

CHALLENGES FOR ERGONOMICS AND IMPROVEMENT OF WORKING CONDITIONS DURING SURGERIES WITH USE OF LAPAROSCOPIC TOOLS

1.1 INTRODUCTION

Surgical procedures are performed in the specific conditions of working environment. On the one hand, they have to ensure patient safety keeping the correctness of medical procedures and specified sanitary regimen, on the other hand, the work conditions should ensure the effectiveness in performing operations by surgeons.

The observed development of medical methods and techniques is focused on increasing the effectiveness of patient treatment. Together with this development increases the degree of complexity of medical equipment and with it changes in such areas as work organization in the operating room and requirements for the exploitation of the equipment. The results of these changes are certainly positive for a patient, but may raise specific problems for medical staff.

Firstly, there is a need to continuously improving the competencies of medical professionals in the field of computer science and engineering that are not normally taught in the path of training surgeons and nurses, as already has been signaled in [1, 2]. This need is caused by the necessity to handle complex medical devices which are based on up to date achievements in science and robotics. Secondly, complex medical equipment brings problems in the shaping of working conditions and ergonomics. They mainly refer to:

- deployment of extended medical devices with auxiliary equipment, such as cables, pipes, which reduce the effective working area [3],
- construction of surgical instruments and medical devices that determines the specific, often awkward surgeons' postures while performing by them surgical procedures,
- changes in a way of doing works from the dynamic, characterized by the free maneuvers of the surgeon, to the static with restricted mobility, as is the case by laparoscopic surgeries.

It can be hypothesized that the problems mentioned above are caused by lack of sufficient ergonomics awareness and poor preparation of contemporary medical staff and management staff in range of how to create ergonomic working conditions. This problem, however, is not a new problem. Already in the early 20th century Frank B. Gilberth, one of the precursors of the scientific approach to the work management, drew attention to the fact

that: „...surgeons could learn more about motion study, time study, waste elimination, and scientific management from industries than the industries could learn from hospitals” [4].

The considerations signaled above have become a background to take in-depth reflection on ergonomics in the field of surgery, especially laparoscopic surgery.

The Aim of the paper is to present the results of preliminary studies on ergonomic needs within performing laparoscopic procedures, which will be the basis for the development of vocational training in range of: creating work conditions in the operating room and ergonomic handling of laparoscopic tools.

Preliminary studies were carried out on the basis of five hospitals, where are normally performed laparoscopic procedures. Research methods are survey research, where questionnaire was developed by the Instituto de Biomecánica de Valencia in Spain, the coordinator of the project "Vocational Training Online course on laparoscopy's ergonomics for surgeons and laparoscopic instruments' designers", as well as free interviews, direct observation and analysis of the literature.

1.2 CHALLENGING AREAS OF CREATING WORK CONDITIONS IN LAPAROSCOPIC SURGERIES

Laparoscopic surgery is one of the rapidly developing fields of minimally invasive surgery and is now used in all areas of general surgery [5].

The set used for laparoscopy include: trocars (tools for putting instruments into abdominal cavity), insufflator, visual track, which includes: video processor, light source, TV monitor, head, in addition diathermy and surgical tools to perform the surgery.

The popularity of laparoscopic methods is because of numerous benefits for patients. These are as follows:

- reduced post-operative complications, such as fever or infection,
- less pain,
- shorter hospitalization,
- faster recovery time,
- faster and less problematic healing of surgical wounds, better cosmetic results.

Despite the undeniable benefits for patients, laparoscopic surgery has brought certain negative consequences for surgeons, formulating in effect the ergonomic challenges in this area. These challenges can be located in five areas:

- the first area is the ergonomics in posture while performing laparoscopic procedures,
- the second area is the ergonomics of working conditions and work organization in operating room,
- the third area concerns the improvement of ergonomic laparoscopic instruments,
- fourth area affects the mental aspects of the surgeons performing laparoscopic procedures,
- the fifth area is the design of ergonomic specific products supporting the work of the laparoscopic surgeons.

The first area

Laparoscopic surgery has changed the way of surgeons interactions in the operating

field, what is revealed by a change in their posture and movements of the upper limbs. Laparoscopic surgeons tend to maintain a more upright posture with limited range of motion and fewer moves of back when compared to the surgeons performing open surgeries [6].

