Effect of Immersive Virtual Reality during Arteriovenous Fistula Puncture on Pain Intensity among Children Undergoing Hemodialysis in El Beheira Governorate

Rodaina Ahmed Mokbel[(1)], Ebtsam Salah Yonis Mahrous[(2)], Samiha Hamdi Sayed[(3)], Naglaa Kamel AbdAllh Hussein[(4)]

(1, 2) Lecturer-Pediatric Nursing-Faculty of Nursing- Damanhour University, Egypt

(3) Assistant Professor-Community Health Nursing-Faculty of Nursing-Damanhour University, Egypt
Department of Public Health, College of Health Sciences, Saudi Electronic University, Saudi Arabia

(4) Assistant Professor-Community Health Nursing-Faculty of Nursing-Damanhour University, Egypt
Department of Nursing, Faculty of Applied Medical Sciences, Al Baha University, Saudi Arabia

Abstract

Background: Pain is an inherently human experience with the Arteriovenous Fistula Puncture, especially among children. Thus, it becomes of utmost importance to devote modern technologies to lessen this annoying sensation aside from the suffering from the disease itself. Thereof, this study aimed to evaluate the effect of immersive virtual reality intervention during arteriovenous fistula puncture on pain intensity among children undergoing hemodialysis in El Beheira Governorate, Egypt. **Methods:** A non-randomized controlled trial was executed in eight governmental hemodialysis units (that were assigned to receive pediatric cases), representing eight administrative districts. All the available children who fulfilled the inclusion criteria were incorporated in the study (36 children). Five tools were used: Socio-demographic and Medical History Structured Interview Schedule, Physiological Pain Indicators, Numerical Pain Rating Scale, Procedural Behavior Rating Scale and the Gold-Rizzo Immersion and Presence Inventory. **Results:** The Analysis of Covariance test (ANCOVA) proved a large effect size of virtual reality intervention on all pain measures ($\eta 2 \geq 0.06$). A statistically significant improvements in the mean scores of all the physiological pain measures was found after virtual reality intervention as compared to baseline (P0=<0.05) and standard care (P2<0.05). Most of the studied children reported either mild (58.3%) or moderate (27.8%) pain with no severe pain after virtual reality intervention with a statistically significant mean difference compared to the baseline ($p0<0.001$) and standard care ($p_2<0.001$). A significant difference was proved between the virtual reality intervention and standard care concerning the observed pain behaviors during the procedure ($p_2<0.001$). A high level of immersion with the virtual reality intervention was revealed among the studied children with a mean percent score of 90.97 ± 7.23. **Conclusion & recommendations:** Virtual Reality intervention proved to be efficient in lessening pain intensity among children undergoing hemodialysis. Thereof, it is recommended to be incorporated in the routine care of pediatric hemodialysis units.

Keywords: Immersive Virtual Reality, Arteriovenous Fistula, Pain, Children, Hemodialysis

1. Introduction

End-Stage Renal Disease (ESRD) is the end-stage of the Chronic Kidney Disease (CKD) which refers to irreversible damage to the kidneys that requires renal replacement therapy in the form of peritoneal dialysis, hemodialysis, or kidney transplantation **(Zhang et al., 2020; Radisic et al., 2022)**.

The prevalence of pediatric CKD has increased fourfold in the last 30 years **(Davidovits & Markus, 2017)**. Globally, it ranged from 15 to 74.7 cases per million of the age-related population (pmarp) in different geographic regions **(Reszke et al., 2021)**. In the European Union countries, its prevalence ranged from about 55–60 to 70–75 pmarp in Spain and Italy **(Masalskiene˙ et al., 2021)** while in the United States, the incidence and prevalence of pediatric ESRD were 14.7 pmarp and 103.9 pmarp for the age group 0–21 years, respectively **(Romagnani et al., 2017)**. In the Arabic region, the prevalence of Chronic Renal Failure (CRF) among pediatric in Saudi Arabia is 80 to 120 per million population (pmp) and 225 pmp in Egypt. **(Ibrahim & Abdelgawad, 2017)**. Additionally, a study performed in Egypt discovered that 1018 children from 1 to 19 years old were suffering from CKD and 587

of them had reached ESRD. The study also mentioned that 93.5 % of those children with ESRD were treated by hemodialysis **(Safouh et al., 2015)**.

Distinctly, ESRD is associated with increased morbidity, mortality with negative sequel on patient's general health and wellbeing which necessitates compatible renal replacement therapy **(El-Ballat et al., 2019)**. Hemodialysis is the most frequent renal replacement modality in children basically through induction of an Arteriovenous Fistula (AVF). It is favored over central venous catheters in pediatrics because it yields better dialysis adequacy, greater freedom of movement, significantly lower infection and complication rates besides lower access failure and durability **(Akturk et al., 2018; Preka et al., 2020)**.

