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THE WAY OF PLANNING AND ORGANIZING RESEARCH IN RANGE OF ERGONOMICS ON THE EXAMPLE OF OBSERVATION OF LAPAROSCOPIC SURGERIES

1.1 INTRODUCTION

A work in every field of human activity is, on the one hand, connected with the desire to achieve benefits for society manifested in the broadly defined services and production, on the other hand may result in negative consequences for the working man. These adverse effects could be inter alia fatigue, pain, illnesses, or even fatal accidents. The development of modern civilization shows that a man is the factor within the process of work that deserves the most attention due to its numerous physiological, strength and adaptive limitations. A man should therefore be the special element with respect to which the whole technical, environmental and organizational sphere conditioning the implementation of specific work processes is designed.

A science that deals with the adaptation of such a work environment to human mental and physical capacity, and whose main aim is the work humanization, is ergonomics. The dominant area of activity which places a particular emphasis on research in the field of ergonomics is the industry. This is reflected in the contents of articles that are published in recognized dedicated journals, among which are: Human Factors and Ergonomics in Manufacturing & Service Industries and International Journal of Industrial Ergonomics.

On the ground of multi-annual and extensive studies in the field of industrial ergonomics, a number of papers on the methodology of ergonomic research, including the used for decades and proven methods of ergonomic diagnosis and assessment were developed. These methods are inter alia OWAS [7], RULA [9], REBA [6] as well as the methods based on an energy expenditure tables according to Lehmann [8]. Despite the fact that industrial activity represents the main domain where research in the field of working safety is developed, it is, however, not the only area where ergonomic intervention is absolutely necessary.

Another area of human activity, characterized by the lack of using ergonomic principles and which carries many risks for employees, is the field of health care, and within it the area of laparoscopic surgery.

Surgical procedures are performed in special conditions of working environment. On the one hand, they must ensure patient safety while maintaining the correctness of implementation of medical procedures and specific sanitary regime, on the other hand, the working conditions should ensure the effective performance of surgeries. The observed development of medical methods and techniques is directed to enhancement of the effectiveness of treatment of patients. Along with the development, the degree of the medical equipment complexity increases at the same time. This changes the organization of work in the operating room and the requirements for exploitation of the equipment. The results of these changes are certainly positive for the patient. However, they imply the specific problems for professionals' health. Surgeons perform their operations in awkward body positions causing musculoskeletal disorders [4, 9], and unsuited medical devices handles to the anthropometric characteristics and predispositions of surgeons cause discomfort, fatigue, numbness and paresthesias of hands [2, 10].

Finally, the specificity of work during laparoscopic surgery, which forces on surgeon performing their operations under pressure of effectively and quickly carrying out the surgery, minimizing the cost of the procedure [2], and also the increase of technical equipment variability and a high degree of complexity of how to do even simple procedures, causes the necessity of increased attention over the whole surgery and thus the severity of pain and general fatigue of a surgeon [3, 4, 5].

In addition, the need for more advanced studies in the field of ergonomics in laparoscopic surgery is the result of the survey carried out in the framework of project (implemented in years 2012-2014): Online Vocational Training course on laparoscopy's ergonomics for surgeons and laparoscopic instruments' designers (Lifelong Learning Program: Leonardo da Vinci Multilateral Projects for Development of Innovation, Agreement number: 2012-3649/001-001, financed by National Agency for Lifelong Learning Programmes Organismo Autónomo Programas Educativos Europeos (OAPPE)), where Silesian University of Technology acts as the project partner. The survey was conducted in six hospitals in the Silesia region of Poland for a population of 56 surgeons performing laparoscopic procedures. One of the issues raised in the survey were the types of ailments that occur most often during or shortly after laparoscopic procedures. Most of the respondents pointed out an overload in the back muscles, shoulders and neck. Among other the identified negative consequences are listed:

- numbness and lack of feeling in the fingers,
- calluses on the fingers,
- musculoskeletal disorders,
- general physical and mental fatigue.

The indicated musculoskeletal disorders as well as the overload of the body are mainly caused by the position at work. According to the respondents the main factors contributing to adoption of a specific body position during surgeries are:

- patient positioning,
- setting the operating table,

- type of laparoscopic surgery,
- monitor setting,
- the need of using pedal of foot activation.

In turn, the factors causing physical loads of operators are mainly:

- duration of the procedure,
- awkward body position,
- monitor setting,
- tools handle design.

