Ergonomic Assessment of Hand Movements in Laparoscopic Surgery Using the CyberGlove®

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Chapter 13
Ergonomic Assessment of Hand Movements in Laparoscopic Surgery Using the CyberGlove®

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Abstract The main objective of this chapter is the automation of the ergonomic assessment of the wrist's positions, through biomechanics analysis techniques, specifically using the rapid upper limb assessment (RULA). So, this allows establishing new use and design guidelines of the laparoscopic instruments, in order to reduce the influence of risk factors in the wrist area, which are associated with forced positions during the development of laparoscopic activities.

The movements of the right wrist of the surgeons have been recorded with CyberGlove® data glove, during basic laparoscopic tasks. The obtained data were processed according to an adaptation of the ergonomic assessment of the RULA method.

The results of the study show the virtual glove is a useful and fast tool to determine the adoption of forced positions of the surgeons' wrist. These positions mean a high risk to suffer from muscle alterations. For this reason, setting out improvements in the use and design of the current laparoscopic instruments is considered indispensable.

Keywords Ergonomics · Laparoscopy · RULA method · CyberGlove® · Wrist joint · Laparoscopic instruments

1 Introduction

The laparoscopic surgery emerged 20 years ago, and currently it is firmly introduced in the surgical practice. The laparoscopic surgery stresses versus the open surgery, owing to its numerous advantages in patients' recovery, although it presents several inconveniences for the surgeon: lack of spatial depth and tactile

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sensation and adoption of forced positions, which mean a high level of muscle–skeletal stress. Consequently, the development of ergonomics studies on design and use of laparoscopic instruments is really important.

In this study, we try to create an automatic technique for analysis of wrist's positions. Taking as starting point the subjective usual techniques of ergonomic study (as video-based analysis) and the objectives ones (as goniometry and the electromyography analysis), we used a recording device of data (CyberGlove®) as alternative method. This device allows recording the movements of the wrist joints for later analysis.

This methodology of ergonomic assessment means the union of the advantages of the objectiveness, speed (improving the video-based analysis), and functionality (less instruments and more comfort for the surgeon than the goniometry).

1.1 Aims

The main objective of this study is the automation of data collection relating to the angles of flexion and extension of the wrist during the performance of basic laparoscopic tasks and their subsequent analysis by the ergonomic method of assessment RULA [1]. This is achieved using the CyberGlove® data glove.

This study also analyzes the influence of five types of laparoscopic instruments in flexion–extension of the wrist joint, both at rest and during performance of laparoscopic tasks.

1.2 Previous Research Works with the CyberGlove®

The CyberGlove® has been present in several clinical and technology research projects. This device has mainly been used in developing virtual reality systems [2–5] and the study of hand movements in the use of hand tools [6–8].

Finally, the research has been focused on the development of the virtual reality systems for the rehabilitation of patients with brain injuries [9, 10] and the development of virtual reality systems to assist surgeons in planning surgery [11, 12] in clinical field.

2 Tools and Method

The data of the ergonomic study have been recorded for a sample of 17 surgeons between 28 and 50 years old, with levels of medium and high experience in laparoscopic surgery. The maneuvers of laparoscopic cutting, dissection, and suturing were carried out in a physical simulator (SIMULAP-IC05®, CCMIJU, Cáceres, Spain). During these activities, the movements of the right hand were recorded, both the wrist and the rest of joints, using the CyberGlove®.

2.1 SIMULAP-IC05 Features

To standardize the study in a controllable and reproducible environment, we have used the physical laparosocopic simulator SIMULAP-IC05®, which is mainly dedicated to the learning of laparoscopic maneuvers with some technical difficulty (vascular anastomosis, Nissen funduplicature, radical prostatectomy, etc.). This training device simulates the abdominal cavity and has a transparent plastic cover that allows the introduction of trocars to handle the instruments.

The surgeon follows the maneuvers performed through the transparent top cover or through the images projected on screens when using the laparoscopic camera integrated in this device [13, 14].

2.2 The CyberGlove® Features

CyberGlove® is a device with a sensor package of conductive material, its resistance varies with the flexion and allows registering the movements of the fingers and wrist joints.

The model of CyberGlove® used in this study has 18 sensors which record the metacarpophalangeal and interphalangeal deviation of the fingers, the distance among them, the turning of the thumb and the little finger with respect to the palm of the hand, and flexion–extension and ulna–radial deviation of the wrist.

