Virtual Reality Assisted Anesthesia (VRAA) during Upper Gastrointestinal Endoscopy: Report of 115 Cases— Analysis of Physiological Responses

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Abstract: Medical procedures, open surgery, physical therapy, and rehabilitation have benefited from the effectiveness of technologies like VR as a supplemental tool to pharmacological pain management strategies, such as anesthesia. The present study elaborates on previously reported findings (Mosso *et al*., 2016) of virtual reality assisted anesthesia during upper gastrointestinal surgery of 115 patients.

Methodology: 115 patients were administered an upper GI Endoscopy with local anesthesia. Prior to endoscopies, they were divided into two groups, one supplemented with VR (n = 56) and the other without VR (n = 59). The VR group was presented with one of four relaxation environments (forest, cliff, castle, or beach) through head mounted displays. Vital signs including heart rate (HR), respiration rate (RR), and oral secretion were measured before, during, and after endoscopies.

Results: Single factor ANOVAs indicate a reduction in visceral response (heart rate, respiratory rate, and oral secretion) in subsets of patients during upper GI in the VR group compared to the non-VR group. Subjective ratings of pain were also significantly lower. Differences and effect sizes for gender, age, and procedure type are discussed.

Conclusions: VR is an effective supplemental tool to pharmacological agents during upper GI. Findings suggest that VR distraction may considerably reduce the need for medication during surgical procedures.

Keywords: Panendoscopy, Anesthesia, Virtual reality, Pain distraction, Gastrointestinal endoscopy, Surgery.

An upper gastrointestinal endoscopy explores gastrointestinal (GI) organs such as the esophagus, stomach, and second portion of the duodenum [1]. A colonoscopy explores structures such as the end of ileum, cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum. In conjunction with an ileoscopy and a retrograde endoscopic cholangiography, these procedures, constitute a Gastrointestinal Endoscopy. Today, over one million GI endoscopies are performed annually, yet a shortage of specialists to perform these procedures is creating a need for more efficient and effective practices [2, 3]. As with any medical procedures, it is pertinent to maintain and control patient comfort. While approaches to this aspect of surgery vary, common practices involve anesthetics and/or pain distraction techniques. In the present study, local anesthesia was administered, enabling patients to stay more aware and responsive [4-18]. Previous studies have shown that immersive virtual reality [VR] distraction is a very useful adjunctive therapy in the management of clinical pain syndromes [19-22]. Notably, Vázquez and colleagues [22] found that when immersed in virtual environments, patients' postoperative anxiety was reduced. Additionally, other studies have used distraction techniques, such as listening to music or watching movies, during procedures to decrease intraoperative anxiety and pain ratings [20, 21].

For more than twenty years, healthcare specialists, from physicians to psychologists, have supplemented treatments and surgeries and even implemented preventative methods using VR [22-38]. Researchers and clinicians have applied VR as a supplementary tool to treat behavioral disorders and phobias [39, 40], reduce anxiety [22], and manage chronic pain in patients [25, 27, 28, 32-38]. These interventions underscore the widespread applicability of VR to serve as an adjunctive pain management tool in a variety of

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healthcare procedures. As such, in a precursor to this article, we examined and reported the first clinical application of VR as a somatic pain distraction technique during endoscopic procedures [41]. Focusing on subjective reports of discomfort, we found VR to significantly reduce pain during surgical procedures administered with local anesthesia [41]. While we are still seeking methods for quantifying pain levels, we have had success with non-invasive physiological monitoring.

The ability of VR to influence autonomic responses is well documented. Researchers reference these capabilities in studies addressing anxiety disorders [26], dental pain [35], and posttraumatic stress disorder (PTSD) [42]. Research validating the efficacy of VR to elicit both arousal and relaxation reinforces these findings [42-44]. Monitoring physiological arousal is increasingly becoming an integral feature of virtual reality therapy (VRT) for pain management (see Table **1**). Mosso and colleagues demonstrated the link between autonomic responses to pain and patients' respective subjective ratings [37]. This study found positive correlations between physiological measurements, such as respiration rate and heart rate, and subjective Likert scale ratings of pain in patients who had recently undergone cardiac surgery. Furthermore, they concluded that immersion in VR can enhance traditional pain management strategies and aid in the reduction of stress [37].

While VR has been implemented as a stand-alone treatment option for pain management, the ability to use it in conjunction with traditional analgesic options, such as anesthesia, offers greater flexibility. Additionally, research suggests that VR may aid in reducing the amount of medication needed for particular surgeries [36]. The present study aims to expand on these findings and explore relationships between subjective and objective measurements of pain in patients undergoing endoscopic procedures. Our initial study [41] reports patients' subjective levels of pain during endoscopic procedures. We also measured a number of important physiological parameters to see if patients had autonomic responses to VR therapy. Objective physiological measures will allow us to quantitate the effective use of VR assisted anesthesia (VRAA) for non-complicated patients in need of upper endoscopic procedures. Thus, extending our initial examinations, we explore the relationship between subjective and objective measurements of pain, the effects of VRAA on physiological measurements of pain, and assess the effectiveness of VRAA in specific procedures, age ranges, and within genders.

Table 1:

Title/Author	Method	Results
Physiological Monitoring as an Objective Tool in Virtual Reality Therapy. Wiederhold BK, Jang DP, Kim SI, Wiederhold MD	Nonphobics (n = 22) were outfitted with a head mounted display presenting six different 3D virtual flying scenes. Aviophobics (n = 36) were first taught relaxation techniques and gradually exposed to flying scenarios. Skin resistance, skin temperature, and heart rate were measured via sensors place on the body and a Likert based anxiety scale was administered.	The intervention was effective in reducing phobics' physiological and subjective measurements of stress.
Clinical Use of Virtual Reality Distraction System to Reduce Anxiety and Pain in Dental Procedures. Wiederhold MD, Gao K, Wiederhold BK.	Five adult patients participated voluntarily. The clinician performed the procedure on each patient for five minutes without VR and then five minutes with VR. Four relaxation worlds were presented in the head mounted displays. The authors measured physiological responses throughout.	VR reduced average heart rate and subjective measurements of stress, suggesting the effectiveness of VR as a technique to control fear and anxiety during dental procedures.
Effects of physiotherapy associated to virtual games in pain perception and heart rate variability in cases of low back pain. Zavarize SF, Paschoal MA, Wechsler SM.	Twenty-one (21) adults diagnosed with lower back pain were split into two groups, both receiving physical therapy, but only one supplemented treatment with virtual games.	Patients in the virtual game group exhibited greater reduction in subjective pain and heart rate variability. This authors suggests the virtual games aid in pain distraction and influence pain perception.
Virtual Reality for Pain Management in Cardiac Surgery. Vasquez JL, Gao K, Wiederhold BK, Wiederhold MD	Sixty-seven patients who had recently received cardiac surgery participated. Each patient navigated through virtual world designed for pain distraction for thirty minutes. Physiological measurements included heart rate, respiration rate, and arterial pressure, while subjective pain was measured on a visual analog scale (VAS).	Results indicate positive correlations between respiration rate, heart rate, and mean arterial pressure and scores on the VAS.

