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ORIGINAL ARTICLE

Comparison of pupillometer, critical care pain observation scale, and vital findings in the evaluation of pain in intensive care patients without oral communication

Sözlü iletişim kurulamayan yoğun bakım hastalarında ağrının değerlendirilmesinde pupillometre, yoğun bakım ağrı gözlem ölçeği ve vital bulguların karşılaştırılması

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Summary

Objectives: The aim of this study was to investigate the effects of portable infrared Pupillometer, Critical Care Pain Observation Scale (CPOT), and vital sign changes during painful procedures on patients with mechanical ventilators in the intensive care unit (ICU), and comparing the efficacy of these methods to detect the presence of pain.

Methods: In 50 patients who could not verbally state pain, admitted to Necmettin Erbakan University Meram Faculty of Medicine ICU, aged 18–75 years, and connected to a mechanical ventilator, vital sign changes, CPOT scale assessments, and pain evaluation with a portable infrared pupillometer were performed during endotracheal aspiration and position changes, which are defined as painful stimuli.

Results: Data were collected from 50 patients with a mean age of 57.4±17.9 years and 48% of males. The systolic, diastolic, and mean arterial pressure and heart rate values, CPOT scores, and pupillometric measurements of the patients increased significantly at the time of aspiration and change of position ($p<0.05$). Neurological pupil index scores showed a significant decrease at the time of painful stimulation ($p<0.05$).

Conclusion: It was found that pupil diameter changes evaluated using a portable infrared pupillometric measuring device can be used effectively and reliably in pain assessment in patients who are treated in the ICU, supported by mechanical ventilation and who cannot communicate verbally.

Keywords: Intensive care; pain observation scale; pain; pupil diameter.

Özet

Amaç: Bu çalışmanın amacı, yoğun bakım ünitesinde yatan mekanik ventilatöre bağlı hastalarda, ağrılı işlemler esnasında, taşınabilir kızılötesi pupillometre, yoğun bakım ağrı gözlem ölçeği (CPOT) ve yaşamsal bulgulardaki değişiklikleri inceleyerek, bu yöntemlerin ağrı varlığını saptama konusundaki etkinliklerini karşılaştırmaktır.

Gereç ve Yöntem: Necmettin Erbakan Üniversitesi Meram Tıp Fakültesi Yoğun Bakım Ünitesinde yatan, 18–75 yaş arası, mekanik ventilatöre bağlı, sözel ağrı bildirimi yapamayan 50 hastada ağrılı uyaran olarak tanımlanan endotrakeal aspirasyon ve pozisyon değişikliği uygulamaları esnasında vital bulgu değişimleri, CPOT değerlendirmeleri ve taşınabilir kızılötesi pupillometre cihazı ile ağrı değerlendirmesi yapıldı.

Bulgular: Çalışmada, ortalama yaşları 57,4±17,9 yıl ve %48'i erkek olan 50 hastaya ait veriler değerlendirildi. Hastaların sistolik, diyastolik ve ortalama arteriyel basınç ve kalp hızı değerlerinin; CPOT skorlarının ve pupillometrik ölçümlerin aspirasyon ve pozisyon değişikliği anında anlamlı yükselme gösterdiği ve daha sonraki ölçümlerde aspirasyon öncesi değerlere geri düştüğü tespit edildi ($p<0,05$). Pupillometrik ölçümlerden nörolojik pupil indeks skorlarının ise ağrılı uyaran anında anlamlı düşüş gösterdiği ve sonrasında normale döndüğü belirlendi ($p<0,05$).

Sonuç: Taşınabilir kızılötesi pupillometrik ölçüm cihazı kullanılarak değerlendirilen pupil çapı değişikliklerinin yoğun bakımda tedavi edilen, mekanik ventilasyon desteğindeki, sözel iletişim kurulamayan hastalarda ağrı değerlendirmesinde etkin ve güvenilir bir şekilde kullanılabileceği belirlendi.

Anahtar sözcükler: Yoğun bakım; ağrı gözlem ölçeği; ağrı; pupil çapı.