One of the most challenging issues that faces patients receiving hemodialysis is the recurring exposure to needle-pricks that lasts lifelong. Hemodialysis patients have an average of two large bore needles inserted three times per week averaging 312 punctures per year producing outrageous pain especially in pediatrics **(Radisic et al., 2022)**. Undertreatment of such pain can result in avoidance of hospitals and refusal for treatment which deteriorate the children's condition **(Shafi et al., 2018; Atzori et al., 2022)**. Conversely, children's watching or focusing attention on the medical procedure can also increase the intensity of pain felt **(Heathcote et al., 2017)**. Thus, non-pharmacological psychological interventions such as distraction can fortunately aid in diminishing pain through distracting thinking by something not related to the medical procedures **(Birnie et al., 2017)**.

Virtual Reality (VR) is evolving as an encouraging distraction technique for pain management among children **(Atzori et al., 2018)**. It can be defined as a simulated experience, created by hardware and software technology able to create the feelings of real experiences where users can see, listen, and feel the experience as if they were in a real environment using special googles with a screen and headphones **(Burrai et al., 2019)**. Immersive virtual reality has proven to be beneficial in reducing pain, anxiety, and distress both in adults and children during a variety of painful medical procedures **(Barad et al., 2020; Trost et al., 2021)**. Moreover, it is now prioritized over pharmacological interventions because of its safety, quick action, and lesser side effects **(Koc-Ozkan & Polat 2020)**.

Pediatric nurses have an extremely prime position among other members of the healthcare team in the evaluation and management of children's pain because they are the ones who spend most of the time directly with the child. The role of the pediatric nurse in managing children's pain includes pain screening, ongoing assessment, and reassessment, formulating nursing diagnosis, implementing pharmacological and non-pharmacological interventions, documentation, and continuous evaluation of care **(Cirik et al., 2019)**. Pediatric nurse also should take into consideration when assessing and managing pain to choose a developmentally appropriate approach for each child, determine the appropriateness and effectiveness of the used non-pharmacological intervention and pay more attention to individual children's preferences to gain optimal results **(Loeffen et al., 2020)**. Moreover, they have an ethical obligation and responsibility to apply evidence-based guidelines in practice to alleviate children's pain and fear during medical procedures and to improve their quality of life **(Cho & Choi, 2021)**.

Significance of the study:

Although hemodialysis is a lifesaving treatment modality, healthcare providers should work to minimize children's suffering with the painful AVF procedure **(CDC, 2019; Wong et al., 2019)**. Therefore, it is necessary to make an intervention targeting children to effectively and immediately control the needle-puncture pain and distress **(Cho & Choi, 2021)**. Immersive VR is a growing technology which can manage the children's painful experience that is regularly encountered in each hemodialysis session **(Hurley-Wallace et al., 2019)**. Degree of immersion during VR session is also an important indicator linked to success of the experience in managing pain. There is a scarce evidence available in this regard especially at national level. Thereof, the present study will be one of the pioneer studies evaluating the effect of immersive VR during AVF puncture on pain intensity among children undergoing hemodialysis in El Beheira Governorate/Egypt.

2. Materials and methods

Operational definitions:

- In this study the experience of pain intensity was measured through:
  - The subjective pain experienced by the children through self-reported numerical rating scale of pain severity.
  - The physiological indicators of pain such as heart rate, respiratory rate, blood pressure, and oxygen saturation
  - Behavioral indicators of pain through direct observation of the children's pain behavior and distress during Arteriovenous Fistula (AVF) puncture procedure.
- In this study immersion denotes a complete detachment from the real environment in terms of place, vision, and sounds with a corresponding complete involvement in the virtual reality environment.

Research Hypotheses:

- Children receiving the VR intervention will exhibit lower self-reported pain severity than those who receive the standard care.
- Children receiving the VR intervention will have more stable physiological pain measures than those who receive the standard care.
- Children receiving the VR intervention will experience less stressful procedural behavioral pain than those who receive standard care.

Research Design:

Non-randomized controlled trial research design was deployed. It was registered in one of the primary registries of the WHO namely, the Iranian Registry of Clinical Trials with the number [IRCT20210612051555N3]

Setting:

The current study was conducted at eight governmental hemodialysis units of the general hospitals affiliated to the Ministry of health in eight administrative districts of El Beheira Governorate – Egypt.

Subjects:

The current study's subjects comprised the children receiving hemodialysis therapy who attended the previously mentioned settings. They were carefully chosen on congruence with the next criteria.

Inclusion criteria:

- Children aged between 7 and 18 years.
- Both sexes.
- Receiving hemodialysis therapy for more than 6 months through AVF.

Exclusion criteria:

- Receiving any other pharmacological and/or non-pharmacological interventions for pain management.
- Complaining of any other source of pain rather than the AVF.
- Suffering from any visual, auditory, or cognitive impairments.
- Using the VR headset before.

Sample size and technique:

A multistage sampling technique was employed to choose the required sample size as follows:

- Eight administrative districts out of the 16 districts of El-Beheira governorate were purposively selected based on the designation of the available hemodialysis unit to receive child cases, as there are no pediatric hemodialysis units in El Beheira Governorate.
- From every district, the available hemodialysis unit in the general hospital was included in the study
- From each hemodialysis unit, all the available children who fulfilled the inclusion and exclusion criteria were incorporated in the study creating total sample size of 36 children as shown in table (1).

