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Stress measurement in surgeons and residents using a smart patch

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A B S T R A C T

Background: Stress may negatively affect surgeons' performance during surgical procedures, jeopardizing patient safety. For measuring stress, complex methods are used that cannot record stress real time. This study reports stress measurements in surgeons and residents using a novel patch sensor to identify activities and risk factors of stress.

Methods: In this explorative study, surgeons and residents wore the HealthPatch™ during all daily activities for 2–3 days. The patch recorded heart rate variability (HRV), and real time stress percentage using a validated algorithm of heart rate (HR) and HRV. The patch was compared with self perceived stress reporting using STAI.

Results: A significant increase in HRV and stress percentage was shown in twenty surgeons and residents during surgery in comparison with other activities. Consultants showed lower stress levels while operating compared to fellows and residents. Stress according to the patch did not correlate with STAI outcome.

Conclusions: Continuous stress monitoring using a wearable sensor patch reveals relevant data on actual stress of surgeons and residents. Stress was highest performing an operation, particularly in fellows and residents.

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1. Introduction

Surgery is a stressful profession.[1] Long and continuous working hours, high workload, dealing with life and death,[1] and technically challenging procedures[2] are common contributors to stress in surgeons and surgical residents. Chronic stress can lead to relational issues, depression, and burnout,[3–5] and also increases the risk of cardiovascular disease and decreases life expectancy.[6–9]

Surgeons and residents spend a large part of their time in the operating room. Stress can both positively and negatively affect surgeon's performance in the operating room. While moderate levels of stress are necessary to improve alertness, focus, efficiency of action and thus overall performance ('good stress'),[10] excessive and long lasting stress is known to compromise technical[11–13] and non-technical skills ('bad stress').[13] During surgical procedures, excessive levels of stress are mainly caused by technical problems, complexity of the procedure, equipment failures, patient complications, interruptions, and high workload.[10,14,15] During laparoscopic procedures, stress is associated with a prolonged operation time,[11,12] poorer motion efficiency, and an increased number of errors.[12,16] Excessive levels of stress also impair non-technical skills such as communication,[10,17,18] teamwork, judgment, and decision-making.[10,17] Loss of these abilities is associated with undesirable events in the operating room and could compromise patient safety.[13–15,18–22]

Research of surgical stress has been focused on the operating room environment and stress has rarely been studied during other activities.[23,24] However, ward rounds and seeing patients in the Emergency Room, the Intensive Care Unit and outpatient clinic may also elicit stress, of which the consequences for the quality of work are unknown.

Heart rate (HR), heart rate variability (HRV), skin conductance, eye blinks, and salivary cortisol[13] are objective markers for stress response. HRV in particular has shown to be a reliable and more time related measure for stress than the other markers.[25] Several studies showed changes in HRV recordings in surgeons during

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surgical procedures, indicating an increase in intra-operative stress.[24,26–31] Qualitative measurement of stress is commonly by self-reporting questionnaires, such as the State Trait Anxiety Inventory (STAI).[32] Arora et al.[33] developed a method to measure surgeons' stress during surgical procedures using the so-called Imperial Stress Assessment Tool (ISAT). By combining heart rate, salivary cortisol and STAI data, they were able to measure intra-operative stress in a reliable and valid manner. Drawbacks of this tool are the complexity, the time consuming and expensive cortisol analyses, and the inability to obtain real-time stress levels and for a longer period.

Recently, wearable sensors became available for use in healthcare, which can continuously measure vital signs such as HR in an easy and reliable way. The HealthPatch™ (Vital Connect, Campbell, CA, USA) is a small, lightweight and comfortable patch, which is attached to the chest. The patch is unique in measuring stress continuously and depicting stress real time, using a validated algorithm that computes stress as a combination of HRV and HR.[34,35] Because of these features the patch has potential to be used in training situations and to assess chronic stress.

An exploratory study was conducted determining the value of the patch in continuously measuring stress levels in surgeons and surgical residents during all work activities in comparison to usual self perceived stress scoring. Important objective was to evaluate to what extent demographic and surgical factors, surgical experience level in particular, affect this stress.