The above presented prerequisites for ergonomics research in the field of laparoscopic surgery force on researchers the use of specific ergonomic methods. These methods can be largely taken over from the industrial field. However, the same way of planning and organization of research enabling their use must be adapted to, different from the industrial, specifics of work in the operating room. The differences are here substantial and in general cases relate to the following aspects:

- predictability of events: in industry: a work is based on repetitive patterns of operations (especially in manufacturing); during surgeries there is a high degree of variability of operational activities and there is the need to take different decisions, moreover, a surgeons' activities exhibit a high degree of dynamism and unpredictability in terms of daily duties;
- availability of a research field: for industry: an access to the test objects (people and equipment) is usually open; during surgeries the access to the operational field is limited because of the presence of special zones: "clean" (inaccessible to the researcher) and "dirty" (accessible to the researcher);
- availability of working tools being a subject of ergonomic analysis: in the industry an access to the tools is open, in health care (hospital) an access to surgical tools is limited due to the sterilization procedures;
- distribution of measuring apparatus: in the industry there are usually no restrictions on the distribution of the measuring apparatus, particularly an apparatus placed on the body of a worker; during surgery, there are numerous restrictions on the placement of equipment in the workplace and on the body of a surgeon because of the sanitary regime inside operating room.

1.2 OBJECTIVE AND SUBJECT OF RESEARCH

Taking into account the indicated in Introduction prerequisites for the need of ergonomics research in the field of laparoscopic surgery, and simultaneously the differences in the traditional approach to research in the industrial field forcing the necessity of adjusting the research schemes to the specific environment in health care, the following objective of this article was formulated:

The objective is to present the methodology for the planning and organization of research, based on techniques of observation, conducted in the work environment of laparoscopic surgeons in order to improve ergonomics and conditions of performing

surgical procedures. The aim of the study is first of all the possibility of using ergonomic assessment methods based on observation of work processes, i.e. OWAS, REBA or RULA methods. The methodology was based on the empirical research conducted in District Railway Hospital (DRH) in Katowice, Department of General Surgery with Sub department of Metabolic and Bariatric Surgery.

In particular, the results of the research made it possible to recognize and analyze in details the problem areas on how to video record laparoscopic procedures, as well as perform ergonomic measurements of an operator's position in real and simulated surgeries. The particular objectives of the research are:

- 01 Recognition of the limitations and development of guidelines on how to record the course of laparoscopic surgeries;
- 02 Definition of the measurement path and development of guidelines for acquisition of data about momentary body poses and volatility of position of the operator's body while performing the surgical procedures,
- 03 Development of the concept of processing research material for the ergonomic analysis in range of performing laparoscopic surgeries.

The subject of research is the following type of laparoscopic surgeries:

- removal of the gallbladder (cholecystectomy),
- bariatric surgeries: partly removal of the stomach (sleeve gastrectomy) that is a resection of the greater curvature of the stomach along the stomach bottom; the surgery of gastrointestinal bypass (gastric bypass) that is the preparation of gastric tank and intestinal anastomosis by method Y-en-Roux,
- inguinal hernia surgery involving the preparation of hernia sac and its removal as well as the sewing a synthetic mesh in (hernioplasty TAPP).

The selection of these procedures was intentional and planned. Its purpose was to provide the researchers with a diverse research material in terms of: time of performing surgery, type of surgical instruments, the number of staff, patient positioning, the surgical team work organization and arrangement of laparoscopic instruments.

1.3 MATERIAL AND METHODOLOGY

The manner of realization of main objective and particular objectives was based on the research material, the sources of which were empirical studies conducted by the authors. The ways of data acquisition were following:

- direct observation, the subject of which were:
 - preparatory actions for recording laparoscopic surgeries,
 - the real surgeries;
- the interview with the participants of laparoscopic surgeries.

Data collection was done using the following recording means:

- 2 digital cameras Sony HDR-XR550 used to recording preparatory actions and laparoscopic procedures (Figure 1.1a),

- the set of the measuring apparatus CAPTIV in the form of wireless sensors (goniometer + torsionmeter) recording in continuously way the positions of selected surgeons' body segments during surgery (Figure 1.1b).

