Analysis and Comparison of Ergonomics in Laparoscopic and Open Surgery – A Pilot Study

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Abstract. This pilot study systematically analyses and compares ergonomics of laparoscopic and open surgery in gynecology and urology. The results will help to identify and describe elements for ergonomic optimization in these professions. Further a supporting technical system to reduce physical demands shall be developed on the basis of assessment. A multiple measurement approach including subjective and objective methods was used with regard to the complex setting in surgery units. Subjective and objective methods indicate musculoskeletal strain for both types of surgery. Several indications for low ergonomics and static work have been found.

Keywords: Ergonomics, healthcare, supporting system, workload.

1 Objective

Physical discomfort and harm due to suboptimal working postures have been shown by surveys among surgeons [1] [2]. With the aim to reduce the physical load on surgeons and surgery staff a research project has been established to investigate the ergonomics of laparoscopic and open surgery. By means of this pilot study, key elements for ergonomic optimization should be described. In a second step, these key elements will be addressed in order to develop a supporting technical system that reduces physical demands (e.g. the reduction of static work). Surgeons and operating procedures of two surgical units (one urological and one gynecological) were investigated.

During this pilot study, the instruments for the systematic analysis of ergonomics, physical demands and musculoskeletal health status among surgeons of the mentioned

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professional disciplines were developed. This paper presents the respective data resulting in differences between open and laparoscopic surgery. In addition, ideas are given to the question whether ergonomic improvements and technical supporting systems should be developed separately for these two kinds of surgery or whether universal concepts might be sufficient.

2 Significance

Work intensification among surgeons [3] and an increasing risk of medical error [4] are reported in the literature. The tendency towards work intensification (more operations per day) and consequently an aggregation of physical demands has also been reported by the surgeons participating in this research project. Furthermore they mentioned critically that higher physical demands may lead to less concentration and an increased risk of errors. As a consequence, this might contribute to less quality in health care and increased costs for further medical treatments.

In this context the improvement of ergonomics in surgery seems to be important for maintaining the workforce of surgeons and surgery staff and to support high quality work of surgical units.

3 Methods

Data was collected from 6 surgeons during 20 surgical interventions (10 laparoscopic hysterectomies, 6 laparoscopic prostatectomies, 4 radical prostatectomies) lasting 20 to 180 minutes. A multiple measurement approach consisting of subjective and objective methods was used. Subjective methods included the NASA TLX [5] and the Nordic Questionnaire [6]. The questionnaire NASA TLX determines the workload during a specific work task according to its six dimensions: physical demand, mental demand, temporal demand, performance, effort and frustration. This questionnaire provides an Overall Weighted Workload Score (OWWS) including all of the mentioned dimensions and more detailed the scores of every single dimension. Higher scores indicate higher demands. The Nordic Questionnaire was used to obtain information about musculoskeletal complaints of the last 12 months and the last week.

The objective methods included muscular strain assessed by surface electromyography (sEMG) and life record data. The electrical activity (eA) of the trapezius muscle (descending part) as the root mean square value of the bipolar sEMG was measured continuously throughout surgery. A reference measurement with an anteversion of both straight arms holding an external load of 2 kg in each hand was conducted before surgery and was used for sEMG normalization. The trapezius muscle has been shown to be an import indicator for physical demands in laparoscopic surgery [2]. Life record data was also determined continuously throughout the whole surgery by a 3-perspective videoanalysis (3 cameras) in order to observe the whole body of the surgeon and to get information about movements, postures and the surgeons' procedures. The camera positions were arranged to realize the back, front and side view of the observed surgeon. The settings of the laparoscopic and the open surgery are shown in figure 1 as well as the positions of the cameras.

