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Acute electrodermal activity changes to short-time noise stimulation in adult Intensive Care Unit patients.

Aslanidis Th[1] MD , Grosomanidis V[1] MD, PhD, [+]Karakoulas K[1] MD, PhD, Chatzisotiriou A[2], MD, PhD

ABSTRACT

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The electrical properties of the skin, also known as electrodermal activity (EDA), are considered as an indirect measure of autonomous nervous system. Along with that, the effects of noise-induced stress in intensive care units, is well explored. This study explores the noise-induced acute electrodermal activity changes in adult critical care patients and to compare these changes with cardiovascular effects of the same stress (noise) stimulus. Skin conductance variability, noise level, selected hemodynamic and respiratory parameters were monitored during 4 hour routine daytime intensive care nursing and treatment in an adult Intensive Care Unit. Average ambient noise levels during the time window (4 min) before the stimulation were 54.33(2.65) dB for Group A and 55.65(3.31) dB, while the noise stimulation was on average for Group A 70.8 (1.98) dB, and for Group B: 71.31(3.31) dB. EDA changes to noise stimulus were more distinct than hemodynamic and respiratory parameters. Yet, a weak relation was found between all EDA parameters and the particular noise level changes. Noise-induce stress causes more distinct EDA changes when measured immediately post stimulus. In addition, sedation level seems to affect the intensity of these changes. However, further studies are needed in to order to reach a definite conclusion.

INTRODUCTION

It a more than 50 years, that noise has been identified as a potential source of allostatic load and consequently, stress[1]. Yet, and despite the fact that World Health Organization (WHO) recommends that the average background sound level in hospitals should not exceed 30dB[2], the

[1]Department of Anesthesiology and Intensive Care Medicine, AHEPA General University Hospital, Thessaloniki, Greece
[2]Laboratory of Physiology, Medical School, Aristotle University of Thessaloniki, Thessaloniki, Greece

literature is full of evidence that noise in Intensive Care Units (ICU) typically exceeds that limit[3-6]. Moreover, the exposure to excessive noise level has a direct impact both on mortality and morbidity of the patients, and on the performance of cognitive tasks of critical care staff[4-7].

There are several studies that record either cardiovascular or endocrine effects of noise-induced stress[8-10]. At the same time - albeit electrodermal activity (EDA) has long been used as stress monitor for several types of stimuli (such as painful and emotional) in perioperative enviroment[11] - here is only one study of EDA changes as means of measuring ICU noise effect in healthy volunteers[12].

The aim of the study is to measure acute EDA changes during noise stimulation in adult ICU patients and to compare these changes with cardiovascular effects of the same stress (noise) stimulus.

METHODS

This prospective observational study was conducted at the adult general ICU, at AHEPA General University Hospital, Thessaloniki, Greece. Fifty four (54) measurements in critically ill patients under sedation, above 18 years old, were initially included in the study. Other inclusion criteria included administered mechanical ventilation>24h and constant sedation level under midazolam or propofol continuous intravenous infusion (c.i.v.). On the contrary, patients with Ramsay sedation score (RSS) 1, diagnosed or with history of hearing problems, psychiatric disorders, neurological diseases, neuro~ or myopathy, delirium, CNS or spinal cord injury, were excluded. Also as exclusion criteria were considered pregnancy, hemodynamic/respiratory instability, edema of the upper limbs (place of measurement) and the presence of sensitive electrical life-sustainable devices such as cardiac pace, renal replacement therapy devices, intra-abdominal aortal counterpulsion pump, extracorporal membrane oxygenation and artificial liver.

Skin conductance (SC) variability, noise level, selected hemodynamic and respiratory parameters were monitored during 4 hour routine daytime intensive care nursing and treatment. Measurements were divided into 2 categories according to sedation level: Group A- RSS 2-4 (n_a=10) and Group B –RAS 5-6 (n_b =15). Another twenty nine (29) 4h-measurements were interrupted due to protocol violation or technical problems.

Med Storm Pain Monitor System (MED Storm® Innovation AS, Oslo, Norway) was used as SC monitor[13]. Three single use Ag/Cl electrodes were attached at the palmar surface of the hand: on the thenar eminence (current), on the hypothenar eminence (measurement) and just below 2nd and 3rd digits (reference). In order to minimize artifacts, the hand least likely to move, with no intravenous or intra-arterial lines was chosen.SC was measured by alternating current of 66Hz and an applied voltage of 50mV. SC parameters recorded were: absolute SC (in μS), peaks/sec or number of SC fluctuations per second (NSCF), the average peak **(**micro Siemens seconds – μSs), the rate of increase or decrease from the start to the end of the measurement window (rise time, in micro Siemens per second - μS/s), area huge peaks (μSs), area small peaks (μSs) and the larger of the two measures (referred as Area under curve- AUC, in μSs). Cut off for NSCF counting was >0.005, much more sensitive than the >0.02 μS used in relative pain monitoring literature[11]. Signal quality <80% was considered artifact and the measurement was also excluded.