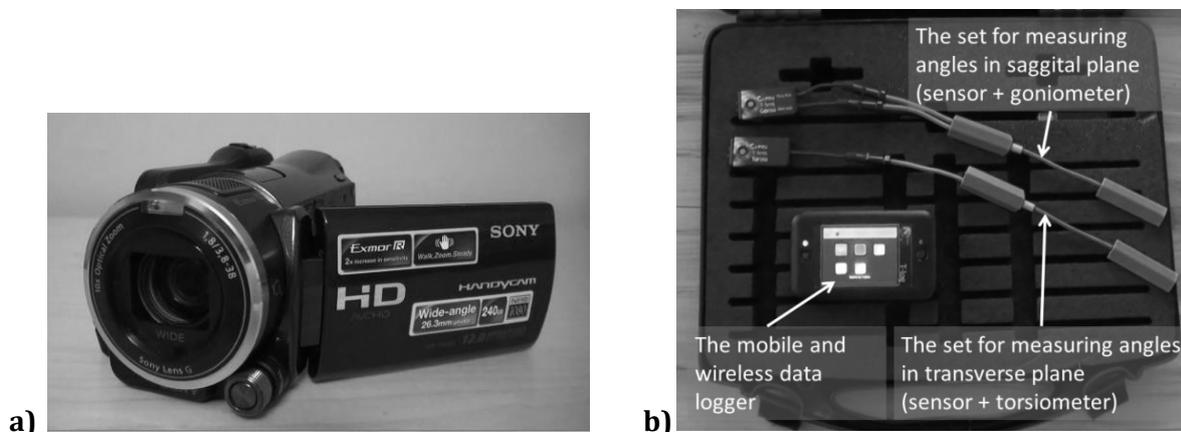


Fig. 1.1 The recording means
a) digital camera Sony, b) the set for the wireless measuring body position

The studies were conducted in the period from January 2013 to June 2014 in the DRH in Katowice. There were observed (recorded) surgeons in the number of $n = 4$ possessing experience in performing laparoscopic procedures, who are differentiated in terms of physical characteristics: weight, height and body structure. The group of surgeons was homogeneous in terms of gender, i.e. 100% of them were male. Each of the operators involved in the observation was informed about recordings and consented to it. In addition, the observations of bariatric procedures have been complemented in 2014 by the use of apparatus for wireless measurement of body position.

Table 1.1 shows a quantitative summary of collected source material.

Table 1.1 Quantitative summary of the source material of recorded laparoscopic surgeries

Type of surgery	Video recordings in years	
	2013	2014
Cholecystectomy	2	0
Hernioplasty TAPP)	2	0
Sleeve gastrectomy	1	16
Gastric bypass	0	2
Total	5	18
	23	

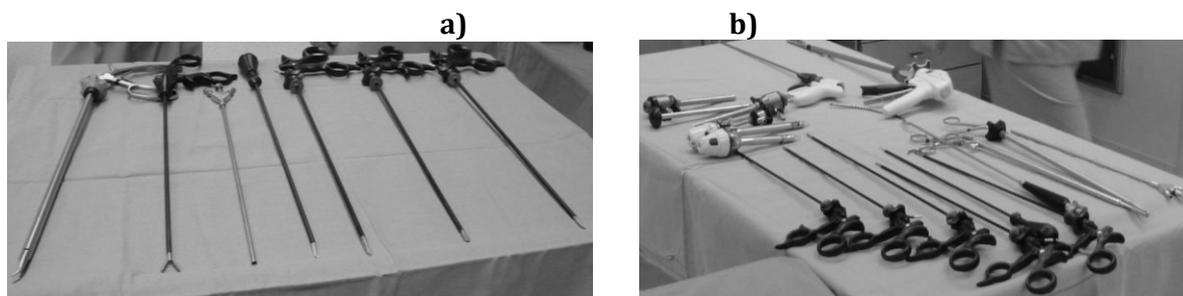
There was used the same medical equipment in all registered medical procedures, composed by: the operating table and laparoscopic column Olympus 3D with the following devices: monitor, light source, laparoscopic camera, fiber optic telescope, insufflators, suction-flushing pump, electrosurgical module, generator for cutting and coagulation of soft tissues.

Table 1.2 Summary of surgical instruments

	Cholecystectomy	Hernioplasty TAPP	Sleeve gastrectomy	Gastric bypass
Veress Needle	X	X	X	X
Trocars	X	X	X	X
Safety graspers	X	X	X	X
Retractors				X
Harmonic knife	X	X	X	X
Laparoscopic scissor	X	X	X	X
Clip applier	X	X	X	X
Laparoscopic hook	X	X		
Extractor	X		X	X
Linear endostapler			X	X
Linear and circular stapler				X
Laparoscopic vice		X		X
Surgical hook	X		X	X
Aquapurator	X	X	X	X
Hook probe	X	X		X
Calibration probe			X	X
Bifunctional pedal of foot activation	X	X	X	X

Another group in this category is a group of laparoscopic instruments. For this purpose, before the video recording of surgeries and ahead of time, the photographic registration of laparoscopic instruments used in each of the surgery type was carried out as well as the simulation of bariatric surgery with the use of laparoscopic instruments was made. During the surgeries carried out in real conditions as well as surgery in simulation conditions there were used the instruments from many manufacturers and that are most commonly in the practice of DRH in Katowice.

