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Evaluation of stress response using psychological, biological, and electrophysiological markers during immersive simulation of life threatening events in multidisciplinary teams

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ABSTRACT

Stress might impair clinical performance in real life and in simulation-based education (SBE). Subjective or objective measures can be used to assess stress during SBE. This monocentric study aimed to evaluate the effects of simulation of life-threatening events on measurements of various stress parameters (psychological, biological, and electrophysiological parameters) in multidisciplinary teams (MDTs) during SBE. The effect of gender and status of participants on stress response was also investigated. Twelve emergency MDTs of 4 individuals were recruited for an immersive simulation session. Stress was assessed by: (1) self-reported stress; (2) Holter analysis, including heart rate and heart rate variability in the temporal and spectral domain (autonomic nervous system); (3) salivary cortisol (hypothalamic pituitary adrenal axis). Forty-eight participants (54.2% men, <7years of experience) were included. Measures were performed at baseline (T0), after simulation (T1), after debriefing (T2), and 30 min after end of debriefing (T3). There was an increase in stress level at T1 ($p < 0.001$) and a decrease at T2 ($p < 0.001$). However, the variations of stress parameters induced by simulation (T0–T1 difference and T1–T2 difference) estimated by the three approaches were not correlated, while, as expected, Holter parameters were well-correlated to each other. Immersive SBE produced a change of stress level in all MDT members with no evidence for status effect but with gender difference. None developed a PTSD. These results support the hypothesis of a complementarity of the stress paths (collective reaction with increased stress level during simulation and a decrease during debriefing) but with relative independence of these paths (lack of correlation to each other). This study also suggests that because of the lack of correlation, stress response should be assessed by a combination of psychological, biological and electrophysiological parameters.

1. Introduction

Stress is defined as a state of real or perceived threat to homeostasis.[1] It requires activation of a complex range of responses involving the endocrine, nervous, and immune systems, collec-

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tively known as the stress response. Stress is both a psychological and a physiological phenomenon[2] and the physiological stress response to the stimuli is accompanied by an anxiety state (psychological stress). Excessive stress can lead to post-traumatic stress disorder (PTSD).[3] In health care activities workload, leadership issues, professional conflicts, and emotional care demands combine to generate stress.[4] This stress impacts performance, described by an inverted U-shaped curve in animal and human studies,[5,6] and contributes to the definition of the arousal theory.[7] Excessive stress and poor management can lead to human errors and decrease recognition of these errors in real life and in simulation-based education (SBE)[8] independently of professional experience.[9] The effect of stress on a medical team during emergency management of patients requires consideration, since it can compromise the safety of patients.[10] Moreover, excessive stress interferes with the retrieval of conceptual knowledge and impedes problem solving.[11] Therefore, evaluation of stress during SBE is of interest to enhance the pedagogical impact of SBE. While debriefing appears to be a crucial time in SBE,[12,13] it is important to assess stress response during the simulation as well. Acute stress activates the autonomic nervous system (ANS), as can be apprehended by the acceleration of heart rate (HR) and modification in its variability (HRV) on Holter.[14,15] Stress also activates the Hypothalamic Pituitary Adrenal (HPA) axis activity, inducing biologic modifications such as an increase in cortisol that can be assessed by salivary cortisol (SC) in simulation.[16] Finally, some events can induce perceived-stress; and a subjective approach to assessment of stress is commonly used in simulation to measure its impact.[17] However, the relationship between self-reported and physiological stress is not unequivocal[2] and may even be controversial.[18] Consequently, stress response can be assessed by objective and/or subjective measures.[19] A combination of some biological, electrophysiological, and psychological measures of stress has been reported.[20] However, most studies have described the use of only one objective parameter of stress[18,21,22] or subjective parameter of stress.[23–26] Post-traumatic stress disorder (PTSD) can develop following a stressful event.[3] Although SBE can produce excessive stress, the occurrence of PTSD, relating to experiences in the simulated learning environment, has never been studied. PTSD usually occurs from one week to one month after a psychologically traumatic event.[27]

We hypothesized that all multidisciplinary team (MDT) members would experience stress during immersive SBE and that it would decline after debriefing. Because of their different physiological mechanisms, we did not expect a statistical correlation between subjective and objective stress measurements. We speculated that stress response would differ according to gender and status within a team with a higher stress level in the leader. We assumed there would be no PTSD among the participants after a simulation session.