Measurement window of interest was 5 sec and 5sec after sound stimulation, provided that a) 4min before and 1 min after the stimulus there was no other stimulus of any kind (i.e. pain) and that b) noise stimulus was minimum 10dB higher than the baseline recorded before and c) with minimum duration (about 2 sec). In order to ensure the observational character of the study, and to waive any possible ethical considerations, noise stimulation (referred as noise "event") was product of the daily nursing/treatment routing inside ICU environment and not artificial deliberately-created noise stimulation. Only those noise "events" that were within the aforementioned frames, were included for further analysis (in total 52 for both groups). Noise level was measured at distance 30 cm from the head of the patient via Sound Level Meter GM13656 (Shenzhen Jumaoyuan Science & Technology® Co., China)[14].

The rest of the parameters were monitored via Bedside Monitor BSM 9101K and Monitor CNS 9601 (Nihon Kohden® Ltd., Japan);and included: heart rate (HR), Systolic (SAP), diastolic (DAP) and mean arterial pressure (MAP), number of ventricular premature contractions (VPC), electocardiographic ST wave deviation in II lead (ST II) and respiratory rate (RR). Since the above were used in the literature[8-10] as possible measures of stress, recordings were used as measure of comparison with SC parameters.

In selected measurements (Goup A: 9, Group B: 22) Bispectral index monitor (BIS) (Covidien®, USA) was also in place.

Data analysis was performed with MS Office Excel 2007 and Rstudio v.0.99.903. Descriptive statistics are presented as mean, standard deviation (SD). Two comparison designs were followed: one examined acute changes before/after the noise stimulus and one that examined the range of change between the 2 groups. Shapiro-Francia normality test is performed for the parameters of interest and then paired t-test or Wilcoxon signed ranked test is calculated. Results are presented as p value (Confidence Interval –CI). Statistical significance for p is set to $p<0.05$ and CI level at 95%. Finally, correlation between noise stimulus level and EDA changes were also investigated.

RESULTS

General characteristic of patients in each group of measurements is illustrated in Table 1. Different averages of APACHE II score, Extended Glasgow Outcome Score (GOSE) and PaO_2/FiO_2 are partially explain the different sedation level.

During recording time, 17 noise "events" occurred in Group A and 35 in Group B that met inclusion criteria for further analysis. Average ambient noise levels during the time window (4 min) before the stimulation, the level of noise stimulation and the time window of the recording (1 min after) are displayed in table 2.

The changes caused from the stimulus in every group are illustrated in Tables 2 and 3 (See Supplement File Figure 1).

Table 1. General characteristics of the patients included finally in each group

	Group A	Group B		Group A	Group B
N measurem	10	15	**APACHE II**	15.4(1.55)	19.6(1.66)
Sex	♂=10,♀=0	♂=9, ♀=6	**SOFA**	6.3(0.9)	7.9(0.4)
Age (years)	66.5(14.8)	63.8(10.9)	**GOSE**	6.4(0.9)	5.2(0.8)
Weight (kg)	90.6(15,1)	89.95(12.6)	**t (°C)**	37.2(0.3)	37.1(0.4)
BMI(kg/m^2)	28(1.65)	30.3(0.85)	**PaO_2/FiO_2**	294(69.3)	230 (81.8)

Presented form: mean (SD), rounded to the nearest decimal

Table 2. Noise levels (dB) in the 2 groups during the period before and after the stimulus.

Group A			Group B		
Before Mean(SD)	**Stimulus** Mean (SD)	**After (during recording)** Mean(SD)	**Before** Mean(SD)	**Stimulus** Mean (SD)	**After (during recording)** Mean(SD)
56.32(4.81)	72.48(5.61)	56.53(5.03)	56.3(3.96)	71.67(5.6)	56.1(4.08)
Comparison before and during recording p[CI 95%]*			**Comparison before and during recording p[CI 95%]***		
0.945 [-3.2,2.5]			0.72 [-1.5,2.01]		

**Wilcoxon rank sum test with continuity correction*

Table 3. Changes before and after noise stimulation in Group A (before/after)