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Introduction

In general, approximately 60% of intensive care unit (ICU) patients experience varying degrees of pain, and one-third of patients experience persistent pain.[1,2] It is expected that pain assessment methods for effective pain management will also yield high efficacy.

The most reliable source of information, considered the "gold standard" about an individual's pain, is their own statement.[3] Visual analog scale or numerical assessment scales are the tools that can be used for this purpose, in patients who can communicate. However, individuals with severe cognitive disorders or patients suffering from a serious illness who are sedated, or those who are mechanically ventilated were unable to report their pain and therefore suffer significant limitations in pain management. Different instruments, such as Behavioral Pain Scale, Pain Assessment Scale, and Care Pain Observation Scale (CPOT), can be used for patients in the ICU.[4] In addition, the evaluation of reflexes associated with pain and nociceptive senses are the parameters that are starting to be used in the management of pain in intensive care patients who cannot communicate. These physiological reflexes include increased heart rate (HR) followed by activation of the sympathetic nervous system in response to pain, tachypnea, and pupillary dilatation. In parallel with technological advances, studies are carried out on the role of methods that facilitate pupil examination and present it to clinical use in pain assessment.[5–7] In this context, pupillary evaluations with a pupillometer device have been proposed as an alternative method for pain evaluation.[8–10]

Clinical pain management is a multidimensional and multidisciplinary process and continues to develop in parallel with advances in medical sciences. The main purpose of this study, which is designed on this scientific background, is to examine changes in infrared pupillometer, CPOT and vital signs during painful procedures in patients who cannot report verbal pain due to mechanical ventilator, and compare the effectiveness of these methods in detecting the presence of pain.

Material and Methods

The study was conducted prospectively with the approval of Necmettin Erbakan University Meram Faculty of Medicine Ethics Committee (ref. 2017/137) in accordance with the Helsinki Declaration.

Fifty patients between 18 and 75 years of age who were hospitalized in the ICU, connected to a mechanical ventilator, and unable to report verbal pain were included in the study. First-degree relatives of the patients included in the study were informed about the study and verbal and written informed consent was obtained.

Patients with a Glasgow Coma Scale (GCS) score of 3, a diagnosis of sepsis, drug use, a diagnosis of psychiatric disease, an intracranial pathology, motor deficit, neuromuscular blocker use, periorbital or facial edema, ocular disease, and anticholinergic agent use were not included in the study.

The demographic data (age, sex, weight, and height), date of admission to the ICU, primary diagnosis, comorbidities, GCS score, sedation level according to Richmond Agitation Sedation Scale (RASS), name of sedative agent and the does used for the patients were recorded. Hemodynamic data, systolic arterial pressure, diastolic arterial pressure, mean arterial pressure (MAP), HR, and peripheral oxygen saturation (SpO_2) records were based on the monitor (Draeger Medical Systems, Inc. Telford, PA, USA). Measurements were performed during the routine care services of both endotracheal aspiration and change of position in the bed, which are considered painful procedures. A total of 5 measurements were performed before, during, and at 3, 5, and 10 min after the painful procedure. Measurements were performed separately for endotracheal aspiration and position change at 30 min intervals. The patients did not receive any painful procedure or medication except for the routine procedure in the ICU.

During the measurements, a portable infrared pupillometer device (Pupillometer NPi-200 ™, NeurOptics, USA) was used to assess pupil diameter. The minimum and maximum pupil diameter, percentage of changes, contraction rate, maximum contraction rate, latency, maximum relaxation rate, and Neurological Pupil Index values produced from these parameters were measured automatically with the pupillometer device. Since the pupil diameter could vary depending on ambient illumination and the point at which the patient focused his gaze, scotopic conditions were provided to optimize the measurements. The light-insulated silicone collar of the device isolated the measured eye from ambient

light. The opposite side of the eye was closed with a thick cover and isolated. Pain scores according to the CPOT scale were also recorded.