METHODS

Participants

This study took place at the Endoscopy Service at the Pisanty Clinic of the ISSSTE in Mexico City. 115 outpatients participated with full informed consent. Thirty four males and eighty one females without cardiorespiratory disease participated (18 to 90 years old). The non-VR group (n=59) received local anesthesia, while the VR group (n=56) received local anesthesia and an immersive VR relaxation environment. In the non-VR group, the age range was 27 to 81 years (M = 53.2), while the treatment group ranged between 27 and 86 years of age (M =47.6). 70% were female and 30% were males.

Stimulus

The immersive virtual scenarios used were *Enchanted Forest*, *Magic Cliff*, *Enchanted Castle*, and *Shell Island*, all developed at The Virtual Reality Medical Center, La Jolla, California (Figure **1**). Each of these four environments are clinically validated pain management and relaxation worlds to reduce autonomic stress responses.

Materials

Necessary equipment for endoscopic procedures included an optic fiber to transmit the image to a monitor, a light source for illuminating the inside of the cavities and insufflation to distend the virtual spaces of organs. Additionally, instruments inserted through the endoscope were used to take samples for cytological and histological examinations (Biopsy forceps), and to cauterize, infiltrate, dissect, cut, and remove superficial injuries. Heart rate and additional sensors were used to measure each patient's vital signs. Oral gauze pads were also used to measure oral secretion.

Procedures

All patients were referred to the clinic with benign diagnoses of Peptic Ulcer Disease (PUD), Gastritis, Esophageal Reflux, upper GI bleeding, Duodenogastric Reflux, Esophageal Varix, and Human Immunodeficiency Virus (HIV) amongst others (see Table **2**). To become accustomed to the intervention, the VR group was trained how to navigate the virtual environment prior to the procedure. We performed upper endoscopy explorations with biopsy tests. Prior to the beginning of surgery, all patients were fitted with heart rate monitors on their chest, respiration monitors around their abdomen, and gauze pads placed in their mouths. Each patient's vital signs were measured before, during, and after the procedure, as were their subjective perceptions of pain, gathered via self-report on the Visual Analog Scale (VAS). With the patient seated, initial vital signs and patient pain were recorded. All procedures were done under local anesthesia—the physician sprayed 5 to 7 shots of spray-xylocaine into the oral cavity before beginning the procedure. With the patient laying on their left side decubitus with an oral protector (nozzle), the physician set up the head mounted display (HMD) linked to a laptop in order to present one of the four virtual environments (see Figure **1**). The physician then inserted the endoscope through the oral cavity into the upper esophagus. Next, the patient was instructed to swallow in order to insert the endoscope through the esophagus. The VR headset and environment was turned on and the patient began navigation. Continuing

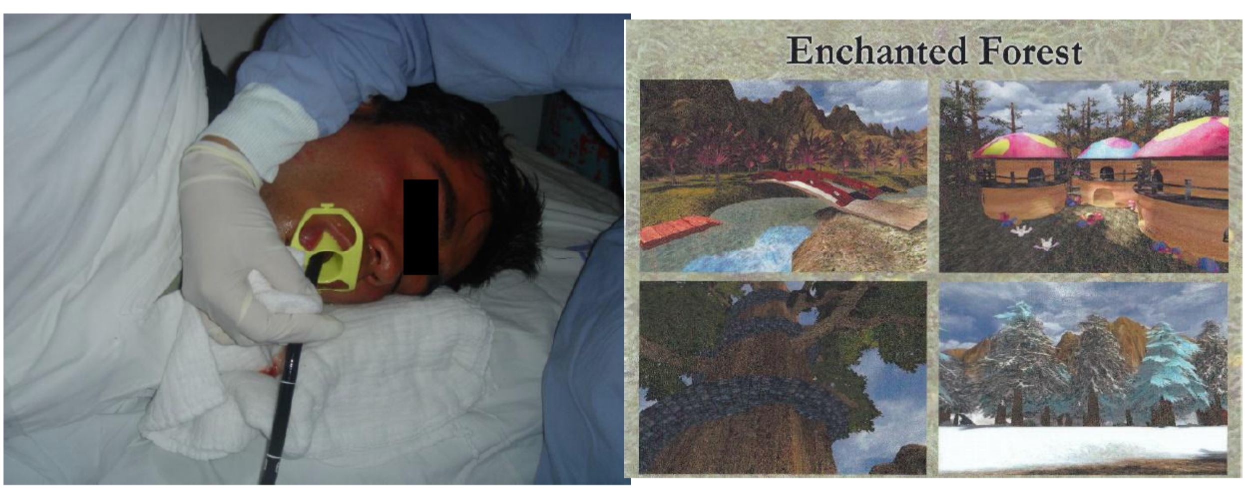

Figure 1: Virtual Reality Head Mounted Display (HMD) and one of four virtual environments displayed to patients.

Table 2: Frequency of Diagnosis in both Groups

Diagnosis	Frequency with VR. (56 cases)	Percentage with VR (56 cases)	Frequency with no VR. (59 cases)	Percentage with no VR (59 cases)
Normal	10	17.8%	12	20.33%
Peptic Ulcer Disease	12	21.42%	8	13.55%
Gastritis	4	7.14%	1	1.69%
Hiatal Hernia	26	46.42%	26	44.06%
Gastroesophageal Reflux	3	5.3%	5	8.47%
Esophagitis	3	5.3%	12	20.33%
Human Inmunodefiency Virus	2	3.57%	0	0%
Esophageal Varix	3	5.3%	1	1.69%
Upper bleeding	1	1.78%	0	0%
Duodenogastric reflux	0	0%	4	6.77%

to explore the stomach and gastric antrum, the endoscopist performed a retrovision maneuver to explore the gastric fundus and its gastric body. Because the bending of an endoscope can cause distention (air inflation) and pain, we decided that this was the optimal time to record intraoperative vital signs. This data was recorded as *Heart Rate (HR) During, Respiration Rate (RR) During,* and *Face*—or subjective, self-report pain—*During*. If necessary, the endoscopist took biopsy samples from the fundus, body, or gastric antrum. We continued with the exploration of the first and second portion of duodenum where vital signs were again measured. The procedure ended and the endoscope was removed. After the endoscope was extracted, gauze pads were analyzed. These oral secretion measurements served as indicators of stress levels during the procedure. Patients in the VR group continued immersion in the virtual environment for 10 minutes after the conclusion of the procedure while the endoscopist cleaned the equipment. At this time, the last vital signs, pain ratings, and gauze pad measurements were recorded.

Measures

Subjective vital signs were recorded before, during, and after the procedure via the pain Visual Analog Scale (VAS). This Likert scale instructed patients to rate pain on a scale of 0-10 (0 = no pain, 10 = maximum pain). Physician Stress was measured on a self-report scale of 1-3 (1 = no stress, 2 = some stress, and 3 = maximum stress). Objective measures of patient stress included hear rate (HR), respiration rate (RR), and oral salivation. HR and RR were both measured via sensors placed on the patient's body. To measure HR, sensors were placed on the chest, while waistband sensors were placed around the abdomen to measure RR. Gauze pad salivation was measured on a scale of 0-3. A score of zero (0) meant there was no salivation. If saliva covered one-third of the gauze, a score of one (1) was recorded. A score of two (2) was recorded if two-thirds of the gauze was covered and a score of three (3) if the gauze was completely covered in saliva or more.

Statistical Analysis

An Analysis of Variance (ANOVA) was conducted between the VR and non-VR groups. Additional ANOVA tests were run to assess physiological differences according to age, gender, and procedural type both between and within groups. Alpha was set at $p \leq .05$. Cohen's d was also calculated as a measure of effect size.

RESULTS

As reported in our initial article [41], overall pain, as measured on the VAS scale (0= no pain, 10= maximum pain) was significantly lower in the VR group (M_{VR} = 4.536, SD_{VR} = 2.662; $M_{non\text{-}VR}$ = 5.814, $SD_{non\text{-}VR}$ = 2.921, F (1, 113) = 5.991, p =.016, d =.469). While statistically non-significant, the average time per procedure—in minutes—with VR was 30% faster than without (M_{VR} = 5.17, SD_{VR} = 1.523; $M_{non\text{-}VR}$ = 5.97, $SD_{non\text{-}VR}$ = 3.279, F (1, 111) = 2.333, p =.13, d =..29); a clinically significant difference between groups supported by a small effect size. When operating on the VR group, the physician rated his stress lower (M_{VR} = 1.43, SD_{VR} = .599) than when operating on the non-VR group ($M_{non\text{-}VR}$ = 1.64, $SD_{non\text{-}VR}$ = .689 F (1,113) = 3.19, p = .077, d = .34) (1=no stress, 2=some stress, 3=much stress) [41].

Table 3: Comparison between Overall VR Autonomic Response vs no VR Autonomic Response during Upper Gastrointestinal Endoscopy with Local Anesthesia

Measurement	Virtual Reality	No Virtual Reality	*p*(α = .05)
Pain During Procedure (0 = much pain, 10 = no pain)	4.536	5.814	0.016*
Heart Rate During Procedure (BPM)	117.911	116.492	0.771
Respiration Rate During Procedure (RR/minute)	22.536	24.593	0.022*
Oral Secretion During Procedure	1.571	2.322	.000**
Physician Stress During Procedure (1 = no stress, 3 = much stress)	1.429	1.644	0.077
Length of Procedure (minutes)	5.35	7.08	0.186

*p < .05,**p < .001.

Analysis of physiological measurements identified respiration rate during the procedure to be significantly lower in the VR group (M_{VR} = 22.536, SD_{VR} = 4.796) than the non-VR group ($M_{non\text{-}VR}$ = 24.593, $SD_{non\text{-}VR}$ = 4.713, F (1, 113) = 5.381, *p* =.022, *d* = .437), along with salivation levels (M_{VR} = 1.57, SD_{VR} = .955, $M_{non\text{-}VR}$ = 2.32, $SD_{non\text{-}VR}$ = .916, F (1,113) = 21.123, *p* <.001, *d* = .865) (Table **3**, Figure **2**). Overall HR was not significantly different in this study, however, subgroups of patients did show reduced HR. Our next study will measure heart rate variability (HRV) as this has been shown to be a more sensitive indicator of stress and pain [44].

There were no between gender differences on any physiological or subjective scales. However, within gender comparisons between the VR and non-VR groups suggest a strong effect of VR on salivation levels (Figure **3**). Males in the VR group produced nearly half as much saliva as males in the non-VR group (M_{VR} = 1.38, SD_{VR} =.973, $M_{non\text{-}VR}$ = 2.46, $SD_{non\text{-}VR}$ = .776; *F* (1, 32) = 11.459, *p* = .002, *d* = 1.231). Females in the VR group also secreted significantly less than their non-VR group counterparts (M_{VR} = 1.68, SD_{VR} =.867, $M_{non\text{-}VR}$ = 2.28, $SD_{non\text{-}VR}$ = .861, F (1, 79) = 9.503, *p* = .003, *d* = .700).