Group A (RSS 2-4), n=17				
Parameters	**Before Mean (SD)**	**After Mean (SD)**	**p**	**CI [95%]**
HR (bpm)	75.9(14)	75.9(14.3)	1	NA
VPC (no)	0.64(1.96)	1(2.5)	0.184	[-3,-1]***
STII	0.1(0.08)	0.1(0.08)	0.588	[-0.03,0.04]**
SAP (mmHg)	116(17.2)	116(17.52)	1	NA
MAP(mmHg)	73.5(9)	73.5(9.01)	1	NA
DAP(mmHg)	53.9(5.8)	53.9(5.8)	1	NA
RR (br/m)	12.2(2.4)	16.1(15.8)	0.371	NA
BIS^{+}	58.2(7.08)	58(6.12)	0.833	[-2,3]
Area Huge Peak (μSs)	0.111(0.3)	0.557(0.806)	0.0011	[-0.8,-0.1]
Area Small Peak (μSs)	0	0.019(0.039)	0.0137	[-0.08,-0.01]
NFSC (μSs)	0.08(0.12)	0.329(0.186)	0.0009	[-0.3,-0.2]
Average rise time	0.004(0.03)	0.022(0.003)	0.1005	[-0.06,0.005]
Average peak	0.07(0.15)	0.14(0.21)	0.0774	[-0.17,0.005]
AUC (μSs)	0.111(0.3)	0.418(0.568)	0.0058	[-0.7,-0.06]
SC average (μS)	8.005(4.09)	8.07(4.14)	0.0093	[-0.14,-0.006]

***Wilcoxon signed ranked test with continuity correction (paired), ** CI 90%, *** CI 60, $^{+}$selected patients (n=9)*

The percentile range of change (Δ%) for the majority of EDA changes in Group B are larger than in Group A, although sedation level is less in the first Group. Only SC average level change (Δ%) is +1.63% in group A and -0.85% in group B. For the rest of the EDA parameters Δ% is between 46-382% and for Group B (where applicable) > 900%. (Figure 1).

On the contrary the percentile range of change (Δ%) of the hemodynamic parameters (HR, SAP,DAP,MAP) is between 0.9-1.7% for Group A and 0-1.89% for Group B, for BIS Δ% is -0.34 and 3.35% respectively and only RR(respiratory rate) Δ% in Group A is considerably large (+32%).

Finally, we explored possible relation between the change in noise stimulation and the change of the other parameters. However, a weak relation was found between all EDA parameters and the particular noise level changes. In addition, the relation is stronger in Group B than in Group A (Table 5, Supplement Figure 2 and 3.).

The relation does not change significantly if certain clusters of ΔSPL are examined [ΔSPL∈(10,15dB) or ΔSPL ∈ (16,20dB) or ΔSPL>20dB].

Figure 1. Percentile change of each parameter in both groups

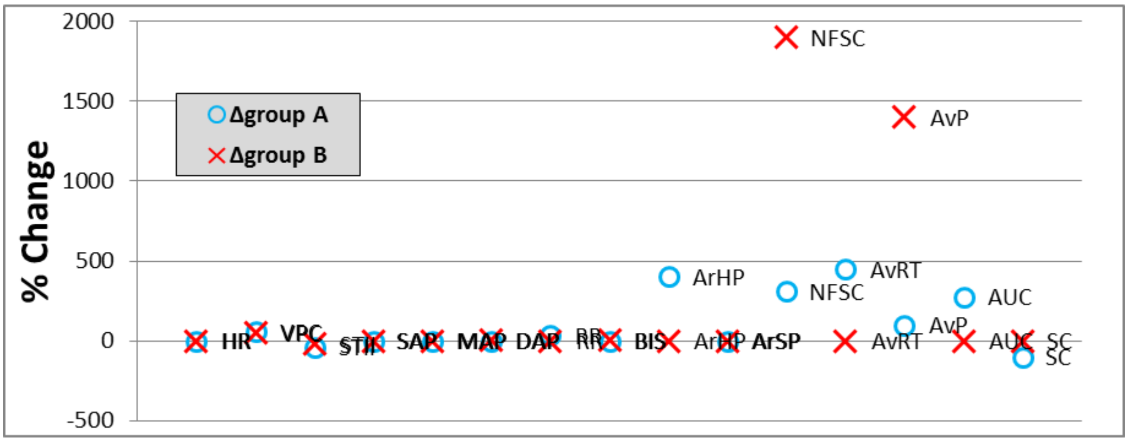

Table 5. Correlation coefficient (τ) between range of noise stimulus (ΔSPL=noise level after-noise level before) and the different EDA parameters (AHP-area huge peaks, AsmP- area small peaks, AvRT- average rise time).

