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Specific stressors in endonasal skull base surgery with and without navigation

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Abstract The goal of modern organizational psychology is to recognize, anticipate and finally avoid stress situations. The aim of this study was to measure objectively the mental and physical demands during transnasal surgery with and without the aid of a navigation system. Forty endonasal surgeries (20 with and 20 without navigation, not blinded and not randomized) done by four different experienced rhinosurgeons (>250 FESS procedures done) were included. The heart rate, the heart rate variability, the respiratory frequency and the masseter tone were monitored as biometrical parameters by the surgeons during the whole surgery for the quantification of mental demand. Stress situations could be identified during the procedures by an increase in the heart rate and a decrease in the heart rate variability. Stress level in procedures with navigation did not significantly differ from procedures without navigation. Interestingly, in 10 % of the cases a navigation system would have been helpful, although the surgeon stated before the procedure that such a system would not be necessary. Other stressors could be identified like time pressure, students or colleagues speaking with the surgeon or chatting in the OR and system failure of medical devices, i.e. navigation, sinus drill, electrocautery or shaver. Surgical stressors blurred vision due to diffuse bleeding and drill out procedures in the sphenoid sinus. Calming situations were a quiet atmosphere in the OR (i.e. closed doors) and the participation of another experienced colleague, especially a neurosurgeon. Stress situations occur when complex medical devices like the navigation do not work. For their proper function it is important that the whole OR-team is trained with it. Unqualified or unmotivated OR personnel create stress for the surgeon and disharmony in the team, which then ends in inadequate behaviour.

Keywords Heart rate variability · Navigation · FESS · Skull base surgery · Mental workload · Stress

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Introduction

Without a doubt, the mental and physical demands of surgeons during functional endoscopic sinus surgery (FESS) and transnasal skull base surgery are high [1]. During every surgery there are more or less stressful situations, which arrest a higher or lower level of attention from the individual surgeon. Depending on the operational experience, age, stage of the clinical hierarchy and ultimately from the individual habituation different stressors take effect on the surgeon and the surgical team [2]. To recognize, anticipate and finally avoid these stress situations is the goal of modern organizational psychology.

In FESS, like in other surgeries, the surgeon has to handle different devices and has to collect information from different sources on the fly and at any time. Surgical navigation systems provide a mass of information and can improve the surgeon´s intraoperative orientation and situation awareness [3]. However, the correct usage of these devices is subject to proper and regular training. Otherwise, these systems create more stress than real help for the surgeons [2]. The specific stressors during FESS and transnasal skull base surgery and while using navigation systems were hardly been evaluated and rarely determined.

The aim of this study is to measure the mental and physical demand of four different rhinosurgeons during transnasal surgery with and without the aid of a navigation system. Afterwards, the following questions should be answered:

– In which situations are the mental demand for the surgeons at the highest level?
– Can a navigation system reduce the cognitive and physical demand?
– How does the surgeon deal with the additional information from the system mentally?

To answer these questions we monitored 40 endonasal surgeries and analyzed stress showing biometrical parameters for the quantification of mental demand: the heart rate, heart rate variability, respiration frequency and masseter tone.

The heart rate is a frequently used parameter for the objective detection of mental effort because of the easy acquisition through the electrocardiogram. It shows that the heart rate increases with an increase in mental effort [4].

A major bias is the influence on the heart rate through external factors like muscle work, respiration or emotions. Although the muscle work during surgery is minimal, because the surgeon cannot move, run or jump in the OR, the psychological effect on the heart rate is not clearly definable [5]. Nevertheless the heart rate is used in several studies as a parameter of mental effort, although the quantity cannot precisely be determined [6, 7]. In addition, the heart rate variability (HRV) describes the variability between the heart beats of a person in a specific situation. In other words the variability of the R–R intervals in the ECG is the interbeat interval (IBI). Since the first studies of Kalsbeek and Ettema, the HRV is used as a parameter and a characteristic variable for the measurement of mental effort [8, 9]. They proved in their studies that the HRV decreases while acting out a binary cognitive task. In other words the heart beats more regularly in situations with high mental workload [10]. The HRV is an established parameter for the quantification of situations with mental effort. It is used for example by pilots and space shuttle operations to register the difficulties of air manoeuvres, the efficiency of the training and the stress level during flights [6, 11].