Statistical Evaluation

Statistical analysis of the study was performed with SPSS 21 (IBM Inc., Armonk, NY) software. In the presentation of descriptive statistics, mean and standard deviation values were used for numerical data, and frequency and percentage values were used for categorical data. Kruskall–Wallis test was used for more than two groups, the Mann–Whitney U test was used for two groups, and the Chi-square test was used for categorical data comparisons. Comparisons between dependent data groups were performed by the Wilcoxon test. In the study, the Type 1 error threshold was determined as 5% for statistical significance.

Results

General Characteristics of Patients

Data of 50 patients were evaluated. 48% (n=24) of the patients were male. The mean age (year), height (cm), and weight (kg) were 57.4±17.9, 167.8±8.3, and 75.2±10.8, respectively.

It was determined that the time the patients were included in the study had a median of their 3rd (2–106) day of intensive care hospitalization. The median RASS scores were –3 (–5–2) and the median GCS score was 9 (4–13).

Vital Sign Measurements

Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), HR, and SpO_2 values of patients before endotracheal aspiration, at the time of aspiration and 3rd–5th and 10 min after aspiration changes are shown in Figure 1. SBP, DBP, MBP and HR values showed a significant increase compared to basal values at the time of aspiration ($p<0.05$). It was found that SBP, DBP, and MBP elevation continued at the 3rd min ($p<0.05$), and it decreased back to pre-aspiration values at later measurements. Oxygen saturation decreased significantly during aspiration and significantly increased at 3 min after aspiration ($p<0.05$).

SBP, DBP, and MBP values at the time of aspiration were significantly higher in patients with a CPOT score >2 ($p<0.05$). This elevation in SBP and DBP values during aspiration continued at the 5th min after aspiration, and the elevation at the MBP value continued at 3rd–5th and 10 min after aspiration ($p<0.05$).

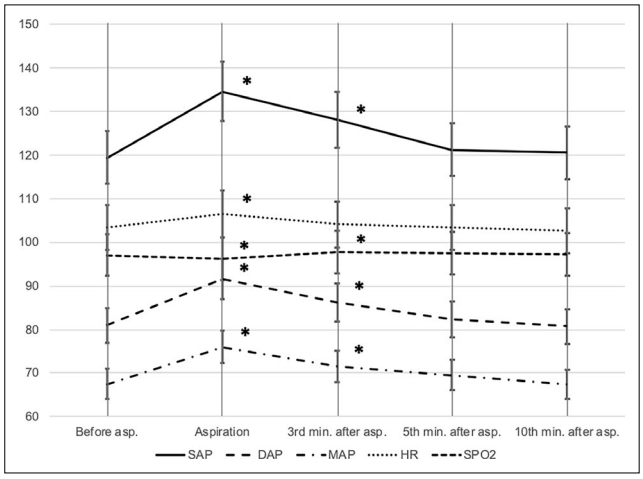

Figure 1. Vital signs before and after aspiration.
*: Statistically significant value compared to basal value ($p<0.05$).

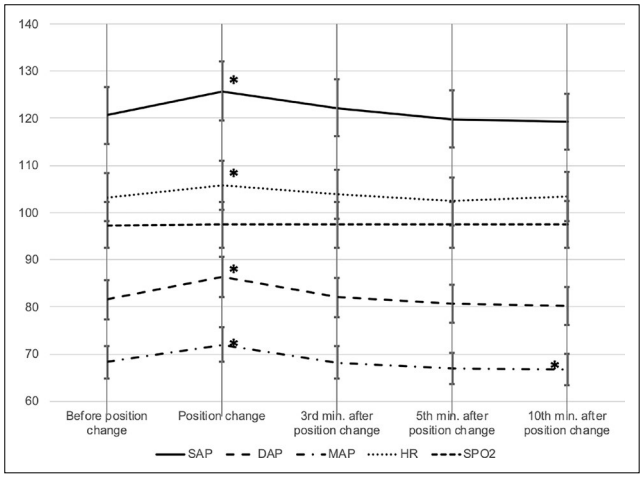

Figure 2. Vital signs before and after position chang.
*: Statistically significant value compared to basal value ($p<0.05$).