The characteristic factors that may simultaneously contribute to creating pain in musculoskeletal system is uncomfortable, repetitive movements of the upper limbs, as well as long-term static and awkward position of the head and back [7].

In most cases, surgeons performing laparoscopic procedures take the standing position, which carries the risk of loss of stability. Surgeons have in fact a limited ability to change their body weight, they have to perform manual maneuvers in precisely way standing often on one leg and using the foot pedal to operate the laparoscopic equipment [5, 6, 8].

Based on laparoscopic procedures observations and interviews conducted with surgeons it can be concluded that the way of taking body position depends mainly on where the surgeon is located in relation to a patient. Surgeon postures will be different when the surgeon is on the left or right side of the patient or when the place of surgeon staying is between the patient's legs. In addition, an important aspect influencing the manner of operating of the upper limbs is the location of incisions for insertion the laparoscopic instruments inside abdominal. If the incisions are too close then laparoscopic tools are parallel to each other, and thus the movements of the surgeon's limbs have a smaller range causing more static loads. Besides, performing the surgical procedure is more difficult. If, however, the both incisions are away, the result is more easily maneuvering of the upper limbs, reducing static burden and facilitating work in the surgical field of abdomen cavity.

The second area

Another, very important and indicated by the surgeons, aspect influencing the overall body posture is to organize the work conditions in the operating room, especially the layout of laparoscopic tools and auxiliary equipment, particularly a monitor.

The problem of the organization of work in the operating room by laparoscopic surgery is associated with previously unforeseen and totally different manner of work when compared to traditional open surgery, furthermore the need for visual interaction with the monitor (and not with the patient as previous), more remote than reality the operation field, or other types of experiences like tactile feedback and force transmission described in [9].

Changing the manner of performing surgeries from the open to minimally invasive with use of specific tools have not led to changes in the organization of the work space in operating rooms. The advances in the field of laparoscopy, such as the development of optics video with higher resolution and improved operational instruments on the one hand allowed doctors to perform more advanced laparoscopic surgeries. On the other hand, this progress has not been accompanied by changes in the design of operating rooms and setting up the monitor which would alleviate the fatigue musculoskeletal system of laparoscopic surgeons [5].

There is recommended the specific location of the monitor [10, 11]:

- In horizontal level the monitor should be positioned in a straight line along the forearm-instrument for each person taking part in the operation. This location will avoid axial rotation of the spine.

- In the sagittal plane the monitor should be placed just below eye level to avoid neck strain.

The location of the monitor presented above, is associated with two problematic consequences: firstly, each additional monitor increases the cost of purchasing a laparoscopic equipment (cost of monitor for laparoscopic procedures is about 20 to 30 times higher than a traditional monitor), secondly the layout of the monitors in a specific position, especially below the line of sight causes huge changes in the organization of the whole workplace. Traditionally, the monitor is located above the equipment due to the concentration of people and devices at the operating table.

The third area

The manner of performing laparoscopic procedures depends on the design of surgical instruments, especially on the shape of the handgrip and the tool length.

There were observed unergonomic patterns of tool grips that are not adapted to the shape and size of the hand and the motor abilities of surgeons' upper limbs, what leads to fatigue, discomfort and paresthesia of hands [12].

The shape of the laparoscopic instruments and the way of using them determine the unusual positions of arms, hands and fingers. There are available different types of handles for use in minimally invasive surgery indeed. However, the principle of using them is similar, based on the positioning tools maneuvering hands and fingers which may lead to the local pressure and the injuries or nerve irritation [13].

Few studies have been conducted in the frame of designing and validation of correctness of usage of ergonomic laparoscopic instruments. An example might be a prototype of the gripper tool that was designed basing on the analysis and evaluation of current tools in combination with the opinion of the surgeons. There was developed a special survey containing questions identifying problems related to using traditional instruments, and questions evaluating ergonomics of prototype tool. The illustrations of the prototype as well as the detailed results of the study are presented in [14]. Another example is an ergonomically designed grasper described in details in [15].