2. Methods

2.1. Participants

Consultants, fellows and residents were recruited from the surgical department of the Radboud university medical center in the Netherlands between July 2014 and December 2014. A sample size calculation was not deemed necessary because of the exploratory nature of this study. Demographics including gender, age, level of surgical experience and concurrent use of medication affecting heart rate were noted. Participants gave verbal consent after being informed about the study and the anonymous reporting of data. After reviewing the study protocol, the institutional review board waived the need for formal review and approval (2014–1603).

2.2. Patch details

The HealthPatch™ is a flexible self-adhesive patch containing two ECG electrodes and a battery (Fig. 1). The patch is validated to measure nine items: single-lead ECG, HR, HRV, stress level in percentage, respiratory rate, skin temperature, body posture, activity and steps. Patch data are streamed to a smart phone via Bluetooth, from where they are transmitted to a secured online cloud for storage. Data can be downloaded from the individual accounts for analysis.

2.3. Procedure

Participants wore the patch for at least 48 h. In the morning of the first day, the patch was attached to the participant's chest and a connection was established between the patch and a smart phone via Bluetooth. Baseline patch data and STAI score were collected during 15 min of rest in which participants were instructed to sit comfortably, not performing any physical activity, not reading or speaking. Thereafter, data were continuously collected during all daily work activities for the next 48–72 h. Participants filled out the STAI before and immediately after each surgical procedure, not before and after other activities. This was decided because the other daily activities are more heterogeneous and more frequent e.g. administrative activity. All participants kept a personal logbook in which they documented the type and time of daily activities and also physical activity (e.g. running, taking stairs). At the end of each working day one researcher (MW) debriefed participants with help of the personal logbook. Technical failures and side effects of the HealthPatch were documented.

2.4. Stress measurements

2.4.1. HRV

The smart patch measures HRV, which is defined as the variation in time interval between heart beats (R-R interval). The R-R interval is the time between the peaks of two consecutive QRS complexes as recorded by the 125 Hz ECG.[36] According to the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology,[37] subsequent intervals of five minutes were used for automatic calculation of the HRV by the patch. This was done by using time domain and frequency domain analyses. For time domain, the standard deviation of the interval between two heart beats (SDNN) and square root of the mean R-R interval (RMSSD) were used as parameters reflecting HRV. Low SDNN or RMSSD indicate stress.[38] In the frequency domain, Fourier transformation was used by the patch to calculate the power spectral density. Three main spectral densities were distinguished: the very low frequency (VLF) component (0–0.04 Hz), the low frequency (LF) component (0.04–0.15 Hz) and the high frequency (HF) component (0.15–0.40 Hz). LF and HF represent two branches of the autonomic nervous system; LF is expected to be a marker of sympathetic modulation with some parasympathetic act and HF is a marker of vagal modulation.[39,40] Stress is accompanied by an increase of sympathetic activity, resulting in an increase in LF and a decrease in HF.[38,40] The LF/HF ratio was calculated separately by a researcher to isolate sympathetic tone more precisely.

2.4.2. Real time stress percentage

The patch shows stress real time every four seconds.[34] This stress depicts the result of an algorithm that uses HR and SDNN: Stress (%) $= \text{HR} + a * \text{SDNN}$.[34] This stress algorithm was validated and has shown to be sensitive for acute changes in psychological stress.[35] When stress occurs, HR will increase and SDNN will decrease. According to the manufacturer a is usually a negative number. The stress percentage is calibrated to the individual baseline HR. This is done by mapping stress to a cumulative distributive function (Gaussian CDF), ranging between 0 and 1 and multiplied by 100. The stress shown is also adapted to the personal range of daily stress by adjusting the Gaussian CDF to new stress data. The lowest stress level is '0' and highest stress level is '100'. The patch stops measuring the stress percentage when physical activity e.g. walking stairs is undertaken. Thus, only mental stress is recorded by the stress percentage.

2.5. Stress perception

For stress perception, the short version of the STAI was used (Table 1).[41] This validated test consists of six items on a four-point scale and measures emotional, cognitive and physical stress. The STAI takes about 2 min to complete. Total STAI scores range from 6 to 24, whereby higher scores indicate an increase in perceived stress.

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