Analysis of physiological data to quantify stress and workload of surgeons with different levels of training during a laparoscopic cholecystectomy

N. Samm[1 2], D. Ostler[1], T. Vogel[1 2], N. Marahrens[1], D. Wilhelm[1 2], H. Feussner[1 2], R. Stauder[3]

[1]Research Group MITI, Klinikum Rechts der Isar, Technical University Munich, Trogerstr. 26, 81675 Munich, Germany
[2]Department of Surgery, Klinikum Rechts der Isar, Technical University Munich, Ismaninger Str. 22, 81675 Munich Germany
[3]Computer Aided Medical Procedures (CAMP), Technical University Munich, Germany

Contact: nicole.samm@tum.de

Introduction

In a difficult and demanding environment such as the operating room, the individual effect of workload on surgeons is of particular importance. The increased stress and workload during an operation can lead to an impairment of technical skills and vigilance that causes an impact on memory and other cognitive processes. These facts can significantly influence our decisions and have an important effect on patient safety. (1)

Apart from the personal stress level of the surgeon, new technologies like robotic or robotic-assisted systems are increasingly finding the way into our operating theatres and will lead to an additional load of stress. Robots do not yet have the cognitive skills and experience of human assistants who can easily recognize, analyze and adapt to changing situations or even stress factors. For a safe human-robot interaction, and therefor a maximum of patients safety in intraoperative stress situations we must fulfill certain requirements. In order to reduce the arising workload of the human-machine interaction we should acquire knowledge of the surgical workflow. Critical situations during an operation should be identified and adapted by the robotic-assisted systems.

The first aim of this study was to examine the specific effects of intraoperative stress on the cardiovascular system at surgeons with different levels of training by measuring the respiratory rate (RR) and heart rate (HR). The second goal of our work was to examine a possible integration of our data into a workflow recognition system to recognize more complex and non- linear correlations by machine learning.

Materials and Methods

In a cross- sectional study during laparoscopic gallbladder resections (n=9) at the University Hospital Rechts der Isar, Munich, Germany the effect of intraoperative stress on autonomic balance, measured by the determination of heart rate (HR) and respiratory rate (RR) was studied.

The subject of the examination was a laparoscopic cholecystectomy performed by an experienced surgeon as well as an intern with less training on that operation. Difficult steps in this operation, that requires a high degree of concentration, are usually the preparation of the Calot triangle, the clipping of the vessels as well as the removal of the cystic duct.

The HRV was quantified by the analysis of the variation of beat-to-beat intervals in the electrocardiogram (ECG).

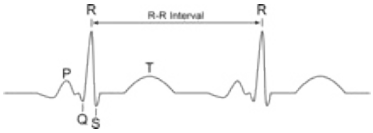

Figure 1: Standard figure of a QRS- Complex of the ECG. HRV can be calculated by the signal.

During the laparoscopic cholecystectomy we measured the respiratory rate, pulse and position of the upper body by using a specially designed chest belt with sensors that recorded the pulse rate and movement of the thorax during in- and expiration. Two experienced and three less experienced surgeons were enrolled as voluntary participants after given their written informed consent. Neither acute nor chronic illnesses within our test persons were present. Each participant was monitored over the course of a laparoscopic cholecystectomy. Data were analyzed with the statistical software SPSS Version 15.0 (SPSS, Inc., Chicago, IL, USA). Results are expressed as percent, median and total range.

Results

The median age of the participating surgeons was 39 years; the body mass index (calculated as weight in kilograms divided by height in meters squared) was in median 22.3 and all participants were in good physical conditions. The surgeons had 11.4 years of practice in middle and worked 49.2 h per week **(Table. 1)**. No participant received any medication or had cardiovascular disease.

Characteristics	Median (range)
Age (years)	39 (28-62)
Height (m)	1.78 (1,73-1,85)
Weight (kg)	70.6 (58-84)
Physical activity rate	6.0 (3,0-9,0)
Years of experience (year)	11.4 (1-35)
Working hours per week (h)	49.2 (40-60)

Table 1: Characteristic of the study sample (n=5);
Physical activity rate: evaluation on a scale from 0(no activity) to 10 (activity more than 8 h per week)

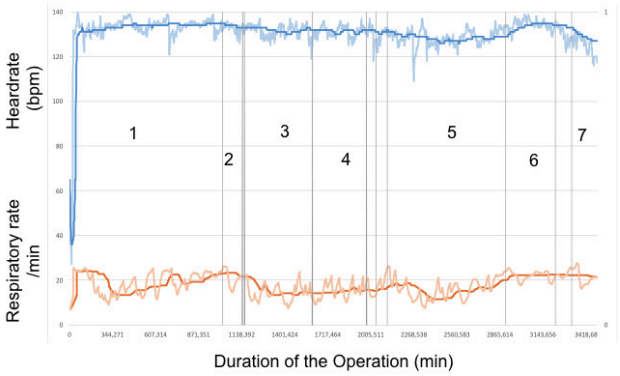

Figure 2: Median measure of the HR (dark blue line) and the respiratory rate RR (dark red line) of the experienced surgeons.