The fourth area

Laparoscopic surgery enforces certain patterns of behavior of doctors. They are often associated with psychological stress and mental fatigue. The factors causing this phenomena are:

- activities under pressure of effectiveness and speed while performing the surgery which should be transformed to reduction of procedure cost [12],
- increase of the technical complexity of the surgical equipment and a high degree of difficulties of even simple procedures, resulting the necessity of increased attention while whole surgery and the severity of pain and fatigue by medical staff [16, 17, 18],
- remote access and changing in the observation of the operating field which enforces unnatural behavior of surgeons in a sense that they do not direct the vision on the patient (which is a natural behavior and for longtime practitioners the subconscious impulse) but

on the monitor where the operating field (on a flat screen) in various degrees of resolution and picture quality is displayed.

According to studies, psychological burden of surgeons performing laparoscopic procedures is much higher in comparison to open surgical techniques [8].

The fifth area

Laparoscopic procedures are characterized by limited mobility and surgeons' high static load during the operations. These circumstances require new technologies and solutions for how to perform procedures that could enhance the comfort of the surgeon. One of such solutions is the auxiliary equipment for surgeons working in the field of minimally invasive treatments such as ergonomic surgical chairs. There was identified only a few propositions in this field.

One of them is an operating chair so called ETHOS platform of ETHOS Surgical enterprise, USA used for laparoscopic surgery [19].

The chair consists of the an integrated seat with adjustable support for the chest. It also includes two individually adjustable armrests and footrests. There was carried out a clinical evaluation of the chair which was clearly positive and indicates that the chair may help minimize the mental and physical stress for the surgeon [20].

Another solution is a chair which allows the surgeon to maintain partly standing and partly sitting position during the operation. As in the previous case, the chair is integrated with the pedals which are comparable to the pedal in the car. Adjustment of the height of chair is driven by electric motors, controlled by a special footswitch. Initial clinical examination of usefulness of the chair indicates that its application reduces fatigue and effectively support the surgeon during long endoscopic procedures [21].

There is proposed by Medisign a similar support construction for both open and minimally invasive procedures. The prototype was evaluated based on seven surgical procedures. In addition a method for electromyography (EMG) to assess muscle activation in back and legs at an experimental setting was used. Results: Six of the seven doctors participated in the experiment indicated that the supported body position is comfortable, safe, and the chair is easy-to-use. EMG results show that the support construction effectively reduces the activity of the muscles [22].

1.3 DISCUSSION ABOUT THE ERGONOMIC LEVEL IN LAPAROSCOPIC PROCEDURES – PRELIMINARY RESULTS OF EMPIRICAL STUDIES

There was summarized the preliminary results of empirical research in the field of ergonomics in laparoscopic procedures. The summary has become the basis for the discussion on the role of ergonomics in laparoscopic surgery, as well as the surgeons' ergonomic awareness and finally training needs for improvement in this area. The discussion is mainly based on the answers of 41 laparoscopic surgeons obtained through the survey research (see p. 1). Wherein, the questionnaire was divided into six major areas: personal data, experience in laparoscopic surgery, course features, level of knowledge, problems of ergonomics and training needs. The surveys were complemented by unstructured interviews touching the issues raised in the questionnaire and observations of two laparoscopic procedures.

The average length of professional experience of the respondents was 12,71 years, which means that the answers are crucial for achieving the objective of research. The vast majority of laparoscopic surgeons are men (70 per cent of respondents). Most of the questioned persons are above 36 years old. This fact is related to a small number of young doctors particularly residents, i.e. people who actually specialize in a certain field of medicine. A specialization in general surgery is not a popular specialization among young people because of the high degree of difficulty. General surgery, including laparoscopic surgery requires from the surgeon an extraordinary concentration during the entire procedure and the necessity of making unforeseen decisions. In contrast to other kind of surgeries, like orthopedic surgery where the surgical procedures are performed in a schematic way and the result of the treatment depends on the mechanical accuracy of surgical activities, in general surgery many times is not possible to work according to strict schemas.

Surgeons spend on average from 1 to 2 hours a day doing laparoscopic procedures. The most commonly performed laparoscopic procedures among surveyed doctors are treatments in the inframesocolic area, including cholecystectomy, i.e. removal of the gallbladder.

Laparoscopy is a rapidly expanding field of medicine, and the same execution of procedure requires a solid and reliable preparation. According to the respondents the most important factors impacting on perfecting skills in laparoscopic surgery are:

- performing as many procedures as possible,
- the possibility of practical training based on working with medical simulators,
- access to laparoscopic instruments allowing perform the staged procedures.

Furthermore the doctors paid attention to such aspects improving the professional skills as the exchange of experience and support from teammates side.

Almost all of surveyed surgeons took part in training in laparoscopy, where most of them assess them as the good and very good. However, these trainings usually applied only to the clinical issues. Unfortunately, in most cases, they have not been and are not related to aspects of ergonomics. Most of the surgeons have not participated in training activities to improve working conditions at laparoscopic surgery. This has negative consequences in unergonomic performing the procedures by them. Wherein, the way of surgery is a result of the components: activities resulting from a certain medical procedure, as well as activities related to the preparation of a patient for surgery, and the organization of working conditions in an operating room. A mode of action of surgeons, including a way of adopting a specific body position, a way of moving, manner of communication, is shaped and fusing over many years of practice. There is a high probability that the change in technology, such as the ability of adjustment the height of operating beds to patient, mobility of devices, will not lead to changing the way of performing the surgery, which after many years has become routine for an experienced surgeon. There is therefore the necessity to educate the surgeons in the field of ergonomics and forming working conditions as quickly as possible i.e. already within medical studies and in the beginning of surgical practice. For experienced surgeons it is suggested to make attempts of changing their habits towards pro-ergonomic behavior and use of ancillary equipment to enforce an ergonomic way of acting.

Lack of knowledge of ergonomics (only less than 15 per cent of the respondents declared their competence in this area) and a specific way of performing laparoscopic

operations by most respondents result overload in muscles of the back, shoulders and neck. Among other identified negative effects are: numbness and loss of feeling in the fingers, calluses on the thumbs, pain in the musculoskeletal system and the overall physical and mental fatigue.

The indicated musculoskeletal fatigue and overall burden is caused mainly by the body position while surgery. According to the respondents the main factors contributing to the adopting a specific body position during surgery are:

- patient positioning,
- position and the adjustment ranges of the table,
- a type of laparoscopic surgery,
- position of the monitor,
- the necessity of using pedals for controlling diathermy systems.

It is worth to note that all of the factors identified above, apart from the type of laparoscopic procedure, are ergonomic factors and therefore those that can be shaped and improved. In turn, to the main factors that directly affect the physical fatigue belong:

- duration of surgery,
- awkward postures,
- position of the monitor,
- the instruments grip design.

The preliminary results of the survey clearly indicate that knowledge of surgeons in the ergonomic design of work can help to reduce the burden during laparoscopic procedures. An optimistic aspect is that all surgeons participating in the research are open to the possibility of conducting training in range of ergonomics. However, the main factors motivating to participate in such training is professional development, by knowing new techniques, furthermore by gaining knowledge of reducing the aches and pains caused by surgical practice and expand general knowledge of ergonomics. Important elements here are also increasing new skills, exchange knowledge with other professionals and gaining knowledge of the proper selection of laparoscopic instruments.

It is suggested that training was mainly a practical dimension. For most respondents, the most appropriate form of training is a mixed form i.e. partially online and partially in the form of traditional classes. A very important aspect for the medical staff is the duration of training. The most indicated length is to 20 hours.

Taking into account such time rigor, the important aspect is to formulate appropriate training structure, corresponding to the real training needs.

According to the opinions of respondents, the most important topics in potential training are:

- ergonomics in the field of laparoscopic surgery,
- ergonomics related to laparoscopic surgical instruments,
- surgeon postural ergonomics,
- ergonomic related to the type of laparoscopic surgery.

Simultaneously the specified areas are those, in which the majority of questioned laparoscopic surgeons would take part.

CONCLUSIONS

Laparoscopy is an opportunity for patients to less pain and faster recovery. It is also a completely different field of surgery when compared to the open surgical procedures and requires specific conditions and new skills of surgeons. First of all, surgeons must operate with a continuous concentration during the whole procedure. An additional factor increasing stress is unnatural operative field presented in the form of visualization on the screen, thus forcing the surgeon to visual contact with the device, and no longer directly with the patient. The serious problem are the somatic relations in antropotechnical system while the surgery, characterized by a long-term static position causing overload and pain in musculoskeletal system. Problematic are also the operations with using handle tools, which are often not adapted to the shape of the operator's hand, causing numbness and lack of sensation of the upper limbs or calluses on thumbs.