Table 1.2 shows a summary of surgical instruments with division into individual laparoscopic procedures. Figure 1.2 shows an example of two sets of surgical instruments: for cholecystectomy (Figure 1.2a) and sleeve gastrectomy (Figure 1.2b).



**Fig. 1.2 The examples of sets of laparoscopic instruments for
a) cholecystectomy b) sleeve gastrectomy**

The surgical instruments used in the surgeries, which were a subject of observation, can be classified into two categories. The first category concerns the division of reusable and disposable instruments. Disposable tools were used by the surgeons in bariatric procedures, and an example a disposable tool is endostapler. The second division includes a division of instruments that have universal character and were used in each of the recorded surgeries and instruments that are specialized and assigned to the certain type of surgery.

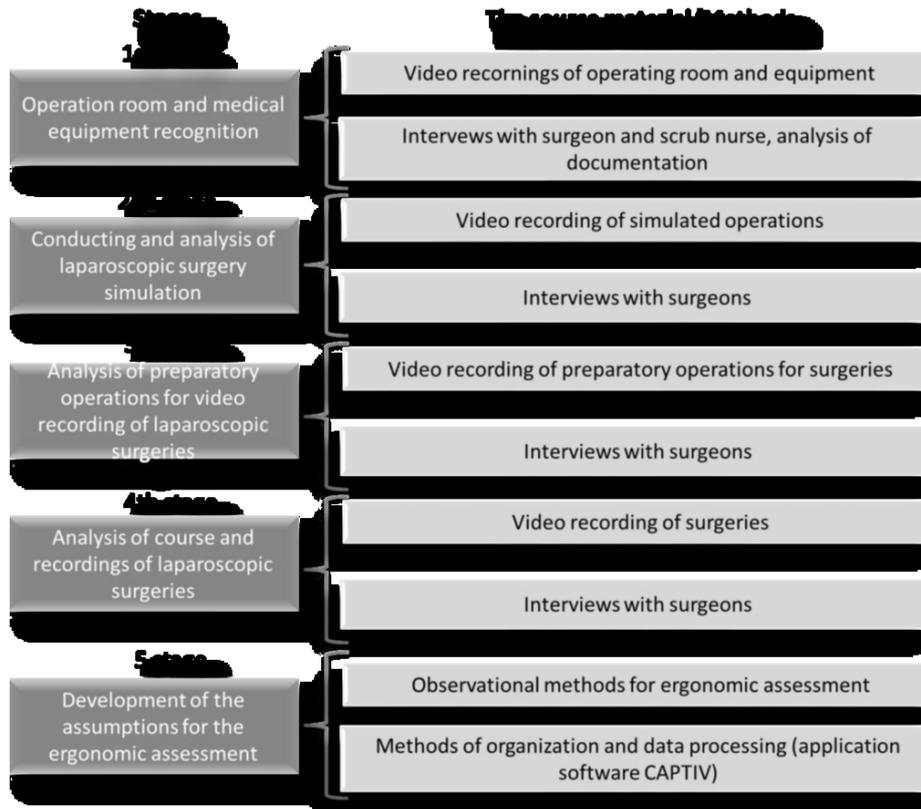


Fig. 1.3 The stages of planning and organization of research concerning ergonomics of laparoscopic surgeries

The collected empirical material became the basis for the development of a standardized method of planning and organization of research in the field of ergonomics in laparoscopic procedures, the stages of which are shown schematically in Figure 1.3.

Stages 1st and 2nd have planning nature and concern mainly the recognition the assumptions and possible ways to implement research, in turn, stages 3rd to 5th have organizational nature and focus on grouping activities and resources, a result of which the specific research goals will be achieved.

1.4 PRESENTATION OF RESEARCH RESULTS AND DISCUSSION

There is presented the results of certain stages of work, as a documented track of implementation of the main and particular objectives of the research (see p. Objective and subject of research).

Operating room and medical equipment recognition

The aim of the stage was to identify the technical and organizational constraints related to the planned observations of laparoscopic surgeries. Figure 1.4 shows the diagram of an operating room including the location of people and equipment, as well as the areas: "clean" and "dirty".