Materials and methods

After approval by the local ethics committee this prospective clinical field study was conducted at the Department of Otorhinolaryngology, Head and Neck Surgery at Ludwig Maximilians University of Munich in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All subjects gave their informed consent prior to their inclusion in the study. Four experienced (more than 250 FESS and transnasal procedures done) rhinosurgeons performed transnasal surgery on ten patients each. Five of these patients were operated with the aid of a navigation system (Vector vision compact, BrainLab, Feldkirchen, Germany) and five patients without. The surgeons of this study were very familiar with this system through prior studies [2, 3, 12]. The study groups were not randomized to meet the ethics committee criteria. The allocation to the groups was determined by the surgeon preoperatively. This was because, first, the patient has a right to know whether a navigation system is used in his particular case or not and, second in difficult cases it is not justifiable not to use such a system which is known to decrease complication rate in certain cases [3]. In summary 40 patients participated. The whole operation was recorded with STORZ AIDA video system. During and 5 min before and after the operation the surgeons were connected to a biofeedback device (Nexus 10, Mindmedia, NL), to monitor the breathing frequency, heart frequency (and variability) and the masseter tonus continuously. Surgical sections of each operation and critical events, i.e. stronger bleeding or if other colleagues were entering the theatre, were marked by a manual trigger of the biofeedback device during the procedure to see whether they had an influence on the stress level.

For a proper heart rate variability analysis, the recorded endoscopic videostream was saved and synchronized with the biometrical data from the biofeedback device postoperatively (Figs. 1, 2).

In the spectral analysis of the HRV three frequency bands are important:

Very low frequency: 0.02–0.06 Hz
Low frequency: 0.07–0.14 Hz
High frequency: 0.15–0.40 Hz

A temperature component is included in the low frequency band, the blood pressure and adrenaline component are included in the 0.1 Hz frequency (low frequency band). The respiratory frequency is a common source of artifacts and was, therefore, monitored in this study for the correct interpretation of the low and high frequency band [13].

In exhausting mental activity the heart beat becomes more regular to ensure a continuous oxygen supply of the brain [9]. The same procedure can be observed by physical effort. The higher the mental or physical effort of the

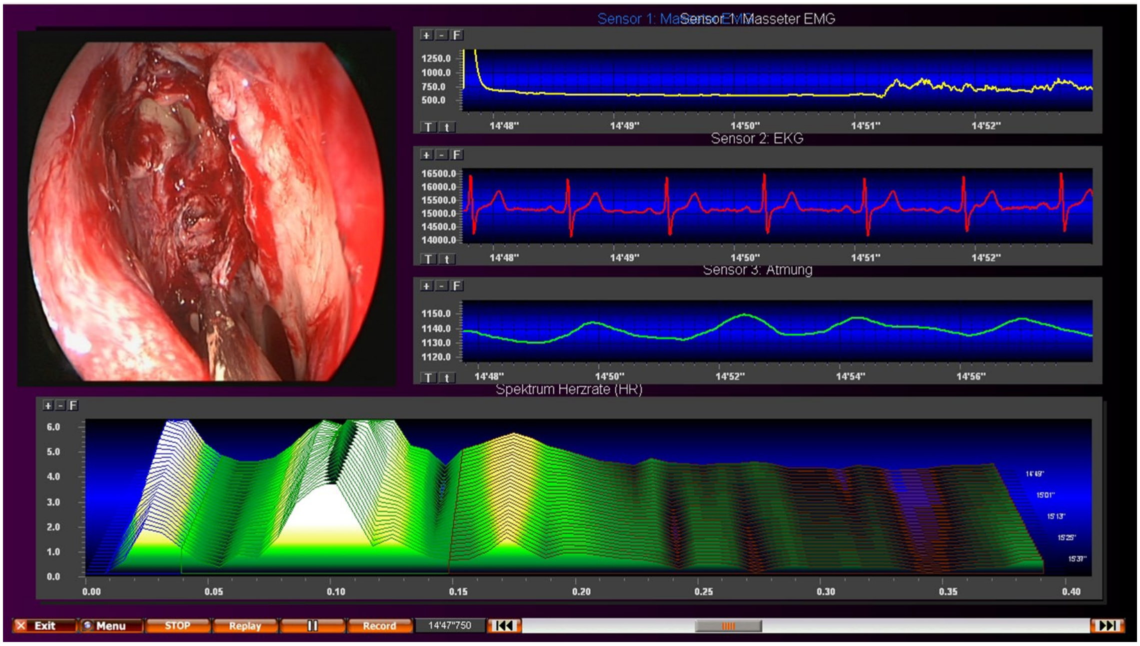

Fig. 1 Screenshot of the intraoperative biofeedback measurements with MindMedia's BioTrace+Software. The experienced surgeon opens the ethmoid and is very calm

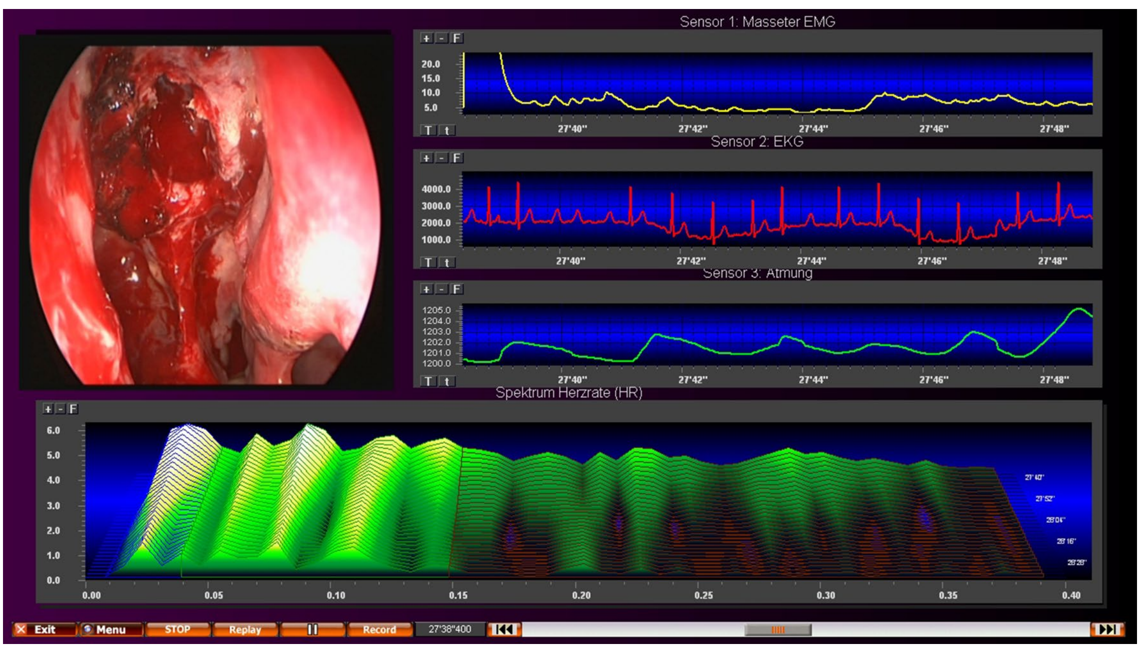

Fig. 2 Screenshot of the intraoperative biofeedback measurements with MindMedia's BioTrace+Software. 15 min later, the posterior ethmoid artery was damaged by accident and the surgeon is stressed

test person is, the lower is the variability of the heartbeat, which means the more regular beats the heart. This way it can be measured how exhausting (mentally and physically) an activity for an organism is.

All three frequencies show a suppression of the HRV by exertion and concentration [11] but the biggest difference is seen in the low frequency band, especially in the 0.1 Hz component [13].

The HRV was monitored during the whole operation and 5 min before and 5 min after, in the operation theatre, continuously. This way a calibration with a rest situation but in the same surrounding (i.e. temperature, O^2-saturation) was given [7].

The spectral analysis of the interbeat intervals have been implemented with the programme CARSPAN (developed by B. Mulder, Groningen) [14]. With this spectral analysis it is possible to make a differentiation of the three frequency bands listed above and to quantify them. CARSPAN uses the discrete Fourier analysis to split the time series into spectra.

As an additional indicator of physical and mental effort the masseter tonus was measured, too [15]. In situations of high tension a significantly higher tone of the masticatory muscles is measurable through the unconscious contraction of the muscles by biting the jaws [16].

At the end of every surgery, the surgeon had to answer the question, how much he had benefitted from the additional information of the navigation system on a visual analogue scale. In case the surgeon had not used a navigation system, the question was how much a navigation system could have helped in the particular surgery.

Statistics

The following objective parameters were statistically evaluated:

1. Heart rate variability
2. Heart frequency

The statistical evaluation was performed with an analysis of variance (ANOVA) for repeated measurements and t test (paired design). The programme used was SPSS 15.0. A significance was considered if $p < 0.05$. The effect size η^2 was also calculated. A pretest power analysis was performed using "Power and sample size calculation Vers. 3.0". Prior studies indicated that the difference of HRV in response to matched pairs is normally distributed with standard deviation 0.6. If the true difference in the mean response of matched pairs is 0.4, we would need to study 20 pairs of subjects to be able to reject the null hypothesis that this response difference is zero with probability (power) 0.8. The type I error probability associated with this test of this null hypothesis is 0.05. Therefore, we included $n = 40$ patients (=20 pairs) and operated on half of them with navigation and half without.

Masseter tone and respiratory rate gave additional information and hints about possible artifacts (speaking, moving and physical work) and situations with special tension (masticatory tense) but were not quantified statistically.

Results

The four subjects (surgeons) were all male, one left-hander and three right-handers. The average age was 39 years (between 36 years and 41 years). All 40 patients were included. The average age of the patients was 47 (SD 9.8) years. Indications for transnasal surgery were:

Chronic sinusitis with/without polyps $n = 26$.
Mucoceles of the frontal sinus $n = 5$.
Inverted papilloma of the paranasal sinus $n = 2$.
Skull base tumours (aesthesioneuroblastoma, intracranial polyps, squamous cell carcinoma, pseudotumor) $n = 4$.
CSF-leaks $n = 3$.
23 (57 %) patients had prior surgery to the paranasal sinus (revision cases).

To classify the grade of difficulty of the endonasal surgery, patients were sorted in four different subgroups: (Fig. 3).

Drop outs

All four surgeons participated in this study performed ten operations each. The included patients participated without drop outs, too. Two operations had to be removed from the heart rate analysis because of an intraoperative system failure of the biofeedback device (no proper ECG was recorded) (Fig. 4).

Heart rate variability analysis and masseter tone analysis

All four surgeons had slightly different individual stressors, which could be identified by the HRV, masseter tone and asking the surgeon to the particular intraoperative situation after the surgery. According to the objective (HRV, HR and masseter tone) and the subjective (questioning) data the following ranking of intraoperative stress situations could be determined:

1. Time pressure.
2. Students or colleagues chatting in the OR.
3. System failure of medical devices: navigation, sinus-drill, electrocautery, storz AIDA recording device, shaver.
4. Diffuse bleeding with blurred vision.
5. Drill out procedures, especially in the sphenoid sinus.

Difficult manoeuvres during the operation or the use of the 45° or 70° endoscope did not lead to a higher masseter tone or a lower HRV in the surgeons. In fact, the following circumstances lead to a higher HRV and a depression of

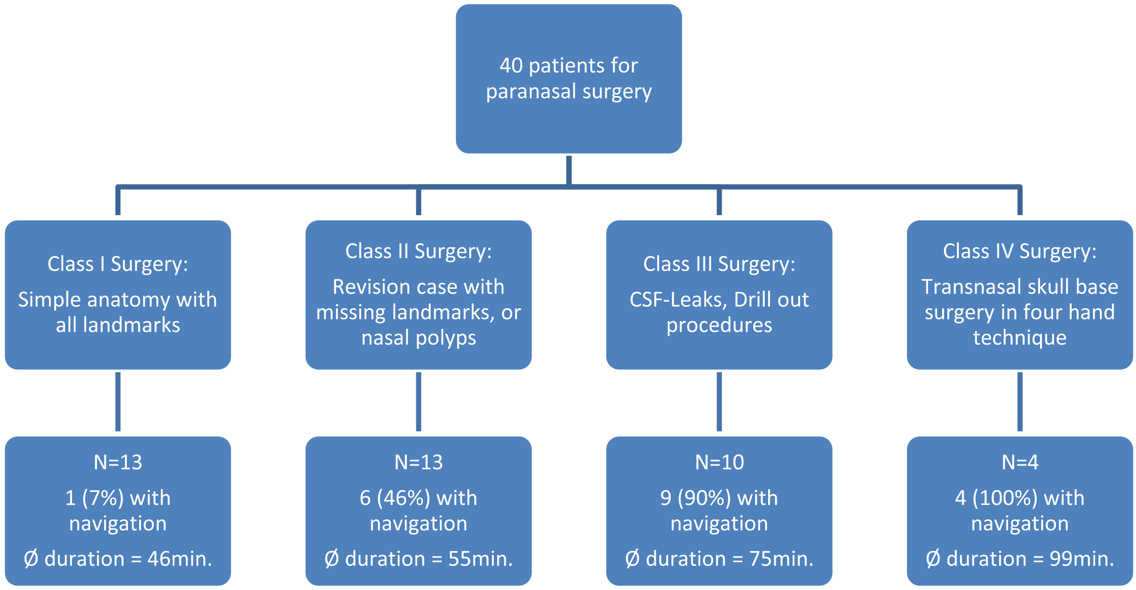

Fig. 3 Allocation of the study subjects to different surgical subgroups in dependence of the difficulty of the endonasal surgery