Table (1): Study settings with the respective number of cases

The district general hospital with the respective hemodialysis unit	Number of children included in the study
1. Damanhour National Medical Institute	6
2. Itay Elbaroud General Hospital	7
3. Kom Hamada General Hospital	3
4. Kafr El Dawar General Hospital	5
5. Housh Eisa General Hospital	3
6. Noubaria General Hospital	2
7. Wadi El Natroun General Hospital	4
8. El Delingat General Hospital	6
Total =8	Total =36

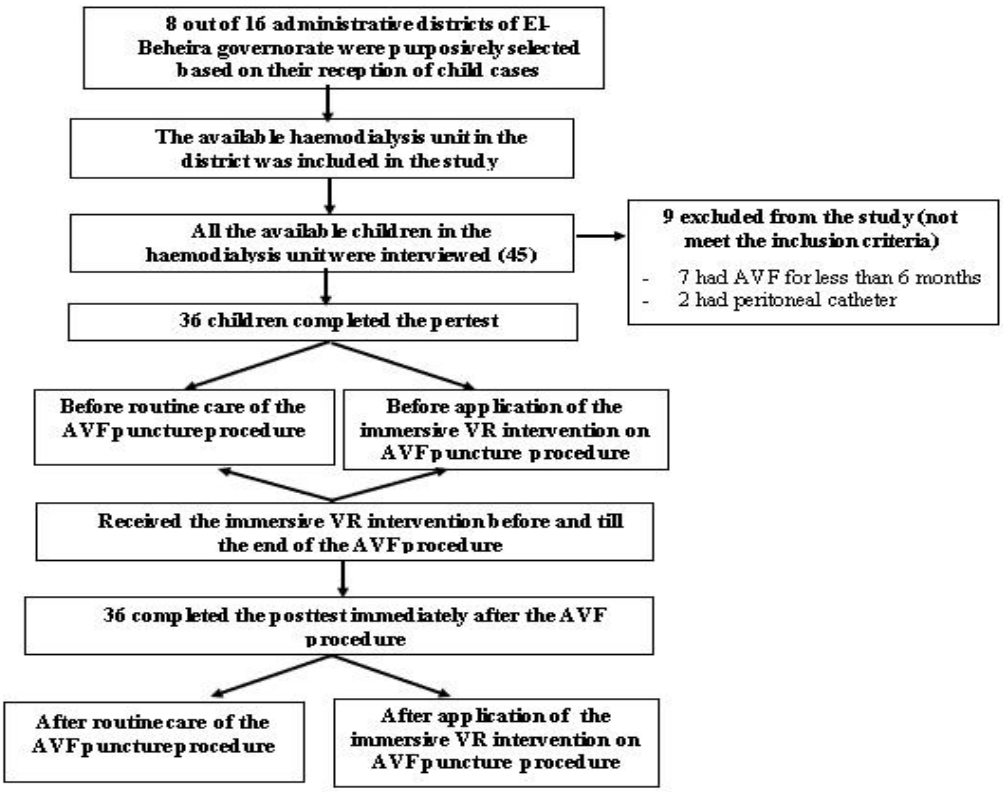

Figure (1): Participants' flow chart

Tools of Data Collection:

Five tools were employed for data collection:

Tool I: Socio-demographic and Medical History Structured Interview Schedule

It was developed by the researchers after reviewing recent and relevant literature, and it was divided into two parts:

- **Part I:** Children's socio-demographic data: age, gender, birth order, residence, and school grade.
- **Part II:** Children's medical history data: duration of the disease, duration of each hemodialysis session, frequency of dialysis sessions per week, site of AVF, and any other underlying diseases.

Tool II: Physiological Pain indicators:

It was developed by the researchers to assess the body's physiological responses to pain including heart rate, respiratory rate, blood pressure, and oxygen saturation (measured before and after using the VR headset).

Tool III: Numerical Pain Rating Scale:

It was adopted from **McCaffery & Beebe, (1993)** where it is developed for subjective pain assessment, and it is the simplest and most used scale in clinical as well as research settings **(Cote et al., 2019)**. It is also well supported for its high validity, reliability (r= 0.97), and positive psychometric properties (**Castarleans et al., 2017; Tsze et al., 2018)**.

It is drawn in the form of a number line graduated from 0 to 10 where 0 indicates no pain while 10 indicates the worst possible pain. Children were then asked to quantify their pain intensity by selecting one whole value that best represents their pain level. The scale was ordered into four levels of pain: (0) no pain, (1-3) mild pain, (4-6) moderate pain, and (7-10) severe pain.

Tool IV: Procedural Behavior Rating Scale-Revised (PBRS-R):

It was first developed by **Katz et al., (1980)** then revised by **Katz et al., (1987)** thus it was adopted in the current study as an objective pain assessment scale. Its reliability has been further supported by **Sparks et al., (2007)** (r= 0.93). It was developed specifically for children up to 18 years to evaluate procedural pain and distress.