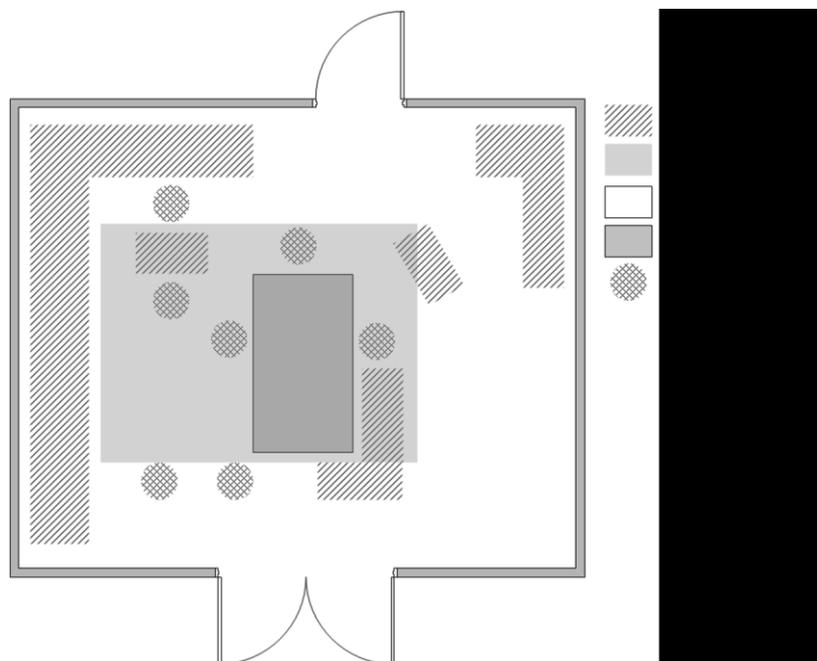


Fig. 1.4 The scheme of layout in operating room

Depending on the type of surgery and the conditions of its implementation the number of medical personnel generally ranges between 3 to 4, and the number of nursing staff is usually 3. There were identified the following limitations associated with video recording of surgeons' operations during surgery which are the result of examination of the operating room, as well as the analysis of interview with the surgeon and the scrub nurse:

- a camera operator can move only in the "dirty" zone;
- the recommend at least two directions of video recording (front and side) of surgeon's operations may not be able to meet because of the barriers in the form of equipment and people involved in the surgery;
- the initial location of the camera operator (or operators) may vary due to the dynamics of the surgical procedure, such as changing the surgeon's position or location of the surgical team members.

Taking into account the specified constraints, it is recommended to use the small hand-held cameras without using tripods because of a relatively high frequency of moving the camera operator during the surgical procedure. Because of possible obstacles during video recording, it is proposed the additional manual registration of the surgeons' body position in a function of time based on the coding method of body position

according to methods OWAS, REBA, RULA or the use of wireless sensors for capturing the surgeons' body position during laparoscopic procedures.

Conducting and analysis of laparoscopic surgery simulation

In addition to the studies on recognizing limitations in the range of recording laparoscopic procedures there was organized and conducted the simulation of sample bariatric surgery. In particular, the aim of the simulation was to determine the condition of real-time acquisition of measurement data on body position of surgeons, which they adopt during surgery. The simulation of surgery took place in a real operating room with the participation of:

- surgeon operator,
- the dummy representing the patient,
- instruments needed to perform the bariatric surgery,
- measuring apparatus (see Figure 1.1 b).

Figure 1.5 shows an example of simulated operations during surgery involving the surgeon with the measuring apparatus installed on the right hand.



Fig. 1.5 The examples of simulated activities with installed measuring apparatus

The simulation of surgical operations has allowed to determine the following facts that can be helpful in organization of registration of real laparoscopic procedures:

- there was positive verified the way of installation and operation of the measuring apparatus for recording surgeon's body position,
- there was determined the time of installation and start-up time of the measuring apparatus,
- there was established the sanitary conditions which enable the installation and the use of measuring equipment in the real laparoscopic procedures.

The analysis of simulation of bariatric surgery confirmed the identified at the 1st stage the conditions features and restrictions in range of video registration of laparoscopic procedures. The results of stages: 1st and 2nd were the basis for the commencement of the organizational activities in the field of ergonomics in work conditions during laparoscopic procedures.

Analysis of preparatory operations for video recording of laparoscopic surgeries

The purpose of 3rd stage was to determine the potential barriers and limitations associated with the preparatory activities for recording the real laparoscopic procedures. Wherein the preparatory activities contained firstly a development of the timetable of laparoscopic surgery along with information about the medical staff composition and scope of the tasks of surgical team members, and secondly the activities directly before the procedure performed in the operating theater area, including:

- preparation of apparatus for video recording and apparatus for measuring surgeon's body position,
- installation of the measuring apparatus on the surgeon's body,
- starting and verification of the correctness of the measuring apparatus and equipment for video recording.

The installed measuring apparatus on the right hand of the surgeon and the moment of starting measuring apparatus just before surgery are shown in Figure 1.6.