The objective of this study was to evaluate the effects of simulation of life-threatening events on measurements of various stress parameters (electrophysiological, biological, and psychological parameters) in MDTs. Secondary objectives were: (1) to evaluate the correlation between the different stress parameters (2) to study stress response according to status and gender; and (3) to search for the occurrence of PTSD.

2. Methods

2.1. Study

This study took place in the ABS-Lab – Simulation Laboratory – INSERM (French national health and medical research institute) #1402, Faculty of Medicine of Poitiers, France. The study protocol, information form, and consent form were approved by the Comité de Protection des Personnes III de la region Ouest (Western France Person Protection Committee III) and were registered under the number 13.05.16. This study is the first part of a randomized single-center study on the relationship between stress and performance, registered by ClinicalTrials.gov under the number NCT02424890. All details of study protocol were reported previously.[28] The calculation of the number of subjects was based on an expected correlation of 0.50 between stress and performance. Four random samples of 12 participants for each of the 4 statuses present in an EMS team [Emergency Physician (EP), Residents (PGY i.e. Post Graduate Year), Registered Nurse (RN), and Ambulance Driver (AD)] were obtained. Each of the 12 MDTs was randomly constituted.

2.2. Population

All participants had less than 7 years of experience working in an EMS. This same level of experience allowed comparison in stress parameters between MDT members since stress depends on the competence and capacity of MDT leadership and co-workers.[29] EPs worked in one of the hospitals in the Poitou-Charentes region (1.8 10^6 inhabitants). They had obtained the University Diploma of Pediatric Emergency Procedures (University of Poitiers, France) after issuance of the American Heart Association and European Resuscitation Council guidelines in 2010.[30] During the university course they had received identical training in pediatric insertion of intraosseous (IO) access with performance assessment on the validated scale for simulated IO insertion.[31] PGYs specialized in Emergency Medicine, were trained in pediatric emergency procedures: clinical training in a Pediatric Emergency Unit and/or the university course. All health care providers (RNs, ADs) from the EMS of the University Hospital of Poitiers had obtained the European Pediatric Immediate Life Support degree over the two years preceding the session. All these EMS teams manage pediatric or adult patients in clinical practice.

2.3. Intervention

A high-fidelity manikin (SimNewB*, Laerdal®) was used for immersive simulation of an infant with hypovolemic shock requiring IO access (Supplemental file 1). All sessions were scheduled in a simulated resuscitation room (Supplemental file 2) on the same day of the week at 2:00pm because of the cortisol circadian cycle. Each simulation – lasting 25–30 min – was preceded by briefing (15 min), and followed by debriefing (30–45 min). In addition, a 45–60 min "snack break" lasting until 5:00pm was planned after each simulation session to allow physiological variables to return to normal conditions. Stressful conditions were related to different sources:[28] the scenario itself, a realistic environment, and the untimely intrusion of simulated parents in the resuscitation room. Four periods of 15 min were dedicated to saliva sampling and to filling out the STAI questionnaire. The saliva sampling was done at the same time for all participants. The chosen period for electrophysiological analysis was 20 min long, starting from 10 minutes prior to the saliva sampling time, to 10 min after the saliva sampling time.

2.4. Measurement of stress parameters

2.4.1. Psychological parameters of acute stress and PTSD

The STAI — State-Trait Anxiety Inventory scale[32] is widely used in simulation.[18] STAI included 20 questions with a 4-point Likert scale. Scores ranged from 20 to 80, with an acute anxiety response to stress for a score over 48 and a normal score around 34/80.[33] Self-assessment of stress can also be evaluated by the Stress-O-Meter (SOM) scale, with a score ranging from 0 to 10.[17,34] The occurrence of PTSD can be assessed using the Impact of Event Scale-Revised (IES-R) on the 7th day after the event[35] and the Post-traumatic Check-List Scale (PCLS) after one month.[36] IES-R ranged from 0 to

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