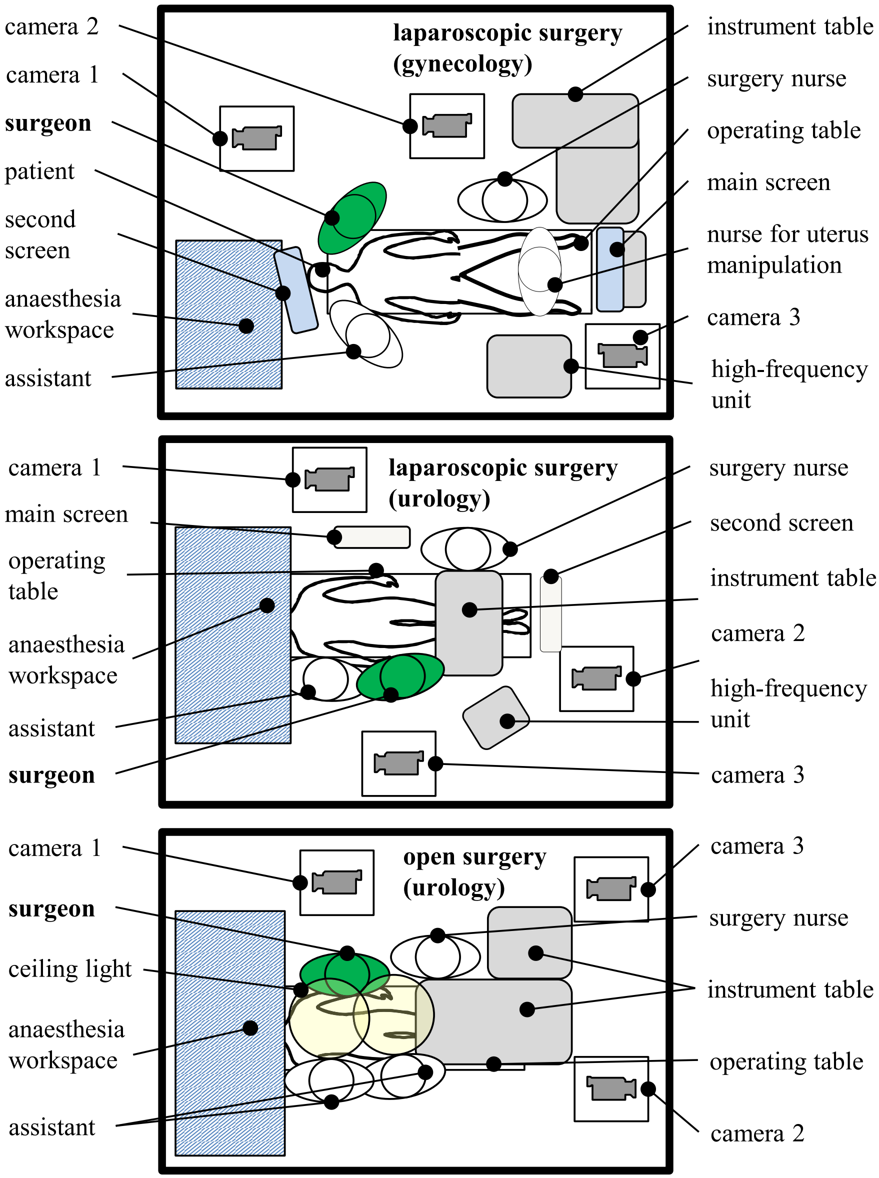


Fig. 1. Setting of laparoscopic (top) and open surgery (bottom) at UKT with cameras for 3-perspective-video-analysis

4 Results

4.1 Perceived Demands and Physical Complaints

The Overall Weighted Workload Score (OWWS) of the NASA TLX between laparoscopic and open surgery is shown in figure 2. Workload during open surgery (49,33 points) was slightly higher than during laparoscopic surgery (39,61 points, 46,43 points).