Maximum speed is 114 kBaud sampling (100 samples of each sensor per second) and is connected to the computer via the RS232 serial port [15].

2.3 Clinical Evaluation Characteristics

Perspectives have been derived from the work area using two video cameras: one with front view and another with left lateral view of the surgeon to be able to compare, in future research, the results obtained with a video metric analysis.

One right hand CyberGlove® is used, which was previously calibrated according to the anatomical characteristics of each surgeon's hand. For data acquisition, how to grip the instrument is analyzed, according to two criteria: the neutral position or at rest, and during the performance of laparoscopic tasks (Fig. 13.1). The instrumental group chosen includes scissors, dissector, and three models of laparoscopic needle holders (curved, straight, and straight with rings).

We define as resting or neutral position, that position of the gripping instrument, which is considered by each surgeon as ergonomics and it is associated with less muscle-skeletal stress for him.

The data are recorded during the tasks of cutting sheet of latex with laparoscopic scissors, the dissection of the gastric serous layer with laparoscopic dissector, and suturing in laparoscopic sheet of latex using three different models of laparoscopic needle holder.

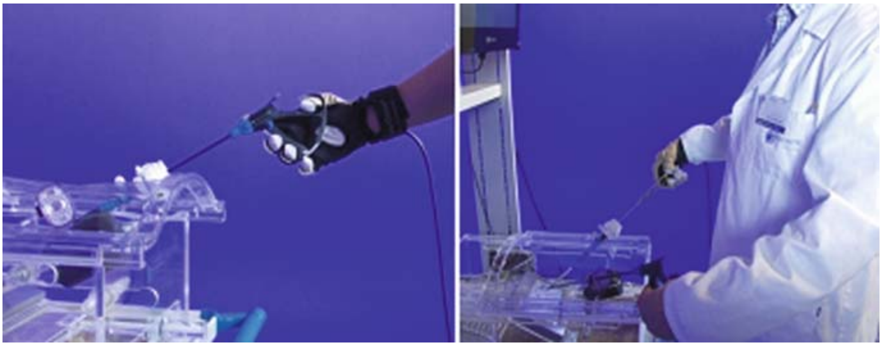

Fig. 13.1 Positions of the surgeon's hand during the recording of data using the CyberGlove®

The time data recording was 5 s for each neutral position and 1 min for each laparoscopic task. The data recording of each laparoscopic task has been taken for the same surgical position for each surgeon.

2.4 RULA Method

For the assessment of risk associated with postural load there are several methods, each one with a scope of application and different results [16–18]. The RULA method, chosen for such experiments, was developed by doctors *McAtammey* and *Corlett* in 1993 to assess the risk factors in workers, which may cause disturbances in the upper limbs of the body: postures, repetitiveness of movement, static activity of the skeletal muscle system, and so on.

We rely on this method for ergonomic evaluation of the wrist in the grip of basic laparoscopic instrumentation.

The RULA method divides its evaluation into two corporal groups: group A, which includes the upper limbs (arms, wrists and forearms), and group B, which covers the legs, trunk, and neck. In our case, the assessment will only focus on the wrist joint, included in the group of upper limbs of the body.

The evaluation of a specific position of a subject with this method only makes sense, if one takes into account both the joint group of upper and lower members.

2.5 Computer Application

To carry out the ergonomic study, we developed a software application on the Microsoft® Visual C++ 2005® platform.

This application analyzes and interprets the degree of flexion–extension of each of the joints of the hand obtained by the data glove. Similarly, it allows the display