Differences in physiological and subjective measurements of pain were also assessed in relation to the four most frequent diagnoses. Patients were most often diagnosed with either a hiatal hernia (n = 54), normal (n = 22), peptic ulcer (n = 22), or reflux (n = 10). Across these four most common diagnoses, we found notable differences, presented in Table **4**. First, heart rate during hiatal hernia procedures was slightly lower in the non-VR group than in the VR group (M_{VR} = 123.58, SD_{VR} = 18.67, $M_{non\text{-}VR}$ = 119.9, $SD_{non\text{-}VR}$ = 23.66, F (1, 52) = .407, *p* = .526, *d* = .177). Similar patterns are reflected in peptic ulcer (M_{VR} = 117.8, SD_{VR} = 24.78, $M_{non\text{-}VR}$ = 115.6, $SD_{non\text{-}VR}$ = 27.27, F (1, 20) = .036, *p* = .851, *d* = .088).

Comparisons of respiration rate between diagnoses also elucidated clinically significant differences suggesting patients in the VR group were more relaxed

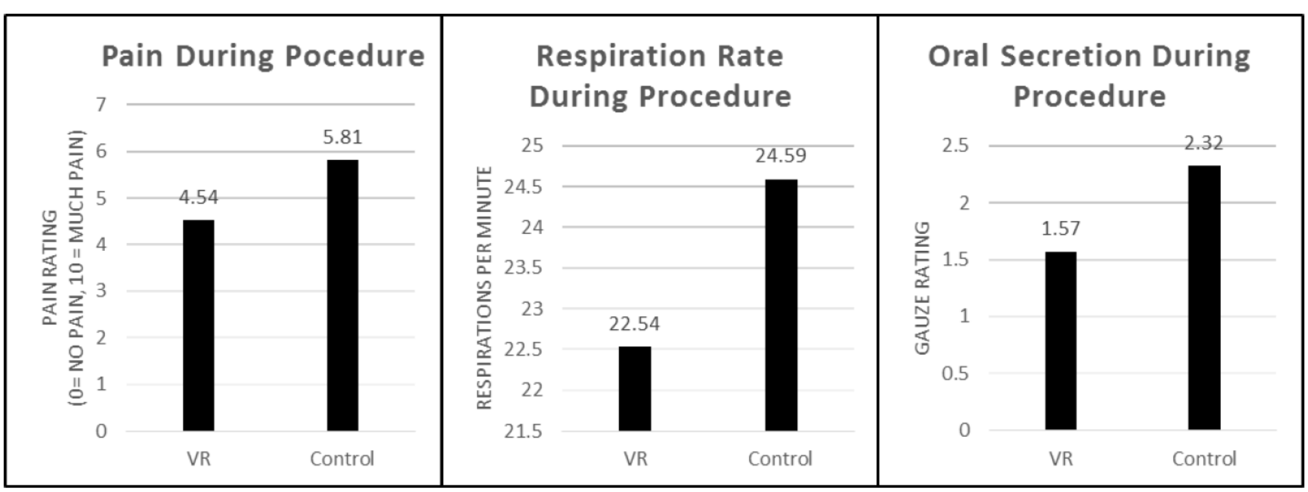

Figure 2:

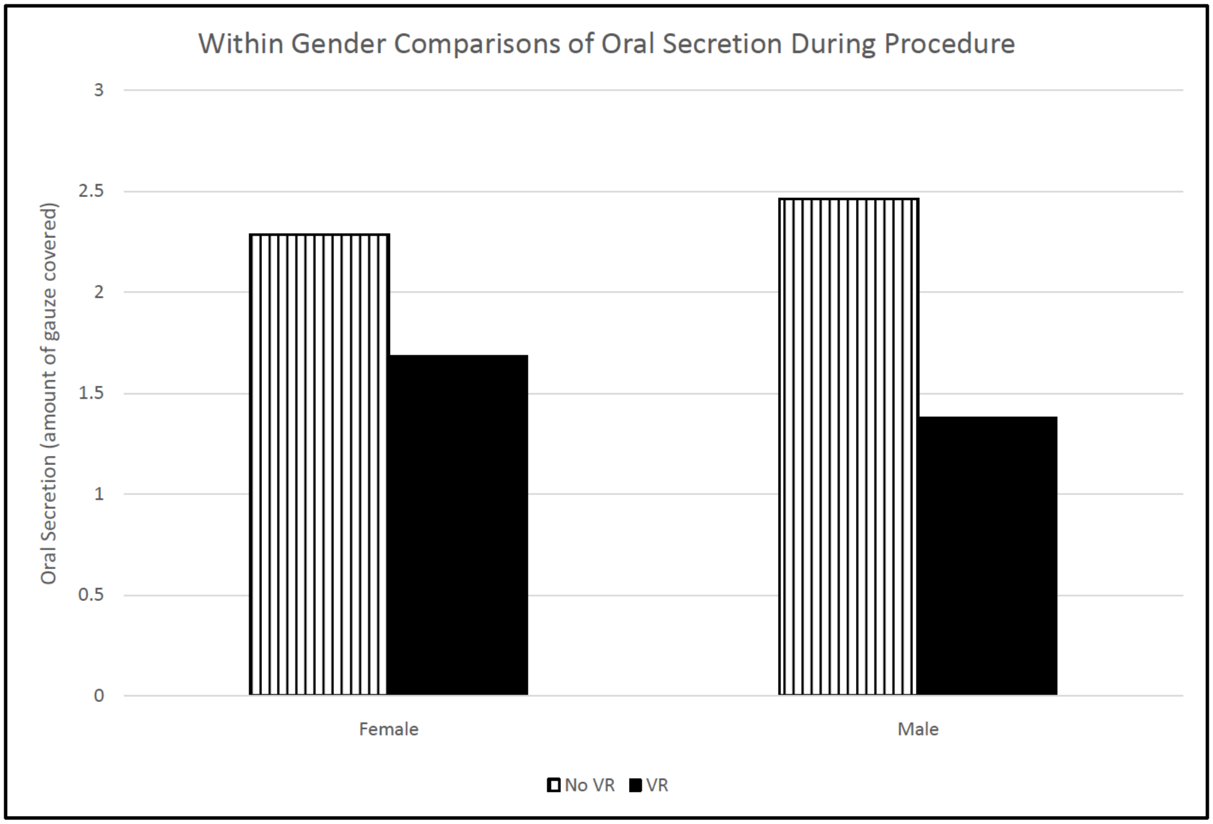

Figure 3:

Table 4: Comparison of Vitals of 4 Most Frequent Patient Diagnoses between both Groups

Heart Rate During Procedure (BPM)				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	123.58	119.86	0.526	-3.01%
Normal (no GI disease)	105.30	119.00	0.331	13.01%
Peptic Ulcer	117.79	115.63	0.851	-1.84%
Reflux	106.00	108.00	0.917	1.89%
Respiration Rate During Procedure (RR/minute)				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	22.58	23.68	0.412	4.87%
Normal (no GI disease)	22.70	25.42	0.149	11.97%
Peptic Ulcer	22.93	24.00	0.547	4.67%
Reflux	22.00	29.71	0.082	35.06%
Pain During Procedure (0 = no pain, 10 = much pain)				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	4.96	5.50	0.493	10.85%
Normal (no GI disease)	2.80	6.50	0.002*	132.14%
Peptic Ulcer	4.64	7.88	0.013*	69.62%
Reflux	5.33	4.43	0.608	-16.96%

(Table 4). Continued.

