Stress and Heart Rate Variability in Surgeons During a 24-Hour Shift

Corinna Langelotz, MD; Mark Scharfenberg, MD; Oliver Haase, MD; Wolfgang Schwenk, MD

Objective: To determine the specific effects of working long hours in surgery and potential cardiac stress in the individual surgeon by measuring heart rate variability (HRV).

Design, Setting, and Participants: This prospective study measured HRV before, during, and after a 24-hour shift in a standardized resting period of 10 minutes. Measurements were repeated over 10 shifts for each participant. Eight surgeons from a high-volume inner-city surgery department took part in the study.

Main Outcome Measures: Time and frequency domain parameters of HRV as parameters of cardiac stress and correlations with perceived stress and fatigue on a visual analog scale.

Results: Perceived fatigue increased over 24 hours (P < .001), whereas stress levels decreased slightly (P = .06). Time domain parameters of HRV increased from before the shift to after the shift (standard deviation of normal to normal intervals, square root of the mean normal to normal interval, and percentage of adjacent pairs of normal to normal intervals differing by more than 50 milliseconds: all P < .01), denoting more cardiac relaxation. Both the low- and high-frequency components increased (P = .04 and P < .001, respectively), showing a heightened activity of the autonomic nervous system.

Conclusions: Measurements of HRV during a 24-hour surgical shift did not show an increase in cardiac stress concerning time domain parameters despite intense workloads for a median of 20 hours. Frequency components increased in parallel, though, suggesting alterations in sympathovagal balance. Perceived stress levels correlated with HRV, whereas fatigue did not. Further studies on occupational stress and its cardiac effects in surgeons are needed.

ment of HRV took place during a standardized resting period, starting with 1 minute of metronomic breathing followed by 10 minutes of rest in a supine position during which the respiration rate was not controlled, in a quiet room without a radio, a television, or other sources of disturbance. Beepers were handed over to colleagues to avoid disruption. Surgeons were not allowed to nap during the measurements, which were repeated over ten 24-hour shifts for each participant. Before each recording of HRV, participants assessed their fatigue and stress levels on a visual analog scale ranging from 0 (fully awake, relaxed) to 100 (very tired, very stressed). Also, the total amount of rest during the 24-hour shift was recorded.

**HRV RECORDINGS**

Measurements with the Polar S810 Heart Rate Monitor were conducted “beat to beat,” an electrocardiography recording mode, identifying each QRS complex and recording all R-R intervals. Recordings were analyzed with the Polar Precision Performance program (Polar Electro Inc), allowing for time and frequency domain analysis according to the recommendations by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. For the time domain, the spectrum of high frequency (HF) (measured in milliseonds squared at 0.15-0.4 Hz) and low frequency (LF) (measured in milliseonds squared at 0.04-0.15 Hz) as well as their ratio (LF to HF) were analyzed. The efferent vagal activity is a major contributor to the HF component, an increase in the LF is considered a marker of increasing autonomic influence (sympathetic and parasympathetic), and an increase in the LF to HF ratio accounts for rising sympathetic influence.

**STATISTICAL ANALYSIS**

Data were analyzed with SPSS version 13.0 statistical software (SPSS Inc, Chicago, Illinois), tested for normality using the Shapiro-Wilk test, and shown as medians and interquartile ranges if not normally distributed. Correlations between continuous parameters were assessed with the Pearson and nonparametric Spearman tests, and medians were compared with the Friedman or Wilcoxon test when applicable. The level of statistical significance was set at \( P < .05 \) (2-tailed).

Eight surgeons (1 woman and 7 men) took part in this study. Each participant repeated measurements throughout ten 24-hour shifts. The median age was 32 years, the participants were of average physical fitness, the median body mass index (calculated as weight in kilograms divided by height in meters squared) was 24, and no participants received any medication, had cardiovascular disease, or had diabetes. There was no difference in the amount of rest during the 24-hour shift between individuals, with a median duration of 4 hours (range, 0-6 hours). Visual analog scale scores for fatigue were as expected, higher after 12 and 24 hours than at the beginning of the day \( (p < .001) \), and correlated with the amount of work hours during the 24-hour shift \( (P = .002; r = 0.366) \). Visual analog scale scores for stress were higher at the beginning and after 12 hours than at the end of the 24-hour shift; however, this difference did not reach the level of significance \( (P = .06) \) (Table 1). Stress scores were not correlated with work hours during the 24-hour shift \( (P = .68) \). The heart rate decreased from before the shift to after the shift \( (P < .001) \), which did not correlate with stress or fatigue scores (respective \( P > .10 \); data not shown). The analysis at the beginning of the workday revealed high intra-individual and interindividual variance for all of the parameters, showing considerable differences in the prevailing sympathovagal regulation. This is exemplarily shown in Figure 1 for