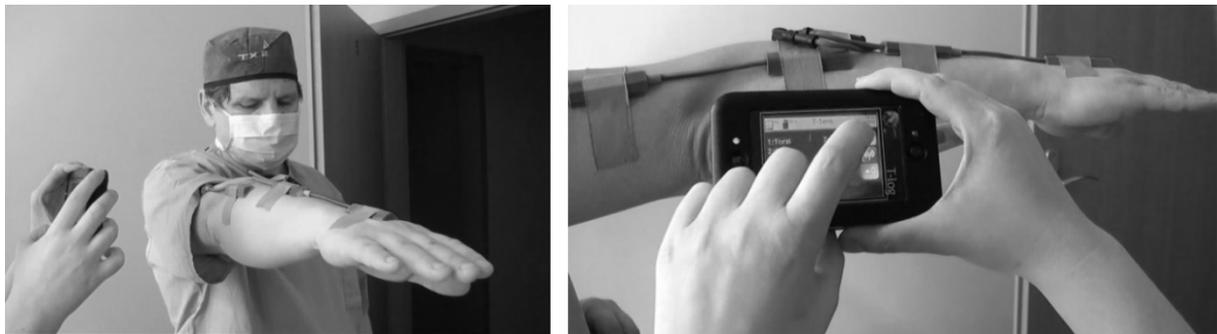


Fig. 1.6 The registration of the way of installation and activation of the measuring apparatus made just before surgery

The results of the preparatory actions analysis indicated the following possible problem situations:

- actions under time pressure,
- the need to start-up of the apparatus several times,
- the occurrence of unforeseen circumstances related to the specific work in a hospital, for example, delays in the initiation of laparoscopic surgeries.

On the basis of the problem situations, the following solutions to facilitate the implementation of preparatory activities for surgery are proposed:

- development of a checklist for verifying the correctness of the installation and starting-up of the apparatus,
- verification of correctness of operation of various components of the apparatus every time before surgery registration.

Analysis of course and recordings of laparoscopic surgeries

The conditions of laparoscopic surgery course revealed the following restrictions disturbing the registration process, as shown in a synthetic manner in Table 1.3.

The identified interference occurring during video recording confirmed, the diag-

nosed at earlier stages, limitations and additionally revealed a new problem areas which have indicated the need to complete guidelines of how to record the laparoscopic procedures. They are as follows:

- preparation of the supplementary equipment of the registration or additional set of batteries in the case of unforeseen circumstances lengthening the duration of surgery,
- earlier diagnosis of composition of the whole surgical team and the preparation of information materials on the purpose, scope and method of performing surgery video recording,
- performance of previous attempt of video recording in lighting conditions similar to those prevailing during surgery, in order to prepare certain recording parameters,
- the ability to change the camera operator due to the burdensome conditions during video recording.

Table 1.3 The limitations occurring during video recording of surgeries

	Cholecystectomy	Hernioplasty TAPP	Sleeve gastrectomy	Gastric bypass
The limitations during video recording				
The necessity of moving the camera operator	X	X	X	X
No possibility of registering the entire surgeon's body	X	X	X	X
Unexpected extension of the surgery			X	X
The lack of agreement with the anesthetists team	X	X	X	X
The incorporation of additional barriers of video recordings, such as screens, additional or new staff etc.	X	X		
The adverse environmental conditions such as high temperature or lack of air circulation	X	X	X	X
No general lighting during surgery	X	X	X	X

During laparoscopic procedures, there was no disturbance on the measuring of surgeon's body position. Figure 1.7 shows the selected images extracted from the video recording of two surgical procedures with the visible sensors of measuring equipment installed on the right hand of the operator.

After finishing the surgery, the surgeons indicated a slight discomfort connected with installed sensors capturing the body positions. However, it was small enough that it does not cause any interference within the course of operational activities.