Oral Secretion During Procedure				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	1.63	2.50	0.001*	53.4%
Normal (no GI disease)	1.50	2.17	0.060	44.44%
Peptic Ulcer	1.38	2.25	0.062	63.04%
Reflux	1.67	2.00	0.611	20.00%
Length of Procedure (minutes)				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	5.35	5.43	0.881	1.54%
Normal (no GI disease)	4.50	12.33	0.228	174.07%
Peptic Ulcer	5.32	5.44	0.861	2.31%
Reflux	4.67	4.71	0.968	1.02%
Physician Stress During Procedure (1 = no stress, 3 = much stress)				
Diagnosis	**VR**	**No VR**	**p (α = .05)**	**% Change**
Hiatal Hernia	1.46	1.86	0.023*	27.07%
Normal (no GI disease)	1.50	1.33	0.608	-11.11%
Peptic Ulcer	1.21	1.56	0.102	28.10%
Reflux	1.33	1.43	0.807	7.14%

$^*p < .05$, $^{**}p < .001$.

than those in the non-VR group. Patients in the VR group diagnosed with hiatal hernia had lower RR than the non-VR group (M_{VR} = 22.58, SD_{VR} = 4.97, $M_{non\text{-}VR}$ = 23.68, $SD_{non\text{-}VR}$ = 4.81, F (1, 52) = .685, p = .412, d = .23), as did those with peptic ulcers (M_{VR} = 22.93, SD_{VR} = 4.70, $M_{non\text{-}VR}$ = 24, $SD_{non\text{-}VR}$ = 1.85, F (1, 20) = .376, p = .547, d = .285), reflux (M_{VR} = 22, SD_{VR} = 6.93, $M_{non\text{-}VR}$ = 29.71, $SD_{non\text{-}VR}$ = 5.12, F (1, 8) = 3.95, p = .082, d = .1.532), and normal diagnoses (M_{VR} = 22.7, SD_{VR} = 4.14, $M_{non\text{-}VR}$ = 25.42, $SD_{non\text{-}VR}$ = 4.3, F (1, 20) = 2.255, p = .149, d = .674).

Assessment of subjective pain ratings across diagnoses showed differences in all groups. Hiatal hernia patients reported slightly lower pain in the VR group compared to non-VR (M_{VR} = 4.96, SD_{VR} = 2.51, $M_{non\text{-}VR}$ = 5.5, $SD_{non\text{-}VR}$ = 3.16, F (1, 52) = .477, p = .439, d = .192). Statistically significant differences in subjective pain were found in peptic ulcer (M_{VR} = 4.64, SD_{VR} = 3.3, $M_{non\text{-}VR}$ = 7.88, $SD_{non\text{-}VR}$ = 1.25, F (1, 20) = 7.486, p = .013, d = 1.272) and normal (M_{VR} = 2.8, SD_{VR} = 2.25, $M_{non\text{-}VR}$ = 6.5, $SD_{non\text{-}VR}$ = 2.66, F (1, 20) = 12.18, p = .002, d = 1.567) diagnoses. Contrarily, patients diagnosed with reflux reported higher pain during the procedure in the VR group than in the non-VR (M_{VR} = 5.33, SD_{VR} = 2.08, $M_{non\text{-}VR}$ = 4.43, $SD_{non\text{-}VR}$ = 2.57, F (1, 8) = .284, p = .608, d = .411).

Analyzing oral secretion as a physiological marker of stress substantiated our hypothesis of the analgesic effects of VR during surgical procedures. For those diagnosed with hiatal hernia, oral secretion was significantly lower in the VR group (M_{VR} = 1.63, SD_{VR} = 1.06, $M_{non\text{-}VR}$ = 2.5, $SD_{non\text{-}VR}$ = .694, F (1, 52) = 12.28, p < .001, d = .972). Additionally, VR had a medium to large effect on oral secretion for normals (M_{VR} = 1.5, SD_{VR} = .707, $M_{non\text{-}VR}$ = 2.17, $SD_{non\text{-}VR}$ = .835, F (1, 20) = 3.985, p = .06, d = .896), peptic ulcer (M_{VR} = 1.38, SD_{VR} = .842, $M_{non\text{-}VR}$ = 2.25, $SD_{non\text{-}VR}$ = 1.282, F (1, 20) = 3.918, p = .062, d = .920), and reflux (M_{VR} = 1.67 , SD_{VR} = 1.156, $M_{non\text{-}VR}$= 2.0, $SD_{non\text{-}VR}$ = .816, F (1, 8) = .28 , p = .611, d = .408). Time per procedure was lower for the VR group across all four major diagnoses and physician stress was lower in the VR group in all diagnoses except for a slight increase in procedures on normal diagnoses. No complications were present in this study.