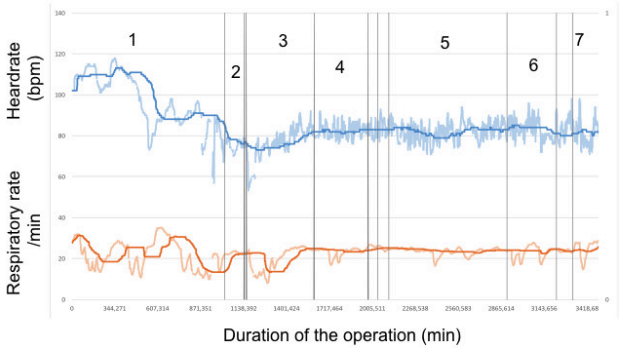

Figure 3: Median measure of the HR (dark blue line) and the respiratory rate RR (dark red line) of the non-experienced surgeons.

The two graphs above show the mean heart rate HR (dark blue line) and respiratory rate RR (dark red line) of the two experienced surgeons measured over the nine trials **(Figure 2)** and the three less experienced interns **(Figure 3)**. To better display the variance in pulse and respiratory rate, the curves have been smoothed. The numbers in the graphs refer to the individual steps during the laparascopic cholecystectomy. 1: prearrangement; 2: insertion of the individual trocars; 3: preparation of the Calot triangle; 4: clipping of the vessels and Ductus cysticus; 5: triggering the stacker; 6: gallbladder retrieval; 7: hemostasis.
The measured values of the experienced surgeons in Figure 2 show a slightly higher pulse but there is no great variance between the individual steps of the operation. Whereas the measurements on the interns with less experience (Figure 3) indicated that starting with a lower HR level, the different surgical steps produced a greater HR variance.

Discussion

In the present study we were able to show that there is an association of perceived stress at work and the cardiac autonomic control in surgeons. Regarding the outcome variables, the two groups of surgeons, divided according to their perceived stress levels, showed differences in the variation intraoperative HR and respiratory rate (RR).
Other research groups confirm to our findings that the analysis of the heart rate and the respiratory rate are very important marker of physical and mental stress as well as workload. (2,3) We postulate that the stress level, measured by HR and respiratory rate and the variation of both parameters, of a surgeon is reciprocally proportional to the level of education and training. Moreover, in general, young physicians are thought to experience more stress than veteran surgeons who are used to differ to different working conditions and follow their daily routine. (4) As we were able to show in our study, the experienced surgeons started with a bit higher HR level but the different steps of the operation with their different degrees of severity caused no big variance in HR or RR. In contrast, the less experienced surgeons showed a lower overall pulse level, but the individual surgical steps led to a greater variance in pulse (HR) and respiratory rate (RR). Therefor we claim that the analysis of the variance of HR shows a correlation on the occurrence of critical events during surgical procedure. However, this knowledge must be adapted to the surgeon's level of training. Moreover the integration of this data and knowledge into a workflow recognition system in order to recognize more complex, non-linear interrelationships by machine learning can lead to a safe human- robot interaction in intraoperative stress situations. This brings us closer to our goal of enabling robots or robotic-assisted systems to recognize problems and react to them independently.
There remain some potential biases of our study. Momentarily we have a small amount of participants in the study and just a few repetitions of the experiment. There are more different ways to gather and analyze physiological data of the participants. Beside the examined heart and respiratory rate, some groups postulate the use of biochemical indicators or eye tracking as well as EEG or EMG. Especially measuring the blink rate, the saccades, the pupil diameters and the duration of fixation with eye tracking seems to be another line leading approach. (5)

Conclusions

In our opinion the analysis of the workload of a surgeon and its effects are very important. According to the Yerkes Dodson law, performance increases with physical and mental stress, but only to a point. When the stress level become too high our performance decreases. But if we link our knowledge with technology in the future, we may be able to minimize the dangers arising from excessive workload and stress with the help of machines.

References

1. Arora S, Sevdalis N, Nestel D, Woloshynowych M, Darzi A, Kneebone R. The impact of stress on surgical performance: a systematic review of the literature. Surgery [Internet]. 2010 Mar;147(3):318–30, 330-6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20004924
2. Rieger A, Stoll R, Kreuzfeld S, Behrens K, Weippert M. Heart rate and heart rate variability as indirect markers of surgeons' intraoperative stress . Int Arch Occup Environ Health [Internet]. 2014 Feb;87(2):165–74. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23370764
3. Weippert M, Behrens K, Rieger A, Stoll R, Kreuzfeld S. Heart rate variability and blood pressure during dynamic and static exercise at similar heart rate levels. PLoS One [Internet]. 2013;8(12):e83690. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24349546
4. Böhm B, Rötting N, Schwenk W, Grebe S, Mansmann U. A prospective randomized trial on heart rate variability of the surgical team during laparoscopic and conventional sigmoid resection. Arch Surg [Internet]. 2001 Mar;136(3):305–10. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11231850
5. Tokuda S, Obinata G, Palmer E, Chaparro A. Estimation of mental workload using saccadic eye movements in a free-viewing task. Conf Proc . Annu Int Conf IEEE Eng Med Biol Soc IEEE Eng Med Biol Soc Annu Conf [Internet]. 2011;2011:4523–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22255344

Acknowledgements

This study was founded by DFG grant 1321.