The revised scale comprised 11 pain-related behaviors namely: cry, cling, pain verbal, flail, stall, scream, refuse the position, restrain, emotional support, muscular rigidity, and requesting termination. Each behavior was scored 1 if it occurred and 0 if it did not occur. The total score was summed and ranged from 0 to 11, where the greater the total score, the higher the pain intensity.

Tool V: The Gold-Rizzo Immersion and Presence (GRIP) Inventory

It was adopted from **Gold et al., (2021)** who designed it to assess children's degree of immersion in the VR experience. It is composed of 16 items distributed under 5 domains namely: a sense of involvement (4 items), perceived realism of the VR experience (3 items), sense of transportation into the experience (1 item), feasibility (4 items), and degree of satisfaction with the VR experience (4 items). Each item was scored on a three-point Likert scale representing the degree of immersion: no (0), a little (1), a lot (2). Two items had reversed scores (questions numbers 10&14). The total GRIP inventory score was calculated and ranged from 0 to 32, where higher scores indicating higher levels of immersion.

Tools' Validity and reliability

- Tools I and tool II were revised for content validity by a jury composed of 3 experts in the fields of Pediatric and Community Health Nursing.
- Tool V was translated into the Arabic language by the researchers and its content validity after the translation was checked by the same jury. Its reliability was tested by Cronbach's alpha coefficient and seemed to have higher internal consistency (0.84).

Pilot study

It was performed on 4 children (approximately 10% of the study sample) to ensure the clarity, applicability, and feasibility of the tools, and no modifications were done, consequently, these children were included in the total study sample.

Data collection:

- An official letter from the Faculty of Nursing, Damanhour University was directed to the Ministry of Health in El-Beheira Governorate to obtain permission for conducting the study.
- Meetings were held with the administrative board of each setting to explain the purpose of the study, to set the time for beginning the study, and to clarify its process in addition to gain their cooperation during data collection.
- The overall period of data collection took about five months (from August 2021 to December 2021).

The data collection process was carried out through four phases:

- **Interviewing phase:**

During the initial visit, the researchers met all the children and their mothers/caregivers at the dialysis units who were recruited based on the pre-determined inclusion criteria. The researchers provided all the children and their mothers/caregivers with detailed information about the process and nature of the study to gain their cooperation, and they consented to join the study after explaining its purpose. The researchers also met all the medical staff who are working in the hemodialysis units to explain the purpose of the study. A good relationship was established with all the participants as well as the medical staff.

- **Assessment Phase:**

In this phase, the researchers collected data related to the children's sociodemographic data and medical history from the mothers/caregivers of the children by using **Tool I**. The assessment took about 10 minutes for each child.

- **Implementation Phase:** The study was implemented over two days:

First Day (No Intervention):

- During this day, the children received a routine AVF puncture by the nurses of the dialysis unit according to the standards of care in the unit without any intervention.
- *Before* starting the AVF puncture procedure, the researchers explained the numerical pain rating scale to the children and taught them how to use it. The physiologic parameters were assessed and recorded by the researchers as baseline data using **tool II**. The children were also asked to report their baseline pain level before the puncture by using **tool III** and the score was recorded by the researchers.
- *During* the process of AVF puncture, the researchers observed the behavioral pain responses of the children while the nurse was performing the puncture and recorded them by using **tool IV**.
- *Just after* the AVF puncture, the researchers re-assessed the physiologic parameters and recorded them by using **tool II**, and the children were asked to rate the intensity of the pain they felt during the puncture procedure by using **tool III** and the scores were recorded by the researchers.

Second Day (Implementing the VR intervention):

- Before the AVF puncture procedure, the researchers informed the children about the VR headset and how to use it, and they played a simple 3D game.
- The baseline data related to subjective and behavioral pain scores as well as the physiologic measurements were recorded before the beginning of the AVF puncture procedure as mentioned before in the first day (**tools II, III, IV**).
- The VR headset was placed on the child's head and adjusted to ensure a comfortable fit. It consisted of special eyeglasses and headphones generating a 3D visual environment in a high definition (HD) quality video and audio to occupy more than one sense and ensure complete immersion in the VR experience. The children started to play the game for about 10 minutes before the AVF puncture procedure and continued playing till the end of the procedure. The game was displayed via a mobile smartphone placed inside the VR headset.
- The researchers observed each child during the AVF puncture procedure while playing the VR game to assess the behavioral pain responses (**tool IV**).
- After the AVF puncture procedure, the VR headset was removed and the physiologic parameters were measured and recorded by the researchers (**tool II**), then the children were asked to rate their pain intensity during the puncture procedure and the subjective pain score was recorded by the researchers (**tool III**).
- At the end of the procedure, the children were asked about their opinion regarding the VR experience and if they enjoyed it or not,

and to what extent they were immersed in it by using **tool V**.