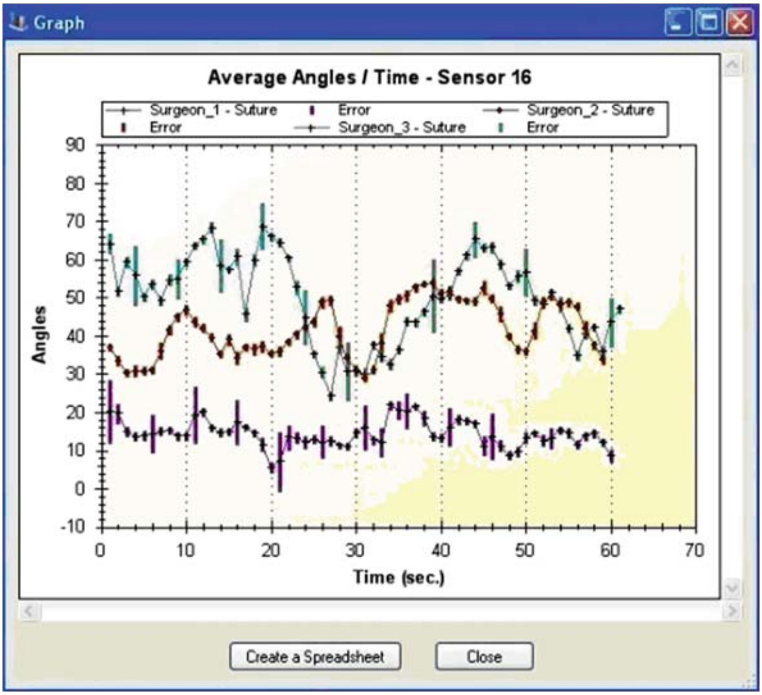

Fig. 13.2 Comparative chart of the angles described by the wrist of three surgeons during the development of laparoscopic suturing in latex using a curved needle holder

of charts of evolution in the degrees of each of the joints and the comparison among different surgeons during a surgical task (Fig. 13.2).

Another utility of the computer application is the automatic comparison of the wrist joint information, using RULA score regarding the flexion–extension wrist movements.

2.6 Data Analysis

We used the arithmetic mean of the degrees of motion (angular average value), with its corresponding error for each sensor. Because we work with a range of positive values, it was not necessary to use the effective value on the sample data [19].

The arithmetic average of the wrist angle of the sample of surgeons has been calculated for each instrumental in his neutral and active position. An analysis of variance (ANOVA) has been conducted for comparison of the values obtained in both positions. The level of significance was set at $p < 0.05$.

3 Results

The typical rating of the RULA method, with respect to flexion–extension of the wrist, has been adapted to the positive range of angles used, which will depend on the values provided by the CyberGlove® (Table 13.1). This range of angles is between 0° and 120°, but it can vary from one subject to another depending on his anatomical features. We consider a score between 1 and 2 as an acceptable extension–flexion of the wrist and a 3 score as inappropriate.

Table 13.1 Adaptation of the RULA method regarding the wrist, for the values obtained from the CyberGlove®

Score	Position
1	If the flexion–extension angle is 60° ± 3°
2	If the wrist is flexed or extended between 45° and 75°, except for the score 1 case
3	If the flexion–extension is greater than 75° or below 45°

Our results (Table 13.2) showed that there is no statistical evidence of relationship between neutral position and the active position for each instrument.

Table 13.2 Comparison of the wrist flexion–extension angle (mean value ± standard deviation) in the neutral position and active position

Laparoscopic instruments	Neutral position	Active position	Significance level
Scissors	19.63 ± 0.65	16.42 ± 1.36	NS
Dissector	26.48 ± 0.77	24.97 ± 1.57	NS
Needle holder	36.41 ± 0.98	35.31 ± 1.95	NS
Axial handle	32.96 ± 1.04	36.64 ± 2.03	NS
Pistol handle	43.52 ± 0.99	42.42 ± 1.98	NS
Ring axial handle	32.74 + 0.90	26.87 + 1.82	NS

NS = not significant

4 Discussion

The necessary applications have been generated to acquire and analyze the degrees of flexion–extension of the wrist and its harmonization with the RULA values.

For all laparoscopic instruments analyzed, most surgeons have unfavorable angles of flexion–extension, both in the neutral position and during the performance of basic laparoscopic tasks.

There has been no statistical evidence of relationship between the neutral or at rest positions, which we consider adequate, and the active position for the wrist angle for each instrument. Consequently, we cannot determine whether adverse angles obtained in most cases are due to an incorrect grip of the tool by the surgeon or the improper design of the instruments used.

Because we used a sample of 17 expert surgeons in laparoscopic surgery, this leads us to focus future works on improving ergonomics in the design of such instruments.

4.1 Future Researches

Within the lines of future work arising during the development of this work, the validation of this technique over other more established techniques, the consideration of the ulna–radial deviation, and the inclusion of a spatial position sensor to assess the twist of the wrist remain.

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