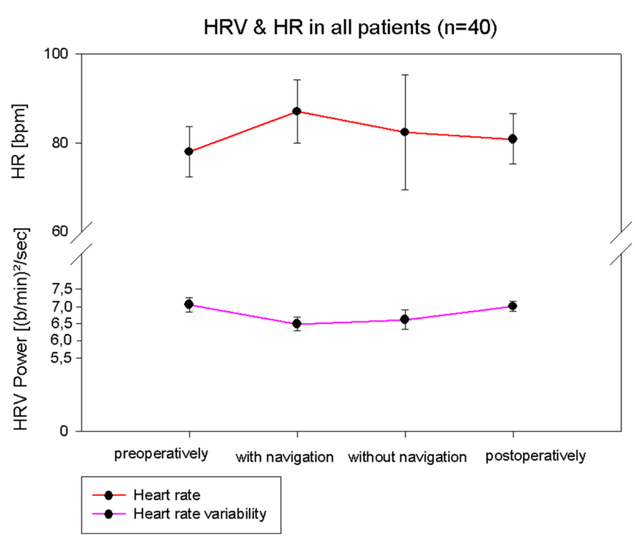

Fig. 4 Heart rate (HR) and heart rate variability (HRV) of the surgeon before and after the surgery and in the two study groups

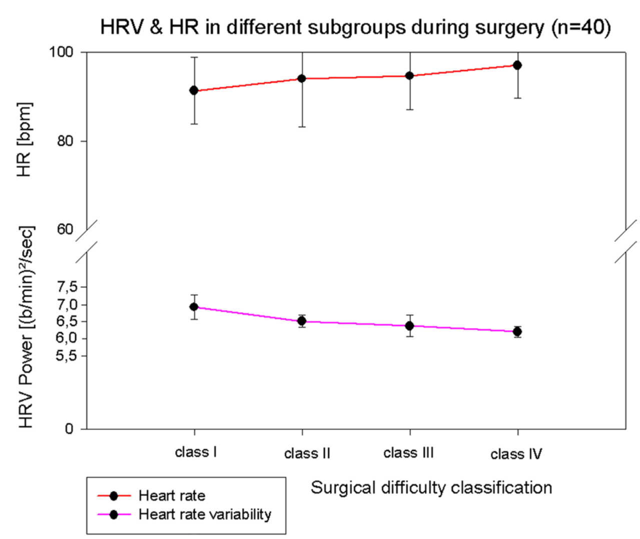

Fig. 5 Heart rate (HR) and heart rate variability (HRV) of the surgeon during the surgery in different complex procedures. Class I is a non-complex procedure, whereas class IV is a highly complex endonasal procedure

the heart rate, which means these were calming down the surgeon:

1. Quiet atmosphere in the OR (i.e. closed doors).
2. The participation of another experienced colleague, especially a neurosurgeon.

The heart rate was significantly higher during the surgery, compared to the HR before and after the surgery. The HRV showed a corresponding inverse graph. It was higher in the preoperative section in comparison to the intraoperative HRV, which was low. After the operation some minutes were required to reach the preoperative HRV level (rest level). During the operation with navigation the exertion was a bit higher (lower power at the middle frequency band). However, the result was not significant, that means there was no significant difference in HR or HRV between the operations with navigation and without ($p = 0.157$, $\eta^2 = 0.203$). An additional mental load with the use of the navigation system could not be observed.

According to the HRV graphs in Fig. 5 the mental workload increased significantly with the higher complexity of the surgery. The data shows that the average stress level in complex (class IV) endonasal surgery is significantly higher than in "simple" (class I) endoscopic sinus surgery ($p = 0.037$, $\eta^2 = 0.46$).

At the end of the surgery and after the baseline measurement all participating surgeons in the navigation group should answer the question whether the additional information of the navigation system was crucial for the operation. After the surgery without navigation, the question whether a navigation system would have been useful for the particular operation should be answered. The results are in Fig. 6.