Final analyses explored age differences between the two groups. Splitting each group into three separate age ranges, 20-39, 40-59, and 60 and above (60+), these tests produced varied results (Table **5**). For 20-39 year old patients, oral secretion (M_{VR} = 1.69 , SD_{VR} = .855, $M_{non\text{-}VR}$ = 2.62, $SD_{non\text{-}VR}$ = .768, F (1, 24) = 8.38 , p = .008, d = 1.182), RR (M_{VR} = 21.85 , SD_{VR} = 2.968, $M_{non\text{-}VR}$ = 25.08, $SD_{non\text{-}VR}$= 5.964, F (1, 24) = 2.863 , p =

Table 5: Group Differences by Age Range

Age	VR	Non-VR	*p* (α = .05)	%Change
20-39 Years Old				
Oral	1.69	2.62	0.008*	54.55%
Face	4.00	4.77	0.541	19.23%
Respiration Rate	21.85	25.08	0.104	14.79%
Heart Rate	120.46	113.69	0.487	-5.62%
40-59 Years Old				
Oral	1.67	2.33	0.005*	40.00%
Face	5.03	6.44	0.040*	28.11%
Respiration Rate	23.09	25.37	0.092	9.87%
Heart Rate	119.15	121.70	0.720	2.14%
60+ Years Old				
Oral	1.11	2.11	0.011*	89.47%
Face	3.89	5.63	0.134	44.81%
Respiration Rate	22.00	23.16	0.453	5.26%
Heart Rate	114.78	111.00	0.708	-3.29%

$^*p < .05$, $^{**}p < .001$.

.104, d = .691), and subjective pain (M_{VR} = 4.0 , SD_{VR} = 2.86, $M_{non\text{-}VR}$ = 4.77, $SD_{non\text{-}VR}$ = 3.44, F (1, 24) = .384 , p = .541, d = .253) was lower in the VR group, while HR was slightly lower in the non-VR group (M_{VR} = 1120.46 , SD_{VR} = 17.54, $M_{non\text{-}VR}$ = 113.69, $SD_{non\text{-}VR}$ = 29.81, F (1, 24) = .498 , p = .487, d = .288). Patients between the ages of 40 and 59 showed a similar trend. Oral secretion (M_{VR} = 1.67, SD_{VR} = .989, $M_{non\text{-}VR}$= 2.33, $SD_{non\text{-}VR}$ = .734, F (1, 58) = 8.44 , p = .005, d = .767), subjective pain (M_{VR} = 5.03 , SD_{VR} = 2.71, $M_{non\text{-}VR}$ = 6.44, $SD_{non\text{-}VR}$ = 2.439, F (1, 58) = 4.42 , p = .04, d = .555), and RR (M_{VR} = 23.09, SD_{VR} = 5.519, $M_{non\text{-}VR}$ = 25.37, $SD_{non\text{-}VR}$ = 4.584, F (1, 58) = 2.942 , p = .092, d = .453) were lower in the VR group. However, unlike patients between 20 and 30 years old, those in the VR group between 40 and 59 had a lower HR than their non-VR comparisons (M_{VR} = 119.15 , SD_{VR} = 26.9, $M_{non\text{-}VR}$ = 121.70, $SD_{non\text{-}VR}$= 27.682, F (1,58) = .130 , p = .719, d = .095). Lastly, patients 60 years old and above mirrored differences of the 20-39 year old patients. Oral section (M_{VR} = 1.11 , SD_{VR} = .6, $M_{non\text{-}VR}$ = 2.11, $SD_{non\text{-}VR}$ = .994, F (1, 26) = 7.589 , p = .011, d = 1.157), pain rating (M_{VR} = 3.89 , SD_{VR} = 1.9, $M_{non\text{-}VR}$ =5.63, $SD_{non\text{-}VR}$ = 3.095, F (1, 26) = 2.4 , p = .134, d = .650), and RR (M_{VR} = 22 , SD_{VR} = 4.272, $M_{non\text{-}VR}$ = 23.16, $SD_{non\text{-}VR}$= 3.5, F (1, 26) = .580 , p = .453, d = .32) were all lower in the VR group with moderate to strong effect sizes. Finally, HR showed a slight increase in the VR group for patients 60 years and older (M_{VR} = 114.78, SD_{VR} = 24.565, $M_{non\text{-}VR}$= 111, $SD_{non\text{-}VR}$ = 24.709, F (1, 26) = .143, p = .708, d = .159).

DISCUSSION

The current study indicates the effectiveness of VR as an assistive analgesic. Our preliminary study with this patient sample [41] suggested the efficacy of VRAA to lower patients' perceived pain by immersing them in clinically validated virtual reality worlds. In addition to that report, we also assessed the capability of VR to manage physiological manifestations of pain, stress, and anxiety in this paper. Statistical analyses reveal interesting results and relationships between physiological manifestations of pain and patients' self-report levels of pain.

First, identifying significant decreases in respiration rate in the VR group suggests that patients, when immersed in virtual worlds, are relaxing more than their non-VR counterparts. Next in the comparisons between groups, we identified significantly lower oral secretion levels in the VR group. This finding supports our initial report of decreased perceived pain in the VR group, as oral secretion is traditionally measured as an autonomic indicator of pain. In addition, when assessing differences within genders, both males and females in the non-VR group secreted nearly twice as much as their VR group comparisons. We did, however, find HR to be increased in some subsets and decreased in other subsets when comparing the VR to the non-VR groups. We suspect that while heart rate can be an indicator of stress, it is rather a characteristic of increased immersion in the virtual environments. In fact, heart rate may not be as valid of a measurement for understanding pain as previously thought. Instead, as Wilhelm and colleagues [45] have implied in a study of virtual reality exposure therapy, the assessment of heart rate variability may be a more valid measure of emotional processing.

Further exploration uncovered the efficacy of VR during specific procedures. We assessed group differences across diagnoses, presented in Table **4**. These results suggest the capability of VR to reduce physiological measurements of pain including respiration rate and oral secretion and reflect the increase in heart rate found in preliminary analyses. Respiration rate decreased across the four most common diagnoses between 4% and 35%. Oral secretion exhibited the most profound differences, with the VR group secreting 45% less, on average, than the non-VR group. This measurement was the most consistent throughout the trial and suggests its validity as a predictive construct of autonomic arousal. In future studies, we will measure Heart Rate Variability (HRV), skin temperature, skin conductance, and the electroencephalogram (EEG) using a quantitative EEG (qEEG) device. Finally, our assessment of age differences shows lower respiration rate, oral secretion, and perceived pain across each age interval, while hear rate, again, maintained or slightly increased between groups.