The changes in the measurements taken before the bed position change, at the moment of position change, and 3rd–5th and 10 min after the position change are shown in Figure 2. It was found that SBP, DBP, MBP, and HR values showed a statistically significant increase ($p<0.05$) at the time of position change and it decreased back to the values before position change in later measurements. There was no statistically significant relationship between SpO_2 and position change ($p>0.05$).

CPOT Measurements

The values of the measurement results of the CPOT scale evaluations were determined before, at the time of aspiration, and 3rd–5th and 10 min after the endotracheal aspiration; and CPOT scale values were

determined before, during, and after 3rd–5th and 10 min of position change are presented in Tables 1 and 2, respectively. In the measurements, facial expression, body movements, ventilator compliance (intubated patient) or sounds produced and all muscle tension parameters increased significantly during aspiration and change of position, and decreased to previous values at later measurements.

Pupillometric Measurements

The change in pupillometric evaluation results measured before, during and 3rd–5th and 10 min after endotracheal aspiration of the patients is shown in Figure 3 for the right eye, Figure 4 for the left eye, and Figure 5 for the differences between the two eyes. According to the results, maximum and minimum pupil diameters increased significantly during aspiration and neurological pupil index decreased significantly in both right eye and left. It was observed that maximum ($p=0.002$) and minimum ($p=0.02$) pupil diameter elevation continued in the left eye at the 3rd min. When the differences between two eyes were evaluated, it was determined that maximum and minimum pupil sizes and neurological pupil index values increased significantly at the time of aspiration.

The change in pupillometric evaluation results measured before, during, and after 3rd–5th and 10 min of position change is shown in Figures 6 and 7 for the right and left eye, respectively, and in Figure 8 for differences between the two eyes. According to the results obtained from the measurements, maximum and minimum pupil diameters and maximum contraction velocity were significantly increased ($p<0.05$) and neurological pupil index significantly decreased during the change of position. The maximum and minimum pupil diameter increase continues in the right eye at 3rd and 10 min and in the left eye at 3rd min. When the differences between the two eyes were evaluated, it was determined that maximum and minimum pupil sizes and neurological pupil index values showed a statistically significant increase at the time of position change ($p<0.05$), and then returned to the previous values.

Discussion

Medical interventions are the main causes of pain experienced by patients treated in the ICU. Studies on this subject have shown that the factors that cause pain in a scale starting from moderate to severe in ICU patients are prolonged immobilization, surgical interventions, mechanical ventilation, endotracheal aspiration, and position changes.[11–13] In one of these studies, Bruster et al.[2] emphasized that the pain caused by these applications should be adequately evaluated and taken into consideration, especially in patients treated in intensive care and on mechanical ventilation or patients in which verbal communication cannot be established.[14,15]

It was found that 61% of the patients followed in the ICU experienced pain, 33% of these cases had persistent pain, and even 63% of the cases had continuing pain after their discharge from the ICU. In this patient group, it is critical to detect pain effectively and treat it with the most appropriate intervention. It is known that severe pain in patients who are followed up and treated in ICU will have negative physiological and psychological consequences.[16,17] These adverse physiological consequences include serious complications that increase morbidity and mortality, such as vasoconstriction, hypercoagulability, and tissue ischemia due to adverse effects of respiratory and cardiovascular functions[18] When all these factors are considered together, the importance of pain assessment with reliable and proven tools in ICU patients is once again apparent.

In this study, we examined changes in vital signs, CPOT evaluations, and pupillometric measurements in order to make an effective and reliable pain assessment in patients who cannot report verbal pain due to ventilator, and determined that it was a reliable tool in pain evaluation for this patient group.

