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BACKGROUND AND OBJECTIVES: *Laparoscopic surgery is a widely used surgical technique, whose benefits either for patients or for surgeons are well-recognized. Despite the rise in the use of this technique, the ergonomics of the operating room is still very low. The consequence is that injuries and illness related to laparoscopic surgery are present. The aims of this study are to investigate how an increase in the surgeon' perception of the fatigue during the execution of the intervention influences the surgeon' health, and to evaluate if there is a correlation between the increase in fatigue and the operating field dimension.*
MATERIALS AND METHODS: *The observation was conducted on a single laparoscopist working at our Institution and the Borg CR 0-10 scale was used to perform this study.* Two *groups of 20 surgical procedures each were analysed. Group A included laparoscopic procedures whose operating field comprehended only one abdominal quadrant. Group B included laparoscopic procedures where at least two abdominal quadrants were involved in the operative field.*
RESULTS: *The results from both groups were statistically compared. There was a significant correlation between the increase in perception of the exertion and duration of the intervention in both groups and a significant difference in term of Borg scale value, which was higher in group B where the laparoscopic surgery was performed on more than one quadrant of the abdomen.*
CONCLUSION: *We suggest an important improvement in the ergonomic aspects, especially in more complex laparoscopic procedures that require longer operating time and include more than one abdominal quadrant.*

KEY WORDS: Ergonomics, Laparoscopic surgery, Operating theatre

Introduction

Laparoscopic surgery has become widely used in the past decade. One of the most significant reasons that led laparoscopic surgery to become so common were the several advantages related to this procedure either for the surgeon or for the patients, such as magnified image of the operating field, reduction of post-operative pain, shorter hospital stay, and the possibility to get back sooner to normal activities [1,2] .

However, from the viewpoint of the surgeons, laparoscopic surgery is demanding as far as ergonomy while performing the mini-invasive technique problem is considered. Surgeon's body position and movements during the laparoscopic approach might be challenging and may induce discomfort to the operating surgeon himself.
Only few studies have addressed ergonomics problems encountered by the surgeon while performing laparoscopic procedures [3-7]. Laparoscopy is probably more stressful than open surgery [8-13] and some factors related to the laparoscopic approach have been investigated and considered responsible for the discomfort reported by the laparoscopic surgeon. Length and complexity of surgical procedure has been scarcely investigated. So far, in our knowledge, ergonomic problem during laparoscopic surgery has not been related to the involvement of more than one surgical fields while performing the mininvasive operation.
In this study, we investigated if there was an increasing perception of fatigue from the surgeon during the execution of laparoscopic interventions and we evaluated if

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there was a correlation between the increase in fatigue for the surgeon and the extension of operative field with one or more abdominal quadrant involved in the laparoscopic procedure.

Patients and Methods

This study was performed comparing results in two groups of 20 surgical procedures all performed by the same surgeon (RV), whose perception of fatigue was evaluated.

Group A included laparoscopic procedures whose operating field consisted in only one abdominal quadrant. Surgical procedures included in this group were laparoscopic cholecystectomies, splenectomies, adrenalectomies, appendicectomies. Group B included laparoscopic procedures where at least two abdominal quadrants were involved in the operative field. These procedures were right and left hemicolectomies, bilateral inguinal hernia repairs, splenectomy associated to cholecystectomy, diagnostic laparoscopy associated to appendectomy, laparoscopic appendectomy and ovariectomy, diagnostic laparoscopy associated to peritoneal adhesiolysis and abdominal cyst excision, cholecystectomy associated to abdominal wall defect repair, cholecystectomy associated to peritoneal adhesiolysis.

To measure the perception of the exertion of the surgeon during laparoscopic surgery, the Borg CR 0-10 scale was used in this study. The Borg CR 0-10 scale is a psychophysical scaling that evaluates the physical work, expressing it in numerical value from 0 to 10, as reported in Table I. Gunnar Borg introduced the concept of perception of effort as early as the 1950s and developed the Borg CR10 scale, by which overall assessment of the perception of effort is achieved as an integration of all the symptoms perceived in the performance of an exercise, from the peripheral work of the muscles and joints to the sensations coming from the thoracic region [14]. Professionals in psychology, ergonomic and physiological assessment use this scales for quantification of effort perception worldwide during exercise.