The ergonomic problems indicated in the article while using the laparoscopic instruments can be mitigated in two ways. The first way is to educate surgeons in the principles of ergonomic proceedings. Wherein the a good idea seems to be an integrated training by the subconsciously shaping pro-ergonomic behavior e.g. learning how to perform laparoscopic surgery on ergonomically correct training place. The second way is to provide designers of surgical tools information on these aspects of the tool construction that should be improved in respect of ergonomic.

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CHALLENGES FOR ERGONOMICS AND IMPROVEMENT OF WORKING CONDITIONS DURING SURGERIES WITH USE OF LAPAROSCOPIC TOOLS

Abstract: *The aim of the article is to present the preliminary results of research into diagnosis of needs for shaping ergonomic work conditions of surgeons performing laparoscopic surgeries. In particular these needs have been diagnosed thanks to such methods as: surveys, interviews, direct observations and literature analysis. Identified ergonomic needs are the base for training preparation the aim of which should be shaping ergonomic awareness of present and future laparoscopic surgeons, manifesting itself in such aspects of activities as selection and further use of surgical instruments, the organization of work and the optimal layout of workplace equipment. The ergonomic needs of surgeons should be transferable to the ground of design process of laparoscopic instruments and are the basis for supporting the work of surgical tools designers. The participation of international project "Online Vocational Training course on laparoscopy's ergonomics for surgeons and laparoscopic instruments' designers" of Lifelong Learning Program: Leonardo da Vinci Multilateral Projects for Development of Innovation, was the direct circumstance for undertaking the research. In addition, the content of the article touches aspects of an exploitation of surgical instruments what is related to the current statutory research of Institute of Production Engineering and the task "Management of innovations in processes of surgical tools exploitation with using ICT".*

Key words: *ergonomics, shaping of work conditions, surgical tools, e-learning, laparoscopic surgeons*

WYZWANIA W ZAKRESIE ERGONOMII I DOSKONALENIA WARUNKÓW PRACY PRZY ZABIEGACH CHIRURGICZNYCH Z UŻYCIEM NARZĘDZI LAPAROSKOPOWYCH

Streszczenie: *W artykule przedstawiono wstępne wyniki badań nad rozpoznaniem potrzeb w zakresie kształtowania ergonomicznych warunków pracy chirurgów wykonujących zabiegi laparoskopowe. W szczególności potrzeby te diagnozowane są za pomocą metody badań ankietowych, wywiadów, obserwacji i analizy literatury. Zidentyfikowane potrzeby ergonomiczne są bazą do opracowania szkolenia, którego celem ma być kształtowanie świadomości ergonomicznej obecnych i przyszłych chirurgów laparoskopowych, ujawniającej się w takich aspektach działań, jak dobór i późniejszy sposób posługiwania się narzędziami chirurgicznymi, czy też organizacja pracy i optymalne rozmieszczenie elementów wyposażenia na stanowisku pracy. Potrzeby ergonomiczne chirurgów są przenaszalne na grunt procesu projektowo-konstrukcyjnego narzędzi laparoskopowych i stanowią podstawę do wspomagania pracy projektantów narzędzi chirurgicznych.*

Bezpośrednią przesłanką podjęcia badań w zakresie ergonomii zabiegów laparoskopowych jest realizacja projektu międzynarodowego Online Vocational Training course on laparoscopy's ergonomics for surgeons and laparoscopic instruments' designers) w ramach programu Lifelong Learning: Leonardo da Vinci Multilateral Projects for Development of Innovation, Treści artykułu dotyczą aspektu użytkowania narzędzi chirurgicznych wpisując się tym samym również w ramy obecnie prowadzonych badań statutowych Instytutu inżynierii produkcji i zadania nt. Zarządzanie innowacjami w procesie eksploatacji narzędzi chirurgicznych z zastosowaniem technologii ICT.

Słowa kluczowe: *ergonomia, kształtowanie warunków pracy, narzędzia chirurgiczne, e-learning, zabiegi laparoskopowe*

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