MAPs and HR increase significantly during nociceptive procedures such as position change or endotracheal aspiration.[11,19] When it was examined whether these changes in hemodynamic parameters are really related to the pain feelings of the patients or not, their own pain reports are correlated with the increase in their vital signs.[19]

According to our findings, systolic, diastolic, and MAPs and HR values had a significant peak ($p<0.05$) during both endotracheal aspiration and position change applications and decreased again after the application. The sudden peaks observed

Table 1. Changes in the CPOT assessments before, during, and after the endotracheal aspiration

	Before aspiration		Aspiration			After aspiration 3rd min			After aspiration 5th min			After aspiration 10th min		
	n	%	n	%	p	n	%	p	n	%	p	n	%	p
CPOT score (Mean±SD)	0.3	1	4.3	2	**0.001**	0.5	1.1	0.06	0.4	1	0.20	0.3	0.9	0.74
Facial expression					<**0.001**			**0.03**			0.06			0.56
Relaxed, neutral	45	90	2	4		39	78		40	80		44	88	
Tense	5	10	23	46		11	22		10	20		6	12	
Grimacing	–	–	25	50		–	–		–	–		–	–	
Body movements					<**0.001**			0.41			0.56			0.56
Absence of movements or normal position	46	92	16	32		44	88		47	94		47	94	
Protection	3	6	25	50		5	10		2	4		2	4	
Restlessness/agitation	1	2	9	18		1	2		1	2		1	2	
Compliance with the ventilator (intubated patient) or vocalization					<**0.001**			1			1			0.32
Tolerating ventilator or movements/talking in normal tone or no sound	49	98	6	12		49	98		49	98		50	100	
Coughting but tolerating/ sighing, moaning	1	2	33	66		1	2		1	2		–	–	
Flighting ventilator, crying out, sobbing	–	–	11	22		–	–		–	–		–	–	
Muscle tension					<**0.001**			0.08			1			1
Relaxed	47	94	12	24		44	88		47	94		47	94	
Tense, rigid	2	4	30	60		5	10		2	4		2	4	
Very tense or rigid	1	2	8	16		1	2		1	2		1	2	

CPOT: Care Pain Observation Scale; SD: Standard deviation.

Table 2. Changes in the CPOT assessments before, during, and after the position change

	Before position change		Position change			After position change 3rd min			After position change 5th min			After position change 10th min		
	n	%	n	%	p	n	%	p	n	%	p	n	%	p
CPOT score	0.2	0.9	2.2	1.44	<**0.001**	0.32	0.89	0.31	0.26	0.85	0.74	0.2	0.83	0.41
Facial expression					<**0.001**			0.41			0.41			0.56
Relaxed, neutral	45	90	9	18		43	86		43	86		46	92	
Tense	5	10	34	68		7	14		7	14		4	8	
Grimacing	–	–	7	14		–	–		–	–		–	–	
Body movements					<**0.001**			**0.03**			1			1
Absence of movements or normal position	48	96	27	54		45	90		48	96		48	96	
Protection	1	2	22	44		4	8		1	2		1	2	
Restlessness/agitation	1	2	1	2		1	2		1	2		1	2	
Compliance with the ventilator (intubated patient) or vocalization					**0.005**			1			1			1
Tolerating ventilator or movements/talking in normal tone or no sound	50	100	42	84		50	100		50	100		50	100	
Coughting but tolerating/ sighing, moaning	–	–	8	16		–	–		–	–		–	–	
Flighting ventilator, crying out, sobbing	–	–	–	–		–	–		–	–		–	–	
Muscle tension					<**0.001**			0.32			0.32			0.32
Relaxed	47	94	20	40		48	96		48	96		48	96	
Tense, rigid	2	4	28	56		1	2		1	2		1	2	
Very tense or rigid	1	2	2	4		1	2		1	2		1	2	

CPOT: Care Pain Observation Scale; SD: Standard deviation.