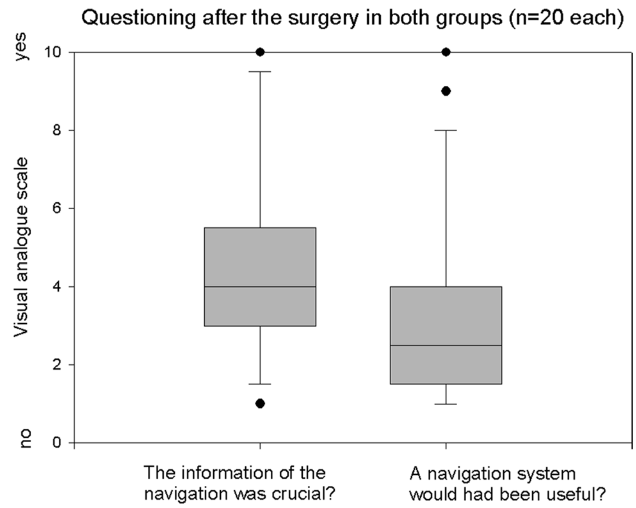

Fig. 6 After every surgery the surgeon had to answer a question on a visual analogue scale about the effort to engage a navigation system for the occurred surgery

Discussion

Cardiovascular indicators of mental load

The heart rates, as well as the HRV, are cardiovascular parameters with a high importance for the detection of psychical and mental effort in surgery [17–19]. With the development of high definition spectral analysis methods the HRV can be split into three different frequency bands during the acquisition "on the fly". Although the suppression of the HRV in situations of mental effort is visible in all three frequency bands, in the middle frequency band it is most obvious [13]. Another reason why this band is to be preferred is the fact that in studies with short acquisition times, like this study, the 0.1 Hz band reacts most sensitively [13] and can be read out in real time.

Nevertheless doubts from several scientists exist for this method [11, 20, 21]. Many studies use the HRV as an indicator for mental effort but the evaluations of the results vary a lot. There exist no standard guidelines for the evaluation of the HRV and there are many activities which cause mental load. However, there is no better objective and reliable method for the measurement of the mental load and effort currently available [14].

Stress factors, cognitive and psychical load

The results of this study underline the state that high mental load dominates in surgical interventions like FESS. During every procedure, the stress levels were significantly higher, than before or after the operations. Preoperatively the HRV is high, during the operation the HRV decreases and is suppressed by adrenaline, which causes the heart to beat more regularly and faster. After the operation the HRV increases again.

During and after the usage of the navigational pointer no suppression in the 0.1 Hz component was visible. On one hand, this means that the application of the navigation system did not cause a higher mental load. On the other hand, the stress level of the surgeon in an operation with similar complexity and without the aid of a navigation system remains unclear and could be much higher. To answer this question a proper randomization would be necessary, which is for ethical reasons impossible to achieve in complex skull base operations.

There was no significant difference in the overall HRV in operations with navigation compared to operations without navigation, which means that the stress level was almost equal in these operations. Regarding this equality of the stress levels, it has to be mentioned that, according to Fig. 3 the navigation system was used in more complex operations, like skull base surgery, and it was expected that this kind of surgery should demand more mental effort from the surgeons. No faithful surgeon would deny the fact that a higher mental workload is needed in complex surgery like transnasal skull base surgery.

A reverse picture to the HRV can be observed with the analysis of the HR. The heart rate is significantly increased during the operation compared to the baselines. However, there was no significant difference in the mental workload between the interventions with navigation and without.

Another point was the question about the effort to engage a navigation system after the surgery [19]. Fortunately, in the non-navigation group in most cases (18/20) a navigation system would have been unnecessary. But in two cases (10 %), the surgeon admitted after the surgery that a navigation system could have been useful, although the surgeon thought that such a system would be unnecessary preoperatively. That means that about 10 % of the apparent "easy" FESS turns out into more complicated procedures where a navigation system would be useful. This is a rather high rate for which further investigations should be done. On the opposite, in more than 50 % of the cases where a navigation system was installed, the additional information was not used or crucial for the operation. This seems a rather normal rate and should be even lower in more experienced and cautious surgeons.

Through the objective measurement of the mental workload some other stressors could be identified and attracted attention independently from the usage of the navigation. A significant depression of the HRV could be monitored when students or colleagues were chatting in the OR. The other way round, a quiet and professional atmosphere in the OR inducted a lower mental workload and stress level.

Partly avoidable stressors are system failures of surgical devices like the navigation, the electrocautery, the shaver or the sinus-drill. A complete system failure never occurred during the study, but electrocautery often not functioned because the cable was not plugged in or the shaver blade was not properly fixed to the handpiece. Although these system failures could be fixed easily, it took time and these unprofessional circumstances stressed our surgeons in the study. Postoperatively the surgeons stated, that stress was created by these situations because of unpredictable time loss and the helpless feeling of “nothing to do, but to wait for someone else to fix the problem”.