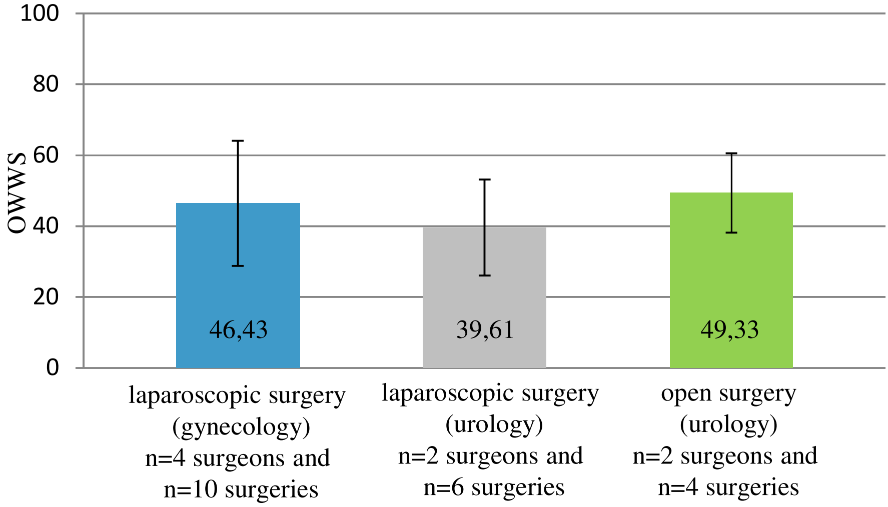


Fig. 2. NASA TLX Overall Weighted Workload Score of laparoscopic and open surgery including the standard deviation

The allocation to six dimensions of the NASA TLX questionnaire is presented in figure 3. In laparoscopic surgery the score of the dimension effort was elevated in comparison to the other dimensions but less than in open surgery. In open surgery the scores of the dimensions performance and frustration were low while the four other dimensions (mental demand, physical demand, temporal demand and effort) were elevated. Further, the scores of these four dimensions were higher than in laparoscopic surgery. The standard deviation was high within all dimensions for both types of surgery.

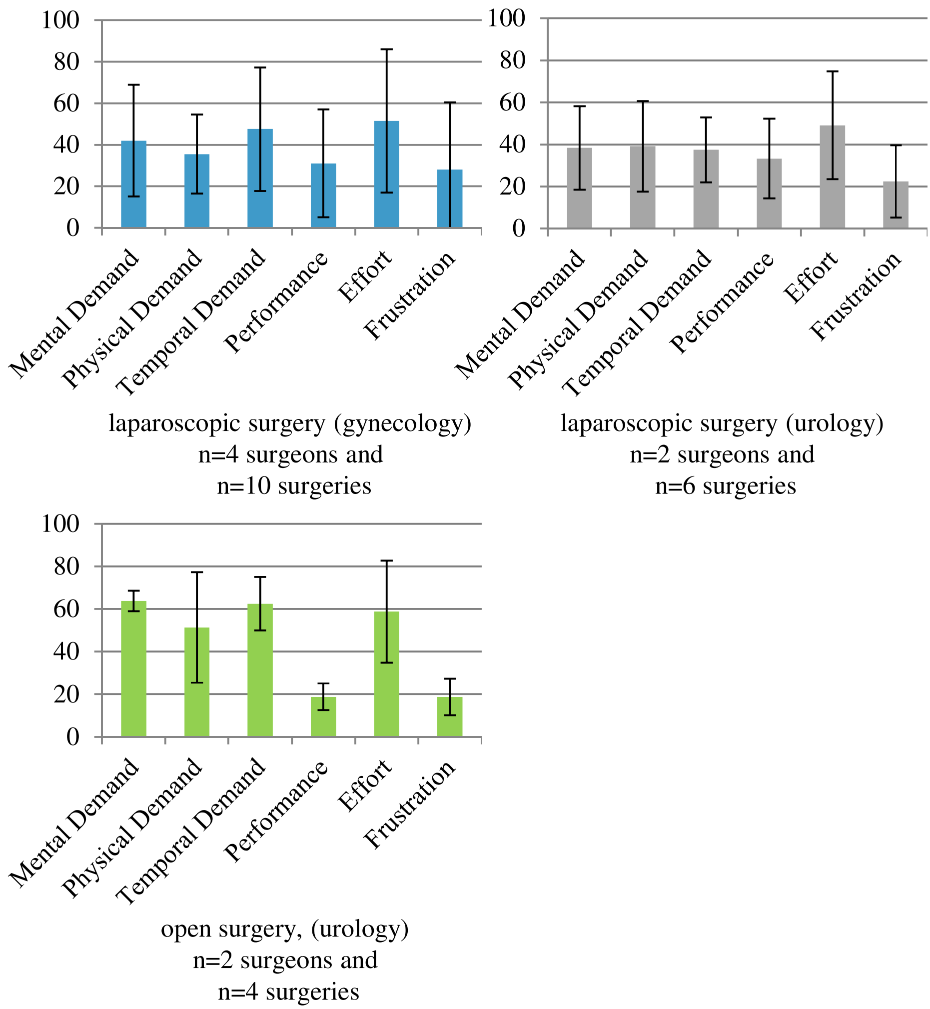


Fig. 3. Examination of NASA TLX dimensions of laparoscopic and open surgery

The results of the Nordic Questionnaire suggested high prevalence of neck or low back pain and therefore confirm the data from literature.

4.2 Muscular Strain (sEMG)

For analysis of muscular strain assessed by electrical activity (eA), only the data derived from the urological unit are used (data from 2 urological surgeons, 3 open surgical interventions, 4 laparoscopic surgical interventions).The measurements performed by the gynecological surgeons were excluded due to differences in monitor height, patient positioning and surgical procedures. In addition, the participating gynecological surgeons were more specialized in laparoscopic surgery and did not perform open surgery in the scope of this research project. Figure 4 shows the normalized electrical activity (eA) of the trapezius muscle, separated to the dominant and the non-dominant arm (only data of the urologic surgical unit). This figure gives an estimate of the physical demands during laparoscopic and open surgery.

The median normalized eA in laparoscopic surgery was 0.54 [given in percent of the reference contraction] for the non-dominant arm and 0.57 % 2kg for the dominant arm. In open surgery the median normalized eA for the non-dominant arm was 0.68 % 2kg and for the trapezius of the dominant arm 0.63 % 2kg.

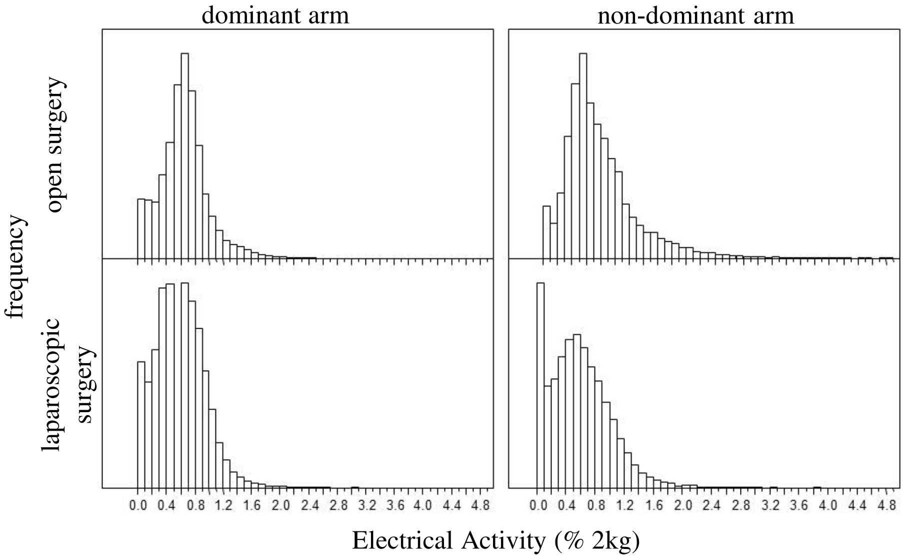
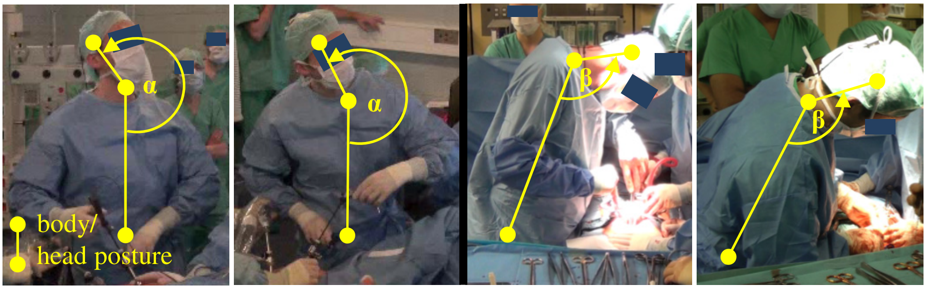


Fig. 4. Frequency distribution of the normalized trapezius eA in laparoscopic and open surgery

4.3 Life Record Data

Life record data showed position changes and body postures of the surgeons in dependence to setting, task and individual factors. Some selected results will be shown in this chapter.

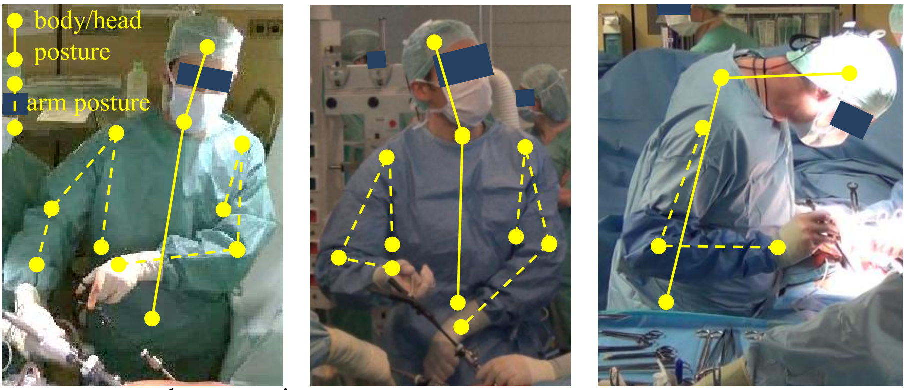
The most obvious difference between open and laparoscopic surgery is the visual reception of the operating field. In laparoscopic surgery the surgeon looks at a screen which shows the videostream of the laparoscope, therefore the surgeon has an indirect view on his surgical task. In contrast, during open surgery the surgeon looks directly at the operating field. This difference induces different body postures especially of the surgeons' head. Figure 5 shows two examples from laparoscopic surgery (left) and two examples from open surgery (right). The angle α for laparoscopic surgery is bigger than the analogous angle β for open surgery (α > β).



laparoscopic surgery open surgery

Fig. 5. Head posture in dependence of surgery type

Both types of surgery are characterized by periods of static postures, especially of the arm, lasting for several minutes. Hence, figure 6 shows observed typical and significant head/body and arm postures of the surgeon for laparoscopic (left and middle) and open surgery (right). In laparoscopic surgery, the typical arm posture consists of the bent right arm beside and in front of the body and the bent left arm in front of the body. This posture is persistented for several minutes without moving the arm or upper body. Consequently this is leading to static work and is observed in the preparation period of laparoscopic surgery in particular. In open surgery, the extreme head flexion position (fig. 6, right) is remarkable and is maintained during most of the time of the surgical intervention. The arm posture shown on the right side of figure 6 is common for open surgery.



laparoscopic surgery open surgery

Fig. 6. Significant body and arm postures in laparoscopic (left) and open surgery (right)

However, the surgeon changes his position, body posture and tasks during open surgery as shown in figure 7. On the left side every picture shows one of the three main positions. On the right side these positions are shown from the top.

