatigue in hemodialysis patients. J Phys Ther Sci 26: 1661–1665, 2014 https://doi.org/10.1589/jpts.26.1661
11. Segura-Ortí E, García-Testal A: Intradialytic virtual reality exercise: Increasing physical activity through technology. Semin Dial 32: 331–335, 2019 https://doi.org/10.1111/sdi.12788
12. Chou H-Y, Chen S-C, Yen T-H, HanH-M: Effect of a virtual reality-based exercise program on fatigue in hospitalized Taiwanese end-stage renal disease patients undergoing hemodialysis. Clin Nurs Res 29: 368–374, 2020 https://doi.org/10.1177/105477831888511
13. Al Nazly E, Ahmad M, Musil C, Nabolsi M: Hemodialysis stressors and coping strategies among Jordanian patients on hemodialysis: A qualitative study. Nephrol Nurs J 40: 321–327; quiz 328, 2013
14. Sahai R, Sadat Ilahi E, Peyrovi H, Akbari Kamrani AA, Shabahdi F: Uncertainty, the overbearing lived experience of the elderly people undergoing hemodialysis: A qualitative study. Int J Community Based Nurs Midwifery 5: 13–21, 2017
15. Kabat-Zin J: Full Catastrophe Living: Using the Wisdom of Your Body and Mind to Face Stress, Pain and Illness, New York, Random House Publishing Group, 1990

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