- For infection control purposes, all the components of the VR headset were cleansed with alcohol-based sanitary wipes according to the manufacturer's instructions after each child.

Evaluation phase:

- The efficacy of the intervention was determined by evaluating the children's pain intensity by comparing the before and after scores of both the routine AVF puncture procedure versus the immersive virtual reality application during AVF puncture using **tool II**, **tool III**, and **tool IV**. In addition, after the application of the virtual reality experience, the degree of immersion was measured with **tool V**.

Ethical considerations

- The study was ethically approved by the ethical committee of the Faculty of Nursing, Damanhour University/Egypt, with the number [2052021].
- All eligible children and their mothers/caregivers were informed about the aim and nature of the study before its beginning, and all their inquiries were replied.
- Written consent from the mothers/caregivers and oral assent from the children were obtained before initiating the study.
- All the medical staff working in the dialysis units were carefully instructed at the beginning of the study on the methodology.
- Children's privacy and confidentiality were maintained.
- Children were informed that participation in the study is voluntary, and they have the right to withdraw from the study at any phase without giving justifications.

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 26.0. (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. The Kolmogorov-Smirnov test // Shapiro-Wilk test was used to verify the normality of distribution. Quantitative data were described using mean and standard deviation. Significance of the obtained results was judged at the 0.5% level. The comparison between the two periods was conducted using the Paired t-test for the normally distributed quantitative variables whereas Wilcoxon signed ranks test were devoted for the abnormally distributed quantitative variables. Analysis of Covariance (ANCOVA) test was utilized to estimate the effect size ($\eta 2$) of the immersive VR using either the baseline or standard care as a reference.

3. Results

Table (2) illustrates that 61.1% of the studied children aged less than 15 years with a mean age of 14.22 ± 2.38. The highest percent of the studied children were females (66.7%) and enrolled in preparatory school (44.4%). A similar percent of them were ranked as the first or second child in their families (44.4%) and 55.6% of them were rural residents.

Table (3) depicts that a similar percent of the studied children (33.3%) was undergoing hemodialysis since 1< 5 or 5<10 years. All the studied children had three hemodialysis sessions per week (100%) with three hours duration per each (55.6%) with the AVF in their left arm (61.1%). Nearly three quarters (72.2%) of them had no chronic diseases associated with renal failure.

Table (4) proved an absence of any statistically significant differences in the mean scores of all physiological measures at baseline between day 1 & day 2 ($p_1>0.05$). During day 1, a statistically significant difference in the mean scores of all physiologic measures was revealed after the standard care of AVF puncture compared to the baseline ($p_0<0.05$) with an observable elevation in the mean scores of all physiologic measures with a reduction in O_2 saturation. During day 2, a statistically significant difference in the mean scores of all physiologic measures after VR intervention was found compared to the baseline ($p_0<0.05$), with a slight elevation in the mean score of all physiological measures, and a reduction in O_2 saturation. By comparing the standard care with VR intervention, a statistically significant

improvement was proved in all physiologic measures with VR intervention than the standard care ($p_2<0.05$).

Table (5) verified a lack of statistically significant difference in the self-reported pain level at baseline on both day 1 & day 2 ($p_1>0.123$). During day 1, the highest percent of the studied children reported either moderate (52.8%) or severe (30.6 %) pain after the standard care of AVF puncture with a statistically significant mean difference compared to the baseline ($p_0<0.001$). During day 2, most of them reported either mild (58.3%) or moderate (27.8%) pain and none of them had severe pain after VR intervention with a statistically significant mean difference compared to the baseline ($p_0<0.001$). A statistically significant difference was shown between the VR intervention and the standard care as well ($p_2<0.001$).

Table (6) portrayed no statistically significant difference in the observed pain behaviors during AVF procedure at baseline in both day 1 & day 2 ($p_1=0.905$). During day 1, a statistically significant elevation in the mean score of the observed pain behaviors was observed after the standard care compared to the baseline ($p_0<0.001$). During day 2, no statistically significant difference in the mean scores of the observed pain behaviors during VR intervention compared to the baseline ($p_0=0.153$). Moreover, a statistically significant difference was proved between VR intervention and the standard care concerning the observed pain behaviors ($p_2<0.001$).

Table (7) represent a high degree of immersion with the VR intervention among the studied children during AVF puncture procedure with a mean score of 29.11 ± 2.31with a mean percent score of 90.97 ± 7.23.

Table (8) illustrates a statistically significant variance in all physiological pain measures, behavioral pain, and numerical pain after the VR intervention while taking the baseline as a reference or day 1 as a reference ($p<0.001$). A large effect size of the VR intervention was detected among the studied children in all physiological pain measures while taking the baseline as a reference or standard care as a reference; heart rate ($\eta2=0.301, 0.715$), respiratory rate ($\eta2 = 0.398, 0.452$), oxygen saturation ($\eta2 = 0.631, 0.291$), systolic ($\eta2 =0.085, 0.776$), and diastolic ($\eta2 = 0.097, 0.821$) blood pressure, respectively. ANCOVA also proved a large effect size of the VR intervention on both numerical and behavioral pain while taking the baseline as a reference ($\eta2 = 0.571, 0.468$) or standard care as a reference ($\eta2 = 0.304, 0.166$), respectively.