Overall, we conclude that the ability of the VR pain management intervention to produce statistically significant lower levels of reported pain, respiration rate, and oral secretion underlines its capability as an effective tool in managing physiological responses to pain. The vast differences in oral secretion between the non-VR and VR groups is important as it highlights the relationship between arousal and pain. Additionally, time per procedure was decreased for patients in the VR group, a clinically significant outcome. Heart rate measurements during VR assisted procedures show variable results. Simple heart rate measurement is useful in a number of clinical conditions where severe pain (i.e. post-operation pain), arrhythmia, dehydration, or high sympathetic tone (as in hyperthyroidism or high metanephrine) are present. Evaluation of underlying stress and anxiety require more sensitive techniques and HRV is one example. We have also evaluated change in the electrocardiogram (not reported). Increased immersion, or psychological engagement, in turn, is more often associated with a decrease in subjective pain.

CONCLUSION

Virtual reality assisted anesthesia (VRAA) is an effective tool during endoscopic procedures in non-complicated patients. Lowering physiological responses to pain, subjective reports of discomfort, and even reducing physician stress and time to complete the procedure indicates a valuable additional tool over traditional pain management techniques. Being the largest study on VR distraction and endoscopic procedures, this study suggests important new constructs and techniques for pain management during upper gastrointestinal procedures. This is the first large series of patients undergoing GI endoscopic procedures and VRT. The VR procedure is flexible and can be adapted to the operating room or the bedside. Whether VR can effectively replace anesthesia is an interesting question to contemplate. Due to the success of this study, however, it may be appropriate to assess the effectiveness of VR in similar procedures, such as colonoscopies.

It is important that subsequent research continues to explore and identify more effective pain management techniques using advanced technologies. As suggested earlier, simple heart rate may not be an appropriate indicator of patient pain. There are many advanced digital analysis techniques that are under investigation for analyzing cardiovascular responses to stress anxiety on pain. We will continue to explore these approaches in our medical and invasive procedures and surgical interventions. Overall, this study provides additional clinical validation for the effective use of virtual reality during upper gastrointestinal endoscopy procedures for diagnosis in non-complicated patients. The ability to manage procedural pain and stress has obvious positive effects and clinical outcomes.

REFERENCES

[1] Hall MJ, DeFrances CJ, Williams SN, Golosinskiy A, Schwartzman A. National hospital discharge survey: 2007 summary. Natl Health Stat Report 2010; 29(29): 1-20.

[2] Pfuntner A, Wier LM, Stocks C. Most frequent procedures performed in US Hospitals 2011.

[3] Gómez V, Bhalla R, Heckman MG, Florit PT, Diehl NN, Rawal B, Lynch SA, Loeb DS. Routine screening endoscopy before bariatric surgery: is it necessary? Biatric Surg Pract Patient Care 2014; 9(4): 143-9. https://doi.org/10.1089/bari.2014.0024

[4] Freeman ML. Sedation and monitoring for gastrointestinal endoscopy. Gastrointet Endosc Clin N Am 1994; 4(3): 475-99.

[5] Carey WD. Indications, contraindications, and complications of upper gastrointestinal endoscopy. In Gastrointest Endosc. WB Saunders Philadelphia 1987; pp. 296-306.

[6] Hart R, Classen M. Complications of diagnostic gastrointestinal endoscopy. Endosc 1990; 22(05): 229-33. https://doi.org/10.1055/s-2007-1010734

[7] Javid G, Khan B, Wani MM, Shah A, Gulzar GM. Role of pulse oximetry during nonsedated upper gastrointestinal endoscopic procedures. Indian J Gastroenterol 1998; 18(1): 15-7.

[8] Dark DS, Campbell DR, Wesselius LJ. Arterial oxygen desaturation during gastrointestinal endoscopy. Am J Gastroenterol 1990; 85(10).

[9] Berg JC, Miller R, Burkhalter E. Clinical value of pulse oximetry during routine diagnostic and therapeutic endoscopic procedures. Endosc 1991; 23(06): 328-30. https://doi.org/10.1055/s-2007-1010708

[10] O'Connor KW, Jones S. Oxygen desaturation is common and clinically underappreciated during elective endoscopic procedures. Gastrointes Endosc 1989; 36(3 Suppl): S2-4.

[11] Oei-Lim VL, Kalkman CJ, Bartelsman JF, van Wezel HB. Cardiovascular responses, arterial oxygen saturation and plasma catecholamine concentration during upper gastrointestinal endoscopy using conscious sedation with midazolam or propofol. Eur J Anaesthesiol 1998; 15(05): 535-43. https://doi.org/10.1097/00003643-199809000-00005

[12] Vawter M, Ruiz R, Alaama A, Aronow WS, Dagradi AE. Electrocardiographic monitoring during coloscopy. Am J Gastroenterol 1975; 63(2): 155-7.

[13] Ristikankare M, Julkunen R, Mattila M *et al*. Conscious sedation and cardiorespiratory safety during colonoscopy. Gastrointest Endosc 2000; 52(1): 48-54. https://doi.org/10.1067/mge.2000.105982

[14] Freeman ML, Hennessy JT, Cass OW, Pheley AM. Carbon dioxide retention and oxygen desaturation during gastrointestinal endoscopy. Gastroenterology 1993; 105: 331. https://doi.org/10.1016/0016-5085(93)90705-H

[15] Malhotra HS, Rana S, Pal LS, Dasgupta DJ. Electrocardiographic changes during upper gastrointestinal endoscopy in ambient hypoxia. J Assoc Physicians India 1991; 39(9): 692-3.

[16] Lazzaroni M, Porro GB. Preparation, premedication, and surveillance. Endoscopy 2005; 37(02): 101-9. https://doi.org/10.1055/s-2004-826149

[17] Osinaike BB, Akere A, Olajumoke TO, Oyebamiji EO. Cardiorespiratory changes during upper gastrointestinal endoscopy. Afr Health Sci 2007; 7(2).

[18] Eddings J, Jacobson L, Illustrator-Wattenmaker PD. How virtual reality works. Ziff-Davis Publishing Co. 1994.

[19] Gold JI, Kim SH, Kant AJ, Joseph MH, Rizzo AS. Effectiveness of virtual reality for pediatric pain distraction during IV placement. Cyberpsychol Behav 2006; 9(2): 207-12. https://doi.org/10.1089/cpb.2006.9.207

[20] Hudson BF, Ogden J, Whiteley MS. Randomized controlled trial to compare the effect of simple distraction interventions on pain and anxiety experienced during conscious surgery. Eur J Pain 2015; 19(10): 1447-55. https://doi.org/10.1002/ejp.675

[21] Umezawa S, Higurashi T, Uchiyama S, *et al*. Visual distraction alone for the improvement of colonoscopy-related pain and satisfaction. World J Gastroenterol: WJG 2015; 21(15): 4707.