Group A							
ΔSPL	**ΔSCav**	**ΔNSCF**	**ΔAHF**	**ΔAsmP**	**ΔAvRT**	**ΔAvP**	**ΔAUC**
Kendall τ	-.103	.069	-.067	0	-.198	-.310	-.119
p	.564	.723	.710	1	.300	.089	.509
Group B							
ΔSPL	**ΔSCav**	**ΔNSCF**	**ΔAHF**	**ΔAsmP**	**ΔAvRT**	**ΔAvP**	**ΔAUC**
Kendall τ	,234*	,313**	,210	,259*	,120	,162	,244*
p	,024	,007	,054	,034	,197	,108	,030

DISCUSSION

There are several studies measuring noise levels in ICU environment[3-7]. Almost all of them report sound levels above 50bB with maximum peaks up to 101dB[16-17]. Its impact upon both staff and patients' mental, emotional and physical health status and their ability for effective communication is negative. Sleep deprivation is probably the commonest result reported in patients. The latter can contribute to delirium, cognitive function impairment and to general morbidity and mortality. However, noise can also produce direct detrimental effects other than sleep disturbances, like cardiovascular and endocrine abnormalities[8-10, 18-20]. The major noise sources identified by the previous studies vary; yet staff conversations and alarms seem to be the more disturbing for ICU patiens[19-20].

Electrodermal activity of the skin is based upon the electrical properties of the skin, which in their turn, are controlled by the autonomic nervous system (ANS). Thus; EDA monitoring is an indirect measuring of the activation of ANS, and therefore a good monitor mean for the effect of various stress-inducing factors (e.g. pain, emotional arousal, etc)[21]. There are several studies of EDA in perioperative environment[22], yet very few of them are coming from ICU environment and none of them examines the effect of noise levels to EDA activity. Available reports are studies conducted mainly in psychology and psychiatry field[23-26]. Yet, due to diversity of the design, no assumption can be made regarding other types of populations.

The present study does reveal a relation, though weak, between short –time sound stimulus and acute EDA changes in sedated ICU patients. In comparison with others, "traditionally" physical measures of stress, like e.g. cardiovascular parameters, EDA seems to be more accurate. Interestingly, EDA changes are found to be more pronounced in patients under deeper sedation. The latter may be explained by the fact that lighter sedation levels allow better accommodation to / better perception of environmental conditions. Thus; an auditory stimulus is not perceived as stress –induced stimulus; and as a result, EDA changes are smaller.

However, those findings do not come without some compromises, the most important of which was the lack of similar literature. Other limitations: i) the physical characteristics of every sound stimulus was not controlled, so as to examine the effect of sound stimuli in real environment. The same sound level may have different frequencies, which may cause different effects. ii) Although the vast majority of the patients included in the present study were diagnosed with acute respiratory failure, beside exclusion criteria, every other diagnosis was included in the study. iii) Recording time was restricted to minimum so as to limit any other co-founding factors in a complex surrounding like ICU. As a consequence, no study was performed regarding possible adaptation to stimulus. iv). Finally, the authors examined EDA changes due to sound stimuli and not due to auditory- stimuli perceived as pain; hence, cut off for NSCF counting was lower than the limit used in most EDA studies in perioperative environment[11].

Even with the above restrictions, the study highlights another perspective in the study of noise-induced stress in ICU. Future investigation, probably in more controlled samples, is needed in order to define the exact role of noise-induced stress in ANS activation. Comparison of EDA measurements with other stress monitoring means Saliva cortisol or heart rate variability have been already studied in other populations[8, 10,27].

CONCLUSION

Noise-induce stress causes more distinct EDA changes when measured immediately post stimulus. Sedation level seems to affect the perception of the stimulus and thus, affect the EDA changes. However, further studies are needed in to order to reach a definite conclusion.

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ETHICS

The study is part of a thesis project, approved by AHEPA General University Hospital Research Committee and by No 16/09-07-2013 General Assembly of Special Composition of Medical School, Aristotle University of Thessaloniki (Ref. No.8220/10-07-2013) and archived in National Archive of PhD Theses (NID:43587).

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Author Disclosures:

Authors Aslanidis Th, Grosomanidis V, [+]Karakoulas K, Chatzisotiriou A have no conflicts of interest or financial ties to disclose.

Corresponding author:

Aslanidis Theodoros MD,

4 Doridos street, PC 54633,

Thessaloniki, Greece,

tel.: +306972477166,

e-mail:thaslan@hotmail.com