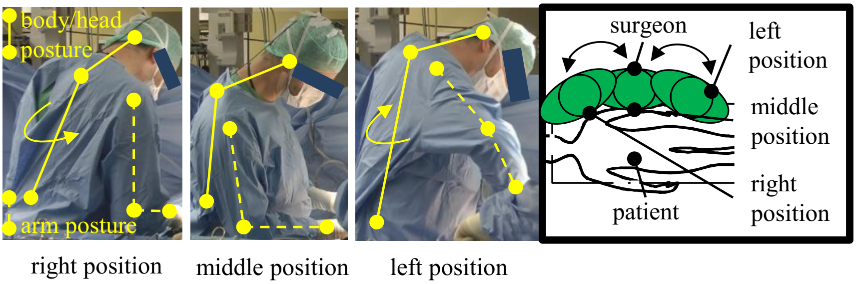


Fig. 7. Positions of the surgeon at open surgery (urologic clinic)

In summary both types of surgery show non ergonomic body postures. Given the data of this pilot study, open surgery exhibits more changes in positions and postures and is characterized by a large head flexion angle compared to laparoscopic surgery. Laparoscopic surgery seems to consist of more static and akinetic body and arm postures. Thus, the musculoskeletal strain is a result of static postures and tasks.

5 Discussion and Conclusion

A tendency towards higher demands in open surgery as compared to laparoscopic surgery was shown by NASA TLX questionnaire. This is supported by the results of the sEMG analysis of the trapezius muscle showing higher activity in open surgery. The explanation for this is given by the information of the video analysis. In open surgery more frequent changes of body position indicating more physical action was observed as well as extreme head flexion positions which are persisted over time. The allocation to six dimensions of the NASA TLX questionnaire show that for open surgery the four dimensions mental demand, physical demand, temporal demand and effort were elevated and in addition higher than in laparoscopic surgery. In laparoscopic surgery the score of the dimension effort was a bit less than in open surgery but elevated in comparison to the other dimensions. The results from the allocation to six dimensions may indicate that the use of a technical system in laparoscopic surgery reduces the perceived physical demand and consequently relieves the operator although the effort is slightly less.

Already published data of this research project considered sEMG of laparoscopic surgery from gynecological surgeons [2] indicating a substantial proportion of static work and asymmetric physical demands of the trapezius muscle. In this recent analysis, the strain of the trapezius of the dominant arm was significantly higher than of the non-dominant arm.

However, this could not be shown for laparoscopic surgery in urology. Differences in monitor height and patient positioning between both settings may be possible reasons for these findings. Thus, this indicates that not only the type of surgery but also the setting might be the reason for increased physical demands.

Ergonomic improvements should therefore include a pre- and post-evaluation of body postures and perceived demands of the surgeons or surgical staff. Considering the two investigated surgical units, ergonomic improvements should focus on strategies to improve the head and the arm posture of the surgeon. Unphysiological head positions were documented in both types of surgery and may lead to physical complaints [7]. Physical demands in the trapezius muscle may be reduced by a supporting technical system. For laparoscopic surgery the supporting system might be sufficient if the dominant arm is addressed. For open surgery it is obvious that a supporting system should consider both arms. Furthermore, short rest periods (several seconds) to enable muscular recovery and to prevent potential muscle fatigue should be considered. Especially routine surgery, as investigated in this study, might not be compromised by such rest periods.

Although both types of surgery require an ergonomic optimization, a supporting technical system will be developed for laparoscopic surgery. The more static character of this type of surgery makes a transfer into practice more realistic and the fact that the supporting system is focused on the dominant arm reduces the complexity of the required system.

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