[22] Vázquez JL, Santander A, Gao K, Wiederhold BK, Wiederhold MD. Using cybertherapy to reduce postoperative anxiety in cardiac recovery intensive care units. J Anesth Clin Res 2013; 4: 363.

[23] Mosso JL, Gorini A, De La Cerda G, *et al*. Virtual reality on mobile phones to reduce anxiety in outpatient surgery. Stud Health Technol Inform 2009; 142: 195-200.

[24] Gorini A, Mosso JL, Mosso D, *et al*. Emotional response to virtual reality exposure across different cultures: the role of the attribution process. Cyberpsychol Behav 2009; 12(6): 699-705. https://doi.org/10.1089/cpb.2009.0192

[25] Hoffman HG, Garcia-Palacios A, Patterson DR, Jensen M, Furness III T, Ammons Jr WF. The effectiveness of virtual reality for dental pain control: a case study. Cyberpsychol Behav 2001; 4(4): 527-35. https://doi.org/10.1089/109493101750527088

[26] Ruskin PE. Virtual reality therapy for anxiety disorders: Advances in evaluation and treatment. Am J Psychiatry 2005; 162(9): 1772. https://doi.org/10.1176/appi.ajp.162.9.1772

[27] Mühlberger A, Wieser MJ, Kenntner-Mabiala R, Pauli P, Wiederhold BK. Pain modulation during drives through cold and hot virtual environments. Cyberpsychol Behav 2007; 10(4): 516-22.

[28] Wiederhold BK, Gao K, Sulea C, Wiederhold MD. Virtual reality as a distraction technique in chronic pain patients. Cyberpsychol Behav Soc Netw 2014; 17(6): 346-52. https://doi.org/10.1089/cyber.2014.0207

[29] Jeonghun Ku WG, Kim JH, Kim KU *et al*. The development of a VR system for the cognitive & behavioral assessment of schizophrenia. Stud Health Technol Inform 2004; 98: 180.

[30] Lozano JA, Alcañiz M, Gil JA, *et al*. Virtual food in virtual environments for the treatment of eating disorders. Stud Health Technol Inform 2002; 268-73.

[31] Van Cleve L, Johnson L, Pothier P. Pain responses of hospitalized infants and children to venipuncture and intravenous cannulation. J Pediatr Nurs 1996; 11(3): 161-8. https://doi.org/10.1016/S0882-5963(96)80049-2

[32] Hoffman HG, Patterson DR, Carrougher GJ. Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy: a controlled study. Clin J Pain 2000; 16(3): 244-50. https://doi.org/10.1097/00002508-200009000-00010

[33] Czub M, Piskorz J. Effectiveness of Different Virtual Reality Environ-ments on Thermal Pain Distraction. J Appl Psychol 2012; 10(2): 7-19.

[34] Mott J, Bucolo S, Cuttle L, Mill J, Hilder M, Miller K, Kimble RM. The efficacy of an augmented virtual reality system to alleviate pain in children undergoing burns dressing changes: a randomised controlled trial. Burns 2008; 34(6): 803-8. https://doi.org/10.1016/j.burns.2007.10.010

[35] Wiederhold MD, Gao K, Wiederhold BK. Clinical use of virtual reality distraction system to reduce anxiety and pain in dental procedures. Cyberpsychol Behav Soc Netw 2014; 17(6): 359-65. https://doi.org/10.1089/cyber.2014.0203

[36] Mosso JL, Rizzo S, Wiederhold B, Lara V, *et al*. Cybertherapy--new applications for discomfort reductions. Surgical care unit of heart, neonatology care unit, transplant kidney care unit, delivery room-cesarean surgery and ambulatory surgery, 27 case reports. Stud Health Technol Inform 2006; 125: 334-6.

[37] Mosso-Vázquez JL, Gao K, Wiederhold BK, Wiederhold MD. Virtual Reality for Pain Management in Cardiac Surgery. Cyberpsychol Behav Soc Netw 2014; 17(6): 371-8. https://doi.org/10.1089/cyber.2014.0198

[38] Cyberpsychol Behavior Soc Netw: Special Issue on Pain. 2014; 1: 17(6).

[39] Wiederhold BK, Jang DP, Gevirtz RG, Kim SI, Kim IY, Wiederhold MD. The treatment of fear of flying: a controlled study of imaginal and virtual reality graded exposure therapy. IIEEE J Biomed Health Inform 2002; 6(3): 218-23. https://doi.org/10.1109/titb.2002.802378

[40] Wiederhold BK, Wiederhold MD. Virtual Reality Therapy for Anxiety Disorders: Advances in Education and Treatment. New York: American Psychological Association Press 2004.

[41] Mosso-Vasquez JL, Wiederhold BK, Miller I, Wiederhold MD. Virtual reality assisted Anesthesia (VRAA) during upper gastrointestinal endoscopy: Report of 115 cases. EMJ Innov 2017; 1(1): 75-82.

[42] Wood DP, Wiederhold BK, Spira J. Lessons Learned from 350 Virtual-Reality Sessions with Warriors Diagnosed with Combat-Related Posttraumatic Stress Disorder. CyberPsychology, Behavior, and Social Networking 2010; 13(1): 3-11.

[43] Wiederhold BK, Bouchard S. Virtual Reality and Anxiety Disorders. Springer US 2014.

[44] Israel SA, Irvine JM, Cheng A, Wiederhold MD, Wiederhold BK. ECG to identify individuals. Pattern Recognit 2005; 38(1): 133-42. https://doi.org/10.1016/j.patcog.2004.05.014

[45] Wilhelm FH, Pfaltz MC, Gross JJ, Mauss IB, Kim SI, Wiederhold BK. Mechanisms of virtual reality exposure therapy: The role of the behavioral activation and behavioral inhibition systems. Appl Psychophysiol Biofeedback 2005; 30(3): 271-84. https://doi.org/10.1007/s10484-005-6383-1

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