Classic endoscopic surgery specific stressors like blurred visions due to diffuse bleeding or manipulation at high risk structures in the sphenoid sinus caused a higher stress level. Interestingly, this specific kind of stress exhausted the surgeon physically but felt comfortable and physiological. This raises the question, whether the stress level and the additional mental load have negative consequences for the long-term health of the surgeons and the outcome of the surgery. During an operation a certain degree of tension and stress is desirable because it goes with increased concentration and situational awareness. This particular type of stress is called eustress [6], and is not like the harmful and unphysiological distress [22]. Distress can typically lead to overload and burn out syndromes [23]. Unfortunately, the line between eustress and distress is not clearly definable and hardly measureable.

Therefore, avoidable stressors like simultaneous teaching of students in the operating theatre should be eradicated as much as possible. Because of these findings we changed the student´s bedside teaching. The teaching of students in the theatres is not performed any more by the operating surgeon but by an uninvolved supervisor.

Unfortunately, after every surgery the surgeons claimed that the biggest stressor is the time pressure. Although this specific stressor is poorly defined and could not be monitored objectively with this setting, it seems to play a certain role in the OR in University clinics in Germany. Time pressure can be avoided, in a certain way avoidable through better planning and realistic anticipation of the needed surgical time. In any case, time pressure can never be an excuse for an unfortunate event which might have medical or legal consequences.

Conclusion

Endoscopic sinus surgery and endoscopic skull base surgery are heavy mental workload even for advanced surgeons. In situations with heavy workload stress reactions are physiological and natural to get better situation awareness (eustress). Too much workload and the powerless feeling of losing control is unphysiological and can exhaust and frustrate the surgeon (distress), therefore, additional and avoidable stressors have to be identified and then avoided. It could be shown that stress factors are measureable objectively. Further investigations should aim at this to increase the quality of life and efficiency of rhinosurgeons in the future. Unhealthy stress had to be identified and should be communicated in the team without shame. An open discussion among the current and next generation of surgeons about mental demand, stress and rough atmosphere is the chance to improve the OR situation and to make surgery more attractive to female surgeons especially.

In our study, all four surgeons stated the time pressure as the utmost stressor. Unfortunately, especially this particular stressor seems difficult to avoid at first sight. However, realistic adverbial of time by the surgeon pre- and intraoperatively and conservative OR-scheduling can take away a lot of time pressure.

Other stressors like loud chatting in the OR, open doors or malfunction of medical devices can relatively easily be avoided. Correct function of medical devices, like navigation systems, can only be guaranteed by proper maintenance and if these devices are operated by qualified and trained personal. Video endoscopy and navigation systems are complex devices, which need regular training. Failure or malfunction of these devices create distress and can be dangerous for the patient, surgeon and OR team. Nowadays advanced rhinosurgeons have to deal with a lot of different medical devices and a lot of important and unimportant information from these devices. For a good result the surgeon has to extract the important and right information from the medical devices on the fly during every surgery. This is hard mental work. Training and high situation awareness is needed for this. Manufactures of medical devices exactly know this and try to create their devices easier to handle, self explaining and intuitive in operation [24]. But in the end the crucial information can only be extracted if the medical devices and the operating team work correctly, otherwise distress is waiting to happen. For proper operation of complex medical devices it is important that the whole OR-team is trained with it. In most cases malfunction of a medical device is due to false operation by an untrained user. Experienced surgeons know this, that is why they are not stressed or get angry with the medical device itself, but with the operating team Every surgery is teamwork. One last ultimate stressor for everybody in the OR is disharmony in the team, which is in most cases due to inadequate training (which then ends in inadequate behaviour) [25]. The experienced senior surgeon, who plays the biggest role and stays in the centre of the team, can contribute most to harmony and adequate behaviour. The senior surgeon is the one who must always take the blame and the one who must reply to any questions if complications occur. The correct and calm behaviour of the surgeon is not only a matter of legal affairs but even of an ethic point of view. The (senior) surgeon has to be aware of this role and has to train this with his or her team in the OR and outside the OR. Guided simulation trainings, team building actions and professional group and single conversations can contribute to a better team work and more professional atmosphere in the team.