Table (2): Distribution of the studied children according to their socio-demographic

Parameter	No. (n = 36)	%
Age (years)		
<15	22	61.1
≥15	14	38.9
Min. – Max.	11.0 – 18.0	
Mean ± SD.	14.22 ± 2.38	
Median	14.0	
Gender		
Male	12	33.3
Female	24	66.7
Educational stage		
Primary	6	16.7
Preparatory	16	44.4
Secondary	14	38.9
Child ranking		
First	16	44.4
Second	16	44.4
Third	4	11.2
Residence		
Rural	20	55.6
Urban	16	44.4

SD: **Standard deviation**

Table (3): Distribution of the studied children according to their medical history (n = 36)

Medical history of the child	No.	%
Duration of hemodialysis (years)		
<1 year	8	22.2
1 – < 5	12	33.3
5 – <10	12	33.3
≥10	4	11.1
Numbers of hemodialysis sessions per week		
3 sessions	36	100
Duration of hemodialysis session		
3 hours	20	55.6
4 hours	16	44.4
Site of AVF		
RT arm	14	38.9
LT arm	22	61.1
Chronic diseases associated with renal failure		
No	26	72.2
Hypertension	6	16.7
Heart diseases	2	5.6
Hypotension	2	5.6

Table (4): Distribution of the studied children according to their physiological measures of pain (n = 36)

Physiological measures of pain	Day 1		Day 2		Test of sig.(p_1)	Test of sig.(p_2)
	Baseline	Standard care	Baseline	VR		
	Mean ± SD.	Mean ± SD.	Mean ± SD.	Mean ± SD.		
Heart rate	72.14 ± 4.77	76.83 ± 5.37	71.83 ± 4.39	73.03 ± 4.46	t= 1.000 (0.324)	t=6.774* (<0.001*)
t(p_0)	**7.689*(<0.001*)**		**4.049*(<0.001*)**			
Respiratory rate	17.11 ± 0.95	18.56 ± 1.16	17.06 ± 0.86	17.28 ± 0.91	Z=0.535 (0.593)	Z=4.725* (<0.001*)
Z(p_0)	**4.880*(<0.001*)**		**2.530*(0.011*)**			
Oxygen saturation	96.58 ± 0.69	94.22 ± 1.07	96.75 ± 0.55	96.33 ± 0.76	Z=1.732 (0.083)	Z=5.170* (<0.001*)
Z(p_0)	**5.297*(<0.001*)**		**2.862*(0.004*)**			
Blood pressure						
Systolic	115.97 ± 9.24	120.28 ± 9.18	115.56 ± 8.52	117.22 ± 7.69	Z=0.714 (0.475)	Z=3.377* (0.001*)
Z(p_0)	**3.685*(<0.001*)**		**2.209*(0.027*)**			
Diastolic	70.42 ± 8.05	74.03 ± 7.82	70.56 ± 7.15	71.94 ± 6.89	Z=0.302 (0.763)	Z=2.976* (0.003*)
Z(p_0)	**3.720*(<0.001*)**		**2.332*(0.020*)**			

SD: **Standard deviation** **t: Paired t-test** Z: **Wilcoxon signed ranks test**

p_1: p value for comparing between **day 1 and day 2 in baseline**

p_2: p value for comparing between **standard care (day 1) and VR (day 2)**

p_0: p value for comparing between **baseline with either standard care or VR in each day**

*: Statistically significant at $p \leq 0.05$

Table (5): Distribution of the studied children according to their self-reported pain level using the numerical pain rating scale (n = 36)

Numerical pain rating level	Day 1				Day 2				Z(p_1)	Z(p_2)
	Baseline		Standard care		Baseline		VR			
	No.	%	No.	%	No.	%	No.	%		
No pain	5	13.9	0	0.0	8	22.2	5	13.9	1.541 (0.123)	5.125* (<0.001*)
Mild pain (1 – 3)	27	75.0	6	16.7	26	72.2	21	58.3		
Moderate pain (4 – 6)	4	11.1	19	52.8	2	5.6	10	27.8		
Severe pain (7 – 10)	0	0.0	11	30.6	0	0.0	0	0.0		
Mean ± SD.	1.78 ± 1.24		5.33 ± 1.66		1.53 ± 1.16		2.50 ± 1.48			
Z(p_0)	**5.270*(<0.001*)**				**3.953*(<0.001*)**					

SD: **Standard deviation** Z: **Wilcoxon signed ranks test**

p_1: p value for comparing between **day 1 and day 2 in baseline**

p_2: p value for comparing between **Standard care (day 1) and VR (day 2)**

p_0: p value for comparing between **baseline with either standard care or VR in each day**

*: Statistically significant at $p \leq 0.05$

Table (6): Distribution of the studied children according to their observed pain behaviors during AVF procedure (n = 36)