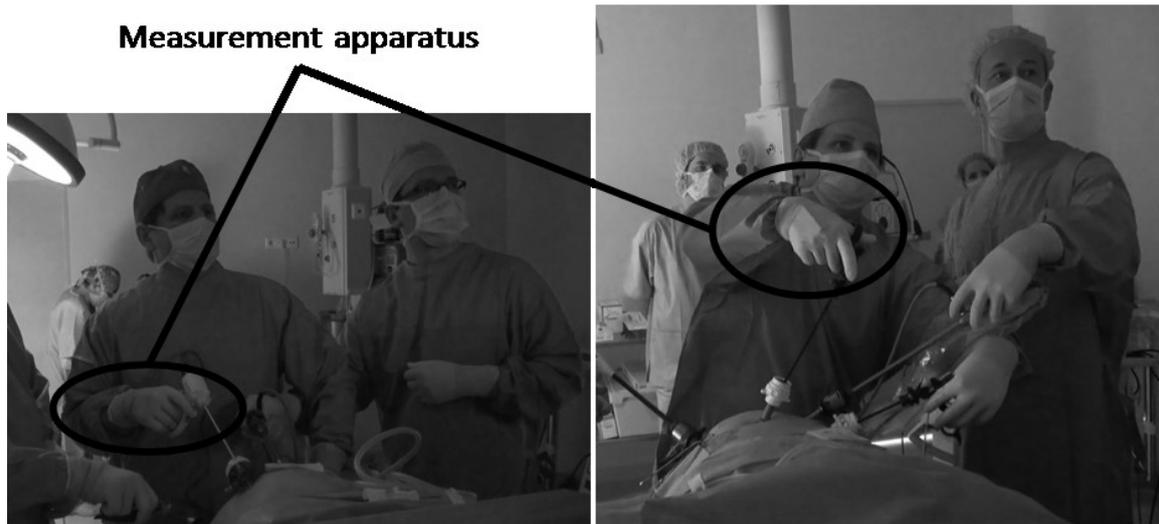


Fig. 1.7 The images extracted from the video recording with the visible sensors for capturing body position

Development of the assumptions for the ergonomic assessment

Considering the conditions and restrictions of research into such a special working environment, which is the operating room during laparoscopic procedures, as well as the essence of ergonomic analysis based on observation methods, the two paths of data processing were defined:

- 1 Data processing of derived exclusively from the video recording.
- 2 Data processing from video recordings and recordings of the measurement of surgeon's body position.



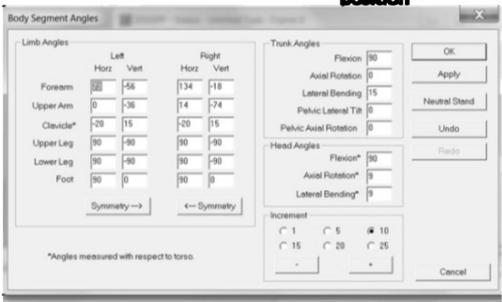
1 Video recording



2 Recognition of momentary positions of body segments, different from a neutral position



3 Modeling of anthropometric features in 3D SSPP



4 Identification of angles in 3D SSPP defining the body position



5 Ergonomic assessment with the use of dedicated method [10]

Fig. 1.8 The track of video frames processing for the ergonomic assessment

Both the first and the second path should enable an ergonomic assessment of working conditions of the surgeons during surgery. Depending on the method of ergonomic assessment, the purpose of data processing is to obtain the required input data which are necessary to apply the specified method.

In this consideration the assumption is defined which is narrowing the ergonomic assessment to static load assessment with the use of the method based on the measurement of angular positions of individual body segments. Within the framework of first path the following processing track, enabling the identification of data defining surgeon's postures, was performed (Figure 1.8).

The method of how to use video recording as a basis for ergonomic assessment has been described in detail in the publication [1]. The second path is extended by measuring track representing the manner of data acquisition from sensors capturing body position of a surgeon (Figure 1.9).

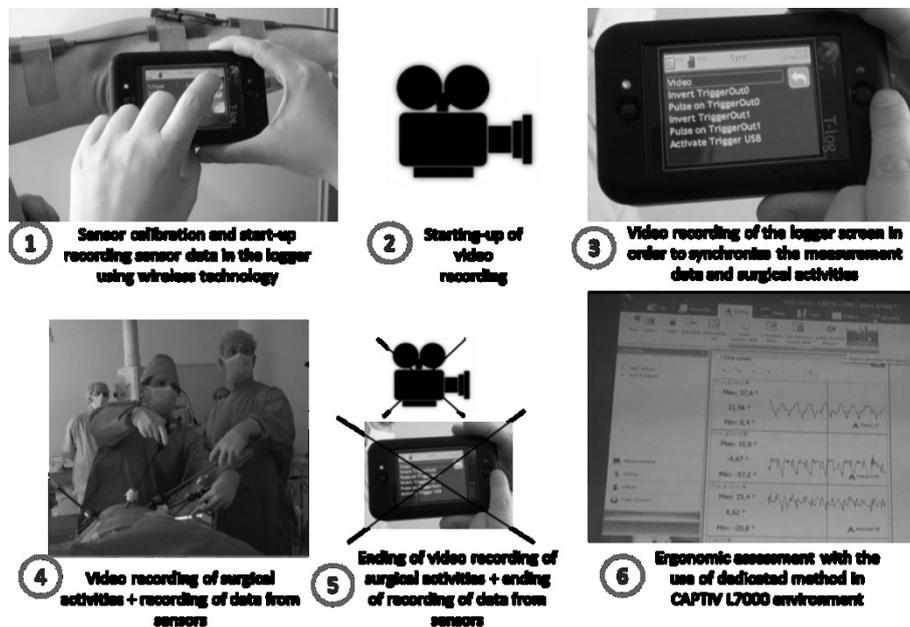


Fig. 1.9 The track of data processing from video recording and measurement recording of surgeon's body position