In this study it is shown for experienced surgeons that it is not the complexity of the surgery or the multiple different medical devices with a mass of medical information that creates distress but the inadequate teamwork of the contributing persons in the OR. This is completely different in surgical training situations, where the trainee is stressed by the behaviour of the supervisor and the handling of different medical devices. In addition to this interesting topic of stressors during surgical training will be published (from our workgroup) in the near future. Last but not least it remains unclear whether the reduction of stress leads to a better surgical outcome. Further investigations in this difficult field of organizational psychology are needed.

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Conflict of interest All authors state that there is no conflict of interest.

References

1. Alobid I et al (2011) Increased cardiovascular and anxiety outcomes but not endocrine biomarkers of stress during performance of endoscopic sinus surgery: a pilot study among novice surgeons. Arch Otolaryngol Head Neck Surg 137(5):487–492
2. Stelter K et al (2011) Evaluation of an image-guided navigation system in the training of functional endoscopic sinus surgeons. A prospective, randomised clinical study. Rhinology 49(4):429–437
3. Stelter K et al (2006) Computer-assisted surgery of the paranasal sinuses: technical and clinical experience with 368 patients, using the vector vision compact system. J Laryngol Otol 120(12):1026–1032
4. Backs RW, Seljos KA (1994) Metabolic and cardiorespiratory measures of mental effort: the effects of level of difficulty in a working memory task. Int J Psychophysiol 16(1):57–68
5. Lee DH, Park KS (1990) Multivariate analysis of mental and physical load components in sinus arrhythmia scores. Ergonomics 33(1):35–47
6. Fowler B, Manzey D (2000) Summary of research issues in monitoring of mental and perceptualmotor performance and stress in space. Aviat Space Environ Med 71(9):A76–A77
7. Luz M et al (2014) Impact of navigated-control assistance on performance, workload and situation awareness of experienced surgeons performing a simulated mastoidectomy. Int J Med Robot 10(2):187–195
8. Kalsbeek JW (1965) Suppression of the irregularity of the heartbeat as an objective measure of mental effort. Tijdschr Soc Geneeskd 43(18):644–648
9. Ettema JH, Zielhuis RL (1971) Physiological parameters of mental load. Ergonomics 14(1):137–144
10. Mulder G, van der Mulder H (1973) Mental load and the measurement of heart rate variability. Ergonomics 16(1):69–83
11. Jorna PG (1993) Heart rate and workload variations in actual and simulated flight. Ergonomics 36(9):1043–1054
12. Ledderose GJ et al (2007) Surface laser registration in ENT-surgery: accuracy in the paranasal sinuses—a cadaveric study. Rhinology 45(4):281–285
13. Nickel P, Nachreiner F (2003) Sensitivity and diagnosticity of the 0.1-Hz component of heart rate variability as an indicator of mental workload. Hum Factors 45(4):575–590
14. Mulder LJ (1992) Measurement and analysis methods of heart rate and respiration for use in applied environments. Biol Psychol 34(2–3):205–236
15. Richardin P et al (1995) Influence of stress and occlusal interference on the EMG activity of some masticatory muscles during a single mastication cycle. J Oral Rehabil 22(10):775–780
16. Haraldson T et al (1985) Relationship between myoelectric activity in masticatory muscles and bite force. Scand J Dent Res 93(6):539–545
17. Strauss G et al (2006) Clinical efficiency and the influence of human factors on ear, nose, and throat navigation systems. HNO 54(12):947–957
18. Manzey D et al (2011) Automation in surgery: the impact of navigated-control assistance on performance, workload, situation awareness, and acquisition of surgical skills. Hum Factors 53(6):584–599
19. Strauss G et al (2006) Evaluation of a navigation system for ENT with surgical efficiency criteria. Laryngoscope 116(4):564–572
20. Apparies RJ, Riniolo TC, Porges SW (1998) A psychophysiological investigation of the effects of driving longer-combination vehicles. Ergonomics 41(5):581–592
21. Siemens P, Hilger HH, Frowein RA (1989) Heart rate variability and the reaction of heart rate to atropine in brain dead patients. Neurosurg Rev 12(Suppl 1):282–284
22. Adriaenssens J, De Gucht V, Maes S (2013) Causes and consequences of occupational stress in emergency nurses, a longitudinal study. J Nurs Manag
23. Romani M, Ashkar K (2014) Burnout among physicians. Libyan J Med 9:23556
24. Strauss G et al (2013) The ‘Surgical Deck’: a new generation of integrated operational rooms for ENT. Laryngorhinootologie 92(2):102–112
25. Bell J, Breslin JM (2008) Healthcare provider moral distress as a leadership challenge. JONAS Healthc Law Ethics Regul 10(4):94–97 quiz 98–99