Behavioral pain scale	Day 1		Day 2		$Z(p_1)$	$Z(p_2)$
	Baseline	Standard care	Baseline	VR		
	Mean ± SD.	Mean ± SD.	Mean ± SD.	Mean ± SD.		
Total score (0–11)	1.39 ± 1.15	3.83 ± 1.86	1.39 ± 1.15	1.06 ± 0.86	0.120	4.919*
% Score	12.63 ± 10.48	34.85 ± 16.90	12.63 ± 10.48	9.60 ± 7.82	(0.905)	(<0.001*)
$Z(p_0)$	**4.839*(<0.001*)**		**1.428(0.153)**			

Z: **Wilcoxon signed ranks test** SD: **Standard deviation**
p_1: p value for comparing between **day 1 and day 2 in baseline**
p_2: p value for comparing between **standard care (day 1) and VR (day 2)**
p_0: p value for comparing between **baseline with either standard care or VR in each day**
*: Statistically significant at $p \leq 0.05$

Table (7): Distribution of the studied children according to the degree of immersion with the VR intervention during AVF puncture (n = 36)

Degree of immersion with the VR intervention	No		A little		A lot	
	No.	%	No.	%	No.	%
Sense of involvement						
1. Did the game grab your attention?	0	0.0	0	0.0	36	100.0
2. Were you interested and involved in the game?	0	0.0	0	0.0	36	100.0
3. Did you get used to playing the game quickly?	2	5.6	9	25.0	25	69.4
4. Did it feel like you were in control of what happened in the game?	1	2.8	10	27.8	25	69.4
Perceived realism of the VR experience						
5. Did the things you saw look real?	3	8.3	5	13.9	28	77.8
6. Did the way things moved, look real?	3	8.3	5	13.9	28	77.8
7. Did the things you heard sound real?	3	8.3	5	13.9	28	77.8
Sense of transportation into the VR experience						
8. Did it feel like you were there, really?	0	0.0	4	11.1	32	88.9
Feasibility						
9. Did you find the game easy to play	3	8.3	5	13.9	28	77.8
10. Were you worried about putting on the headset?	27	75.0	6	16.7	3	8.3
11. Was the headset comfortable when you had it on	0	0.0	4	11.1	32	88.9
12. Were the controls easy to use?	3	8.3	6	16.7	27	75.0
Satisfaction						
13. Did you enjoy the game?	0	0.0	0	0.0	36	100.0
14. Were you sad or disappointed when the game was over?*	33	91.7	3	8.3	0	0.0
15. Was the game interesting compared to other computer games you've played?	0	0.0	0	0.0	36	100.0
16. Would you like to play the game again?	0	0.0	0	0.0	36	100.0
Degree of immersion into the VR game	**(0–32)**					
Total mean score ± SD	29.11 ± 2.31					
Mean % Score ± SD	90.97 ± 7.23					

SD: Standard deviation

Table (8): Effect size of the VR intervention using ANCOVA test

Pain parameters	ANCOVA (reference Baseline)				ANCOVA (reference standard care)			
	F	Df	p	Partial η2	F	Df	p	Partial η2
Physiological parameters								
Heart rate	29.648*	1	<0.001*	0.301	173.321*	1	<0.001*	0.715
Respiratory rate	45.611*	1	<0.001*	0.398	56.994*	1	<0.001*	0.452
Oxygen saturation	117.901*	1	<0.001*	0.631	28.336*	1	<0.001*	0.291
Systolic Bp	6.425*	1	0.014*	0.085	238.462*	1	<0.001*	0.776
Diastolic Bp	7.450*	1	0.008*	0.097	315.612*	1	<0.001*	0.821
Numerical pain rating								
	91.846*	1	<0.001*	0.571	30.114*	1	<0.001*	0.304
Behavioral pain								
	60.784*	1	<0.001*	0.468	13.734*	1	<0.001*	0.166

Note: *Significant at P ≤0.05, Analysis of Covariance (ANCOVA) η2= Eta Squared (effect size)

Discussion

The existing study results accepted the study hypotheses and revealed that both subjective and objective pain scores had significantly decreased after applying the VR intervention which go in line with prior research hypotheses and with a large effect size for all the studied pain measures. In harmony, numerous studies noted a large effect size of VR interventions on pain scores among children undergoing different medical procedures such as blood sampling **(Gerçeker et al., 2020)**, venous port access in pediatric oncology units **(Semerci et al., 2021)**, and port-access using Huber needle among hematology-oncology pediatric patients **(Gerçeker et al., 2021)**. In contrast to, **Caruso et al., (2020)** noted a small effect size of VR interventions as the VR didn't reduce pain intensity or needle-associated fear among children undertaking vascular access, though it was accompanied with a great level of satisfaction. This finding could be attributed to the heterogeneity of the studied inpatient pediatric population besides the variation in the selected clinical settings during which the vascular access procedure was performed as well (preoperative center, radiology unit, cancer center, short stay unit, emergency department, intensive care units, and acute care units).

The present results depicted that utilizing the VR headset before AVF puncture significantly decreased the subjective pain scores as measured by the numerical pain rating scale. Although the pain intensity increased from baseline in the two sessions, it was significantly less when using the VR rather than during the standard nursing care. This finding may be explained on the basis that VR shifts the focus of attention from concentration on unpleasant stimuli, through alteration of the perceived environment. Besides, VR diminish memorization during the procedure, so any unpleasant stimulus will not have any effect on the current time. In accordance with these findings, a systematic review and meta-analytic study that assessed the effectiveness of VR interventions on children's pain scores regarding needle-related medical procedures compared to standard care methods. It depicts an effectiveness of deploying VR in children's pain scores where it significantly decreased the associated symptoms **(Czech et al., 2021)**. Moreover, many studies had also added to the growing body of literature supporting the values and usefulness of using VR in reducing children's pain related to different medical procedures in different medical settings. **(Chan et al., 2019; Gerçeker et al., 2020; Le May et al., 2020; Lopez-Valverde et al., 2020; Dawood et al., 2021; Althumairi et al., 2021).**

The changes in pain sensation were also objectively assessed to support the results of the subjective approach for pain assessment and the findings demonstrated a significant decrease in the total behavioral pain score when using VR versus the standard care. In accordance **Lee et al., (2021)** declared that Korean children who used VR had lower behavioral pain scores than those in the control group in analyzing the feasibility and potential efficacy of VR on young children during intravenous placement in the pediatric emergency department. In contrast, a systematic review by **Lambert et al., (2020)** to investigate the efficiency of VR interventions and its adverse effects for children (0 to 18 years) with acute pain in different healthcare settings, mentioned that a very limited number of studies stated no beneficial effect of VR compared to the greater number of studies that favor and recommend its use in different healthcare settings. This discrepancy may be due to the different ages and developmental stages of children and their different perceptions and reactions to pain. In addition to, the dissimilarities in the medical procedures itself (e.g. venipunctures, intramuscular injections, burn wound dressings, hemodialysis sessions), and the resulting level of pain experienced.

The physiologic parameters related to pain were also measured, and a significant improvement among all of them was observed when using the VR versus the standard care. This finding may be attributed to the fact that pain causes a marked changes in vital signs and when this pain is eased, the vital signs return to their normal state. This result was confirmed in an Indian study by **Mohanasundari et al., (2021)** which stated that heart rate and

respiratory rate which were measured during the painful procedure were more in the control group compared to VR. The study examined the effectiveness of VR on pain among children undergoing painful procedures. Conversely, **Rao et al., (2019)** who assessed the effectiveness of VR as a distraction tool on pain perception in children undergoing restorative treatment, found that the oxygen saturation levels during and after the treatment was not statistically significant. This may be due to the varied intensity of the experienced pain among the children and the associated increase in the metabolic rate that consumes more oxygen, given the different nature of the procedure itself.

When using the VR technology, children no longer discriminate between the external environment, which is stressful as represented by the hemodialysis session (hemodialysis machine, led lights, alarms, technologies, hospital odors, noises hospitals, and hospital colors) and the pleasant reality that is going through VR. This experience produces a profound state of distraction and total immersion in the new reality **(Burrai et al., 2019)**. In agreement with the previous evidence, the current results revealed a great satisfaction and increased degree of immersion in the game among the children in the study, where all the children reported that they would like to play the game again. This may be explained by the influence of the VR technology by allowing children to enjoy the sensation of being, acting, and living inside the virtual environment during the painful situations. This result was reinforced by **Walther-Larsen et al., (2019)** who performed a study in Denmark to investigate the effect of immersive VR for pediatric procedural pain and reported that they found a high level of patient satisfaction with using the VR three-dimensional interactive game, and all children reported their preference for the VR as a distraction for a later procedure.

A movement toward non-sedating medical procedures using VR interventions may lessen the side effects of medications and improve overall health outcomes for children with chronic medical needs **(Gold et al., 2021)**. Thus, the results of the present study are most appropriate for being used with children during hemodialysis sessions because of the previously mentioned benefits.

Conclusion

The present study accepted the alternative hypotheses where it proved the efficiency of the VR intervention in reducing pain intensity level during AFV puncture procedure among children undertaking hemodialysis. This is evidenced by improvement of the physiological measures and lower self-reported pain levels by the studied children after AVF intervention, in addition to lower observed pain behaviors during the AVF procedure with the VR intervention than the standard care.

Recommendations

The subsequent recommendations were yielded based on the existing study findings:

- Pediatric hemodialysis units should incorporate the VR intervention during AVF puncture in their routine care.
- Negotiation with the ministry of health to support the pediatric hemodialysis units through assuring the availability of VR glasses and related equipment.
- Devoting hemodialysis units for children suffering from renal failure in El-Behira Governorate as they are integrated with adult patients.
- Replication of the current study on a larger sample size from different governorates to support the existing evidence.
- Build capacity of the health care staff through in-service educational and training programs about pain assessment methods and implementation of VR intervention.

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