**Table 1. Characteristics of Participants and 24-Hour Shifts**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median</th>
<th>Interquartile Range</th>
<th>( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants (n=8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>32</td>
<td>30-34</td>
<td></td>
</tr>
<tr>
<td>Weight, kg</td>
<td>80</td>
<td>65-86</td>
<td></td>
</tr>
<tr>
<td>Height, cm</td>
<td>184</td>
<td>181-189</td>
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</tr>
<tr>
<td>BMI</td>
<td>24</td>
<td>20-25</td>
<td></td>
</tr>
<tr>
<td>24-h Shifts (n=80)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work, h</td>
<td>20</td>
<td>19-22</td>
<td></td>
</tr>
<tr>
<td>Rest, h</td>
<td>4</td>
<td>2-5</td>
<td></td>
</tr>
<tr>
<td>Stress according to visual analog scale score( ^b )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beginning of shift</td>
<td>20</td>
<td>10-33</td>
<td>.06</td>
</tr>
<tr>
<td>After 12 h</td>
<td>20</td>
<td>10-45</td>
<td></td>
</tr>
<tr>
<td>After 24 h</td>
<td>15</td>
<td>5-30</td>
<td></td>
</tr>
<tr>
<td>Fatigue according to visual analog scale score( ^b )</td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Beginning of shift</td>
<td>10</td>
<td>5-30</td>
<td></td>
</tr>
<tr>
<td>After 12 h</td>
<td>40</td>
<td>20-60</td>
<td></td>
</tr>
<tr>
<td>After 24 h</td>
<td>50</td>
<td>25-63</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

*Friedman test, beginning of shift vs after 12 and 24 hours.

**Figure 1.** Intra-individual and interindividual variance in heart rate variability. SDNN indicates standard deviation of normal to normal intervals.

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the SDNN of all of the 8 physicians at the beginning of the shift. Changes in HRV were correlated with the initial preshift values as shown for SDNN in Figure 2 ($P$ < .001; $r$ = 0.830), and all of the other HRV parameters showed the same highly significant correlations (data not shown). Results remained the same after exclusion of data from the 1 female surgeon; these data were therefore included in all of the analyses (Figure 1, participant 7).

Surprisingly, parameters of the time domain, SDNN, RMSSD, and pNN50, increased significantly over 24 hours ($P$ = .003, $P$ < .001, and $P$ < .001, respectively), suggesting increasing levels of relaxation. In the frequency domain, both HF and LF increased ($P$ < .001 and $P$ = .04, respectively), accounting for an increased level of sympathetic and parasympathetic activity. However, the LF to HF ratio remained unchanged because of the rise in parallel ($P$ = .15) (Table 2).

Correlations of perceived stress during and after the shift with HRV parameters of both time and frequency domains were found, but no such correlations were present for fatigue (Table 3).

**COMMENT**

Analysis of HRV in surgical residents and specialists showed increasing levels of autonomic activity during a 24-hour work shift, which were correlated with subjective feelings of stress but not with fatigue and workload. The degree of arousal was predetermined by preshift autonomic activity rather than duration of rest, perceived stress, or fatigue during the 24-hour shift. Time domain parameters showed increased relaxation alongside a decrease in stress scores over 24 hours. In general, stress is an inevitable part of a demanding work environment and surgeons are especially exposed to it on a daily basis. The effects of stress on mental and physical well-being have received increasing attention during the past decade.18 Cardiovascular disease as a consequence of external and...
internal stressors has been recognized as one of the major public health problems to be tackled. Also, the general public is concerned as not only the health of the surgeons but the directly intertwined health of the patients are at stake. Nevertheless, specific research on the particular work conditions of surgeons is still relatively limited. Two major issues need to be addressed: the effects of the physical and mental strain as well as the coping strategies and performance of the individual. Several studies correlating lack of sleep with poorer performance on a laparoscopic simulator caused quite a stir, and articles on fatigue among clinicians and patient safety contributed to the current changes in working directives in Europe and the United States.1,2,4

Recent studies addressed coping in surgery and showed that negative stress-coping strategies among novices in surgery correlated with poor performance on a virtual laparoscopic simulator.19 Another study on the effects of stress on surgical performance showed that stress had both positive and negative effects, although undue stress levels led to impaired judgment and decision making.3

The cardiovascular effects of these working conditions and coping strategies are still in question, and the existing literature is in part controversial. Aasa et al20 analyzed frequency domains during a 24-hour shift and found that subjective and physiological characteristics of ambulance personnel did not indicate distinctive stress, whereas Mitani et al21 also analyzed the frequency domains but showed that the circadian variation of cardiac autonomic nervous system activity was affected during a 24-hour shift.

Growing amounts of research address this problem and refined methods in HRV analysis facilitate this task, with ambulant Holter monitoring and now even less cumbersome devices such as the Polar S810 Heart Rate Monitor as reliable tools.17 Our study addressed the question of HRV changes indicating possible cardiac stress and risk in surgeons over a 24-hour shift. To ensure standardized conditions, recordings took place during a standardized resting period of 10 minutes before, during, and after the 24 hours. Surprisingly, there was no increase in cardiac stress over time but there was an increase in relaxation parameters in the time domain despite significant increases in subjective fatigue levels. The frequency domain parameters showed a general increase of both sympathetic and vagal arousal. The stress levels remained unchanged, although a nonsignificant trend toward a decrease at the end of the shift was seen. As stress levels were correlated with HRV parameters but fatigue levels were not, it could be interpreted that lack of sleep and amount of work hours are not the crucial factors leading to cardiac stress, but more so the perceived mental stress irrespective of the physical strain. On the other hand, it could be argued that measurements during 10 minutes of rest did not reflect the actual stress but led to instantaneous relaxation, with most surgeons being well trained at using every chance for a quick rest, although napping during the recordings was forbidden.

Another question that arises is whether results are influenced by personality trait–specific stress coping in surgeons, as other studies on white- and blue-collar workers showed work stress and worry leading to reduced HRV.21-23 Among the different medical specialties, work attitudes and acceptance of long work hours vary widely, with surgeons having a generally much higher acceptance of greater work volumes.8 In 1990, Green et al18 had already suggested in their survey on stress in surgeons that perhaps the price one pays for a more pressured work pattern is the raised potential for coronary heart disease but the bonus is that one is less depressed.

In conclusion, it is necessary to differentiate between short-term cardiac effects of stress peaks that are inevitable in this profession, cardiac effects beyond that peak, and reversibility of these effects at rest. Therefore, further studies with continuous measurements of HRV during work and rest, with detailed recordings of workload, particular stressors, resting periods, and perceived levels of stress and fatigue, are needed.

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Correspondence: Wolfgang Schwenk, MD, Department of General, Visceral, Vascular, and Thoracic Surgery, Charité–Universitätsmedizin Berlin, Campus Mitte, Charitéplatz 1, 10117 Berlin, Germany (wolfgang.schwenk@charite.de).

Author Contributions: Study concept and design: Langelotz, Scharfenberg, Haase, and Schwenk. Acquisition of data: Langelotz, Scharfenberg, and Haase. Analysis and interpretation of data: Langelotz, Scharfenberg, Haase, and Schwenk. Drafting of the manuscript: Langelotz, Scharfenberg, and Schwenk. Critical revision of the manuscript for important intellectual content: Langelotz, Haase, and Schwenk. Statistical analysis: Langelotz and Schwenk. Administrative, technical, and material support: Haase and Schwenk. Study supervision: Haase.

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**Announcement**

The Archives is pleased to announce the appointment of distinguished surgeons Pamela A. Lipsett, MD, and Selwyn M. Vickers, MD, to our Editorial Board.

**Pamela A. Lipsett, MD** received her medical degree from the University of Massachusetts, Worcester, and completed her residency in general surgery at the Johns Hopkins University, Baltimore, Maryland. Dr Lipsett is certified by the American Board of Surgery, with a special certificate in surgical critical care. She is presently a professor of surgery and nursing and an assistant professor of anesthesiology and critical care medicine at the Johns Hopkins University. Dr Lipsett serves as program director for general surgery, fellowship director of surgical critical care, and codirector of the surgical intensive care units at the Johns Hopkins Hospital.

**Selwyn M. Vickers, MD** received his medical degree from the Johns Hopkins University and completed his residency in general surgery at the same institution. He also completed a fellowship in surgical oncology at the Johns Hopkins University. Dr Vickers is certified by the American Board of Surgery. He is presently the Jay Phillips Professor and Chairman of the Department of Surgery at the University of Minnesota, Minneapolis, and associate director of Translational Research at the University of Minnesota Cancer Center.