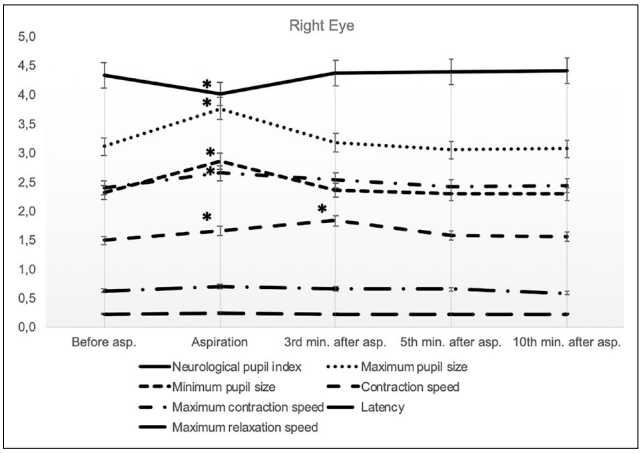

Figure 3. Right eye pupillometric assessments before and after the aspiration.

*: Statistically significant value compared to basal value ($p<0.05$).

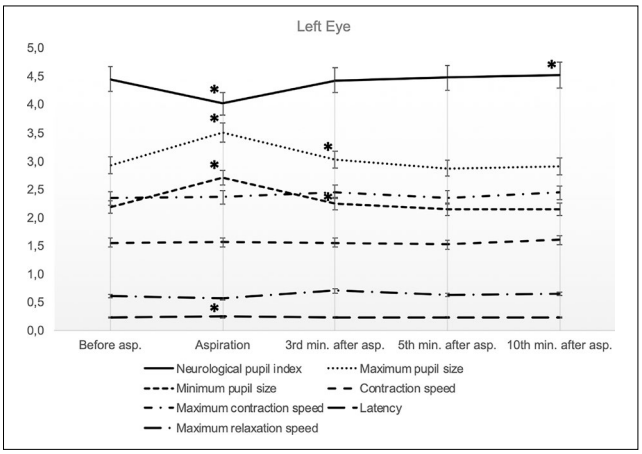

Figure 4. Left eye pupillometric assessments before and after the aspiration.

*: Statistically significant value compared to basal value ($p<0.05$).

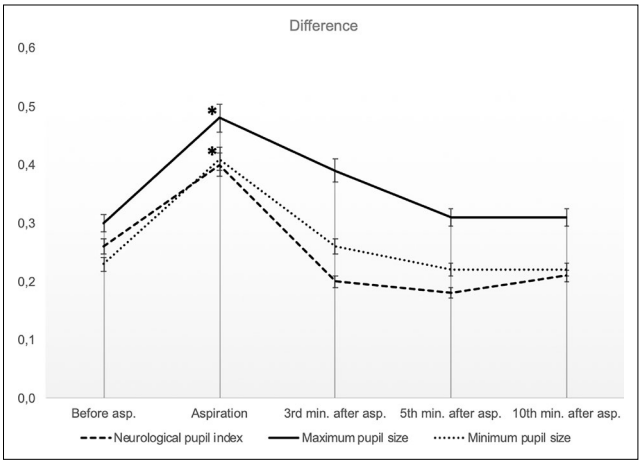

Figure 5. Difference of pupillometric assessments of bilateral eyes before and after the aspiration.

*: Statistically significant value compared to basal value ($p<0.05$).

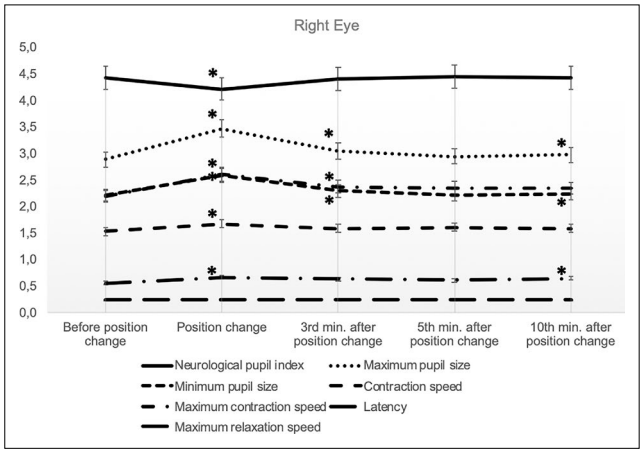

Figure 6. Right eye pupillometric assessments before and after the position change.

*: Statistically significant value compared to basal value ($p<0.05$).

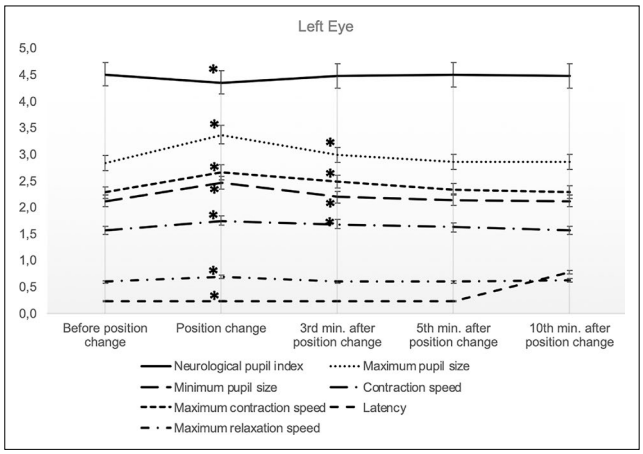

Figure 7. Left eye pupillometric assessments before and after the position change.

*: Statistically significant value compared to basal value ($p<0.05$).

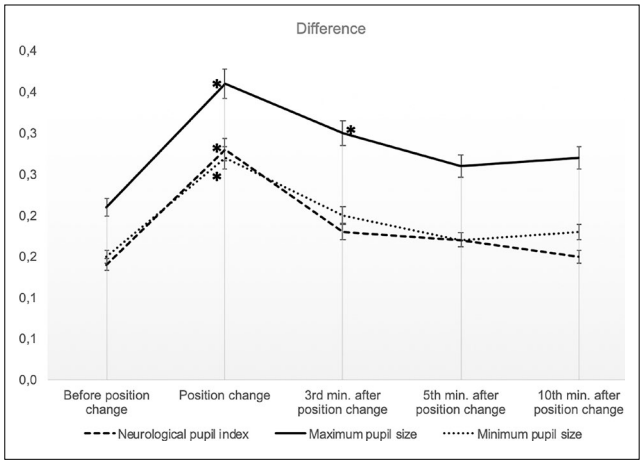

Figure 8. Difference of pupillometric assessments of bilateral eyes before and after the position change.

*: Statistically significant value compared to basal value ($p<0.05$).

in vital signs during endotracheal aspiration and change of position, which are defined as painful stimuli, can be interpreted as objective indicators that indicate that patients feel pain. This assumption is based on the activation of the autonomic nervous system in the event of painful stimulation in patients and the change in vital signs depending on this autonomic response.[20]

Changes in hemodynamic parameters may not always be associated with painful stimuli. In a study on this subject, it was reported that blood pressure and HR might increase during both nociceptive (change of position) and non-nociceptive (eye care) procedures and cannot be associated with direct pain.[21]

It has been reported that behavioral parameters such as facial tension, eyebrow scowl, eye squeezing, startling, fist clenching, contractions, touching the aching area, or immobility can be seen as behavioral parameters in the case of pain sensation in the ICU. It has been determined that the majority of ICU patients use facial, eye, hand-arm, and leg movements to express their pain.[1,22,23] These behavioral patterns need to be examined more carefully, especially in patients who have difficulty communicating verbally, those who are sedated, or experience change in consciousness and those who receive mechanical ventilation support. In this context, different tools such as Behavioral Pain Scale, Behavioral Pain Assessment Scale, and CPOT have been developed and brought into clinical practice to be used in pain assessment in patients with the advanced critical disease or those in intensive care.

In our study, changes in facial expressions, body movements, ventilator compliance in intubated patients, voices produced by non-intubated patients, and change in muscle tension of patients were examined as behavioral parameters in CPOT examinations performed during endotracheal aspiration and position change applications. In the analysis, it was determined that all of the behavioral parameters of the patients changed significantly, indicating pain, both at the time of aspiration and position change, and they returned to normal status after the completion of the procedures. These changes suddenly appeared as tension and grimace in the facial expressions of the patients, protection and restlessness/agitation in body movements, resistance to the ventilator or crying, and increased muscle tension and stiffness. CPOT scores, a total score of these behavioral patterns, showed a significant increase with painful stimuli, and a return to pre-procedure levels was detected after the procedure.