The presented manner of recording video and measurement data enable integration of video material and measured information on surgeon's body position. Ergonomic assessment in this case can be complex through the use of common software environment as a place of data acquisition as well as ordering information for ergonomic assessment and the analysis of its results. In this case the CAPTIV L7000 is used as the software environment. CAPTIV L7000 is a computer program used to data analysis on how to perform actions. The analysis is conducted on the basis of video recordings and related to them encoded information, for example: concerning the body positions, and also types of activities, physical environmental parameters, etc. Particularly, CAPTIV software environment can be a place for integrating the encoded information and ergonomic methods, such as REBA, RULA or OWAS.

CONCLUSION

The presented in the article issues on how to perform the ergonomic research in the working environment of surgeons is a part of extensive study on improving ergonomics in laparoscopic procedures conducting by the authors. The carried out in the years 2013-2014 video recordings of different types of laparoscopic surgeons allowed to formulate restrictions and specific guidelines to facilitate the planning and organization of the research in such a unique environment which is the operating room (see objective O1). In the paper the prerequisite were determined for the development of the concept of transformation and integration of research material collected for the purposes of comprehensive ergonomic analysis associated with the manner of doing laparoscopic surgeries (see objectives O2 and O3).

The presented description of complex planning of activities and organizational arrangements for video recording of laparoscopic surgeries and body position measurement with specialized motion capture sensors confirms that the careful preparation of the research is the factor determining a high degree of accuracy of the analysis, thus giving the basis for conducting the competent and reliable scientific research.

ACKNOWLEDGEMENT

This study was supported by the LapForm project (527985-LLP-1-2012-ES-LEONARDO-LMP). This project has been funded with support of the Lifelong Learning Programme of the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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THE WAY OF PLANNING AND ORGANIZING RESEARCH IN RANGE OF ERGONOMICS ON THE EXAMPLE OF OBSERVATION OF LAPAROSCOPIC SURGERIES

Abstract: The article presents the results of studies on the identification and analysis of problem areas concerning aspects of ergonomics in laparoscopic surgeries. The studies were based on the research carried out in both real conditions and simulation conditions. The described methodology and research material refers to the photographic documentation of the operating room and laparoscopic instruments, in addition to performed staged procedure as well as the way of planning the deployment of members of the surgical team and patient positioning. The next step in the research was acquisition of the data concerning the way of performance of bariatric procedures in real conditions with the use of wireless goniometer and torsionmeter, made with video recording. The method of carrying out the research as well as the identification of barriers in the process of ergonomic assessment of laparoscopic procedures have allowed the authors to obtain the research material which was the starting point for the development of a research model for ergonomics in laparoscopic procedures.

Keywords: Ergonomics, laparoscopy, planning of studies, capturing the body position

SPOSÓB PLANOWANIA I ORGANIZACJI BADAŃ W ZAKRESIE ERGONOMII NA PRZYKŁADZIE OBSERWACJI ZABIEGÓW LAPAROSKOPOWYCH

Streszczenie: W artykule przedstawiono wyniki studiów w zakresie identyfikacji oraz analizy obszarów problemowych dotyczących aspektów ergonomii w zabiegach laparoskopowych w oparciu o przeprowadzone badania naukowe w warunkach rzeczywistych jak i warunkach symulowanych. Opisana metodyka i materiał badawczy odnoszą się do wykonanej przez Autorów dokumentacji fotograficznej sali operacyjnej oraz narzędzi laparoskopowych, przeprowadzenia inscenizacji zabiegu jak również zaplanowania rozmieszczenia członków zespołu chirurgicznego oraz ułożenia pacjenta. Kolejnym opisanym etapem badań jest akwizycja danych dotyczących sposobu wykonywania zabiegów bariatrycznych w warunkach rzeczywistych z zastosowaniem bezprzewodowych goniometrów dokonana za pomocą rejestracji wideo. Sposób przeprowadzania badań jak również rozpoznanie barier w procesie oceny ergonomicznej zabiegów laparoskopowych pozwoliły Autorom na uzyskanie materiału badawczego stanowiącego punkt wyjścia do opracowania modelu badawczego w zakresie ergonomii zabiegów laparoskopowych.

Słowa kluczowe: Ergonomia, laparoscopia, planowanie badań, przechwytywanie pozycji ciała

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