TABLE I - *Borg's CR-10 scale.*

0	Nothing at all	
0,5	Extremely Weak	(just noticeable)
1	Very weak	
2	Weak	
3	Moderate	(light)
4		
5	Strong	(heavy)
6		
7	Very strong	
8		
9		
10	Extremely strong	(almost max)

The analyzed laparoscopist had a negative anamnesis for osteoarticular disorders, like lumbar discal hernia, ankylosing spondylitis, ligamentoplasty of the knee, scoliosis.

The operating surgeon was asked to give a number from this scale in all the performed procedures at the intervals of 30 minutes starting from the beginning of the procedure up to 90 minutes.

Discomfort with effort and exertion at the left and right shoulders, at the neck and the back, were investigated and noted at each time interval.

To assess if there was an increase in the perception of the effort by performing an intervention on more than one quadrant compared to an intervention on a single quadrant, a comparison between the two groups was performed using the non-parametric unpaired Mann-Whitney U test.

The comparison of the Borg scale average between both groups was performed by Friedman test. Results were considered significant when the p-value was lower than 0.05.

In order to understand if there was an increase in the perception of exertion during the execution of the procedures, the Friedman test was used. Dunn's multiple comparison test was used to assess if there was a significant difference between the data collected during the 90 minutes of observation for each group. Data were expressed as mean, standard deviation, and standard error of the mean, and are shown in II.

Results

The mean values of Borg CR 0-10 scale observed were 2,35 (SD= 0,49) in group A and of 3,1 (SD= 0,605) in group B at 30 minutes after the beginning of the procedures; 3,5 (SD= 0,513) in group A and 4,5 (SD= 0,513) in group B at 60 minutes; 4,2 (SD= 0,834) in group A and 5,45 (SD= 0,51) in group B at 90 minutes (Table II).

A significant difference (p-value <0,0001) of Borg scale mean values between the two groups, calculated at 30 minutes, 60 minutes and 90 minutes, was found.

Between 30 minutes and 60 minutes, in group A there was a significant difference with a p value <0,5, whereas in group B there was no significant difference. Between 30 minutes and 90 minutes, in group A there was a significant difference with a p value <0,00005, and the same in-group B. Between 60 minutes and 90 minutes, either in group A or in group B there was not a significant difference.

Borg scale average increased over the time of observation, as evaluated by means of Friedman test and Dunn's multiple comparison test, showing a particular increase at the end of the interventions.

The p-values of the two groups calculated with the Mann-Whitney U test at 30 minutes, 60 minutes and 90 minutes resulted statistically different, with a significant increase of the Borg scale values in group B.

TABLE II - *Comparison between group A and group B by Borg's CR-10 scale values*

	30 min.		p-value	60 min.		p-value	90 min.		p-value
	A	B		A	B		A	B	
Mean	2,35	3,1	0,0008	3,5	4,5	<0,0001	4,2	5,45	<0,0001
SD	0,49	0,605	-	0,513	0,513	-	0,834	0,51	-
Std. error	0,1094	0,136	-	0,1147	0,115	-	0,1864	0,114	-

Discussion

Laparoscopic surgery is a widely used surgical technique, whose benefits either for patients or for surgeons are well-recognized.

Despite the rise in the use of this technique, knowledge on the ergonomics of the operating room and on the fatigue of the operating surgeon is still very low.

The consequence is that the injuries and illness related to laparoscopic surgery are still presents.

The International Ergonomics Association defines the term "ergonomics" as the scientific discipline concerned with the understanding of the interaction among humans and other elements of a system, as the profession that applies theory principles, data, and methods to design to optimize human well-being and overall system performance. In short, it is the science that design the work environment to fit the worker, instead of forcing the worker to fit the working environment [15].

In the operating room, ergonomics is the scientific study of the "choreography" of the surgical gesture with the purpose to improve performance through the design of the instrumentation, the distribution of the instrumentation, and the coordination of the operating team.

Transition from open surgery to laparoscopic surgery changed radically the relation between the surgeon and the operating field. The ergonomic challenges in laparoscopic surgery derive from a series of reasons. First, there is a mutation of the surgeon body postures and of the upper extremity movements. Laparoscopic surgeons tend to maintain an upright position with fewer back movements and less weight shifting than surgeons performing open surgery [4,5], since the operating field is visualized in a monitor.