In the study, where the threshold CPOT value indicating pain was accepted as 2, CPOT scores were significantly correlated with the pain severity indicated by the patients on the numerical assessment scale. On the other hand, none of the fluctuations in vital signs showed a significant correlation with patients' pain complaints.[24] It was concluded that CPOT scores >2 observed during endotracheal aspiration in ICU patients were 86% sensitive and 78% specific for the presence of pain.[25] In the ICU patients, the change in position and/or endotracheal aspiration procedure and CPOT score during painful procedures were found to be 2.23 in unconscious patients and 3.47 in conscious patients. It has been reported that behavioral reactions are still observable even in patients receiving sedative and analgesic drugs.[26]

It was determined in this study that the changes in vital signs determined in the patients were consistent with the change pattern of CPOT scores, and these evaluations reflected the pain experienced by the patients during aspiration and position changes. SBP, DBP, and MBP values during aspiration were significantly higher in patients with a CPOT score >2, compared to those with a score <2 ($p<0.05$).

Although vital signs can be used as supportive findings in the pain assessment of patients who are followed-up and treated in the ICU and for which verbal communication cannot be established since these are not definitive pain indicators and behavioral assessment scales provide more reliable and valid results in pain assessment, the research on methods that can assess the presence of pain more clearly in this patient group continues. In these studies, physiological responses to pupil dilatation against painful stimuli have been reported in both adult and pediatric populations under general anesthesia[27,28] and in ICU patients with deep sedation.[29]

Pupil light reflex physiology response has been extensively described. Research reports that pupil light reflex may be affected in cases of sedation or sympathetic activity.[30–33] Specifically, pupil diameter or variation increases with increasing sympathetic activity. In particular, the increase in the percentage of pupillary change is important in assessing the effect of sedative and analgesic drugs on sympathetic/parasympathetic balance. In a study conducted by

Lukaszewicz et al.,[5] where the role of pupillometry was examined in analgesia evaluation, a threshold value of 19% was reported to be the distinguishing feature of pain in pupil change.

It was found that pupil diameter changes during both endotracheal aspiration and position changes were more than 20% for both eyes and showed the presence of pain in the patients in this study. When the other findings obtained in pupillometric evaluation in our study were examined, it was observed that maximum and minimum pupil diameters increased significantly during endotracheal aspiration and position change applications and neurological pupil index decreased significantly. These changes in pupillometric parameters were found to be consistent with the changes in vital signs and CPOT scores. With these results, it was seen that pupillometric measurements can be used in pain assessment together with other assessment methods.

The pupillary response may vary for acute and chronic pain, or some medications may increase or decrease pupillary response to pain. One of the limitations of our study was that it was performed with an inhomogeneous group of patients from different ICUs. While some of our patients were postoperative intensive care follow-up patients and could be considered acute pain, some were chronic pain patients with a long-term intensive care stay. Because different sedation agents and doses were used, sedation levels were heterogeneous.

Conclusion

It was concluded that pupillometric measurements using an automatic infrared pupillometer for pain assessment, which is a very important issue in intensive care medicine today, will be very valuable in daily clinical practice. It is thought that the application of this method will save time for physicians and health personnel in patient evaluation and will be a more objective evaluation criterion, especially in cases where verbal communication cannot be established. In addition, it will be an effective evaluation method to ensure adequate analgesia in these patients. Nevertheless, as with other assessment methods that have just begun to enter clinical practice, clinical trials involving pupillometric evaluations and a broader range of patient groups with different etiological characteristics need to be performed.

Ethics Committee Approval: The Necmettin Erbakan University Clinical Research Ethics Committee granted approval for this study (date: 11.01.2017, number: 2017/137).

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