Although there has been a rise in the use of the laparoscopic approach, there have been no concomitant changes in operating room design and video monitor set-up to ease musculoskeletal fatigue of surgeons performing laparoscopic surgery [5]. Surgeons, however, must cope with disadvantages caused by a non-ergonomic working place involving architecture, operating room design, team interaction, equipment and, finally, posture and instrument handles [3]. The monitor position is one of the most important variables that influence the operator's position. The right position of the monitor should be not too much high but also not so low to avoid an excessive neck flexion and in front of the first operator [3,16]. The incorrect placement of the monitor and the optic could lead to "spatial disorientation" of the surgeon, resulting in performance reduction. This occurs especially during the execution of endo-abdominal operations where the camera is pointed to the opposite direction to the instrument.

According to the study by Matern et al., a second frontal monitor should be useful for the execution of more complex gestures [3]. The operator's posture is also influenced by the height of the operating table, the pedal shape and position, training level and manual dexterity.

The table's height should be adjusted according to the stature of the taller surgeon, providing appropriate rises for the other operators. An inappropriate table's height forces the laparoscopist to an excessive arm abduction. If a riser is required, it is often not large enough for including both feet and the pedal used for the control of electrosurgical cutting. This leads the surgeon to take uncomfortable positions for the feet.

The main recommendations aiming at preventing the work-related musculoskeletal disease included assuming a correct position, with arms perpendicular to the floor and the forearm parallel to the floor, the elbow flexed at 90° (or less but not more than 120°) and abduction of the shoulders lower than 30°; angle of work of about 60° between the handle of the instruments and the hands; monitor at the same height of the eyes, which allows a neck flexion not superior than 20° (neutral position); the height of the operating table set to the highest operator.

Second, the surgeon is required to move long instruments through fixed ports, resulting in the fulcrum effect, limited degrees of freedom, and loss of tactile feedback [4,17]. The position of trocars is fundamental for ergonomics and is important to avoid the interference between instruments and between instruments and the scope inside the abdominal wall. In order to perform correctly and simply a laparoscopic suture, the instruments must reach the surgical field without obstructing the vision and with an angle that allows passing a stitch perpendicularly to the suture line itself. During the execution of the suture it is better to start distally, from the corner farthest from the optic, and continue moving close to this, in order to prevent the covering of the instruments.

Ergonomics does not only depend on the posture assumed by the surgeon during the execution of laparoscopic surgery, but also on the use of non-ergonomic instruments. Reports of muscle exhaustion, pressure areas

and neural injury caused by instrument handles have been reported in the Literature [16]. At the moment, the majority of handles utilized among surgeons in Europe satisfies less than 50% of the ergonomic criteria.
The pedal has also a significant role in the ergonomics of the operating room. In particular, the ideal pedal should have a design that avoids a forced static position of the surgeon, be activated with an instep flexion less than 25°, be positioned near the surgeon's foot in an ergonomic position, have different shapes recognizable with the foot in order to not accidentally activate the wrong function, and avoid displacement during the use. A bad pedal ergonomics could be the cause of low back pain or heel inflammation of the operator. In order to reduce this problem some instruments have headpieces with manual activation.
In the Literature, there are studies that confirm the presence of these postural problems in laparoscopic surgery. As reported by Catanzerite et al., the surgery-related musculoskeletal pain and injury are very common among either the laparoscopic or the open surgeons [19]. The estimated prevalence of work-related musculoskeletal disorders reported are between 66% and 94% for open surgery, between 73% and 100% for "conventional" laparoscopic surgery, between 23% and 80% for laparoscopic robotic surgery. Then, it seems that there is a major risk of work-related musculoskeletal disorders for laparoscopic surgery.
Other studies demonstrated that the performance was more stressful for the surgeons who work in laparoscopic surgery than in open surgery.
Miller K et al. [11] recruited 61 surgeons and gave them a questionnaire to fill out. Respondents included 32 general surgeons, 6 bariatric surgeons, 21 obstetricians/gynecologists, 1 gastroenterologist and 1 urologist. Sixty-one laparoscopic surgeons (100%) reported at least 1 injury/illness symptom as a result of performing laparoscopic surgery. The most prevalent of these injury/illness symptoms were neck stiffness (26%), back stiffness (26%), and back pain (23%), leg stiffness (66%), hand/wrist numbness (64%), and leg pain (62%). Symptoms occasionally reported included neck stiffness (66%), irritability (64%), back pain (64%), and back stiffness (61%).
Berguer et al.[9] analyzed the surgeons' body positions recording that on videotape during four laparoscopic and six open operations. These video have confirmed that in laparoscopy there is a greater staticity/stiffness of the head, neck compared to traditional surgery, and trunk with limited movements but repeated rotation/flexion, which causes muscular tension on the neck and back. In addition, the more limited posture may induce fatigue because of the limited natural changes in body posture that occur during open surgery.
Nguyen et al. showed that there is an association between static and forced, not natural positions and uncomfortable movements of the upper arms. Some of these movements are the shoulder intra-rotation, the elbow deviation/flexion, the supination and the alternating deviation of the wrist [4].
There is a postural problem also for assistants as Lee et al. highlighted it in their study. It seems that assistants tend to disproportionately bring 80% of body weight on the posterior chain of inferior limbs over time [10] with a muscular stress that is similar or higher than the first operator [20].
Another frequent problem is the psychological stress [18,21]. Psychological stress is due to excessive noise inside the operating theatre, excessive lighting of the operating theatre, lacking of compliance or preparation of the team, quality of communication between the members of the team, operating theatre design, workloads, awkward visual and physical interface of video-endoscopic surgery. The psychical stress, as well as physical stress, related to laparoscopic surgery were accentuated by the duration of the procedure and by the operating volume. Cuschieri described a syndrome called "surgery fatigue syndrome", a nosocomial entity that remains anecdotal, characterized by mental tiredness, irritability, impaired surgical evaluation, reduced dexterity. He found a correlation between the manifestation of this syndrome and the duration of the procedure. In fact, it seems that this syndrome tends to arise after 4 hours of continuous activity [6].
In this study, we found that there was a significant relationship between the increase in the perception of the exertion and the duration of the intervention in both groups.
Comparing the two groups of interventions, we found a significant difference in term of higher value of the Borg scale in group B where the laparoscopic surgery was performed on more than one quadrant of the abdomen.
In conclusion, we suggest an important improvement in the ergonomic aspects, especially in more complex laparoscopic procedures that require longer operating time and include more than one quadrant.

Riassunto

La chirurgia laparoscopica è una tecnica chirurgica ormai ampiamente utilizzata, i cui benefici sia per i pazienti che per i chirurghi sono ben conosciuti.
Nonostante questa tecnica sia sempre più applicata nel mondo, l'ergonomia della sala operatoria è ancora molto bassa. La conseguenza è che si verificano in cronico patologie osteo-articolari legate alla chirurgia laparoscopica.
Gli obiettivi di questo studio sono di indagare come un aumento della percezione della fatica da parte del chirurgo durante l'esecuzione dell'intervento influenzi la salute del chirurgo e di valutare se esiste una correlazione tra l'aumento della fatica e la dimensione del campo operatorio.
Materiali e metodi. L'osservazione è stata condotta su un singolo laparoscopista che lavora presso il nostro Istituto

e per eseguire questo studio è stata utilizzata la scala Borg CR 0-10 al fine di quantificare la percezione della fatica.
Sono stati analizzati due gruppi di 20 procedure chirurgiche ciascuno. Il gruppo A comprendeva procedure laparoscopiche il cui campo operatorio coinvolgeva un solo quadrante addominale. Il gruppo B comprendeva procedure laparoscopiche in cui almeno due quadranti addominali erano coinvolti nell'intervento chirurgico.
Risultati. I risultati di entrambi i gruppi sono stati confrontati statisticamente. C'era una correlazione significativa tra l'aumento della percezione della fatica e la durata dell'intervento in entrambi i gruppi e una differenza significativa in termini di valore della scala di Borg, che era più alta nel gruppo B dove la chirurgia laparoscopica è stata eseguita su più di un quadrante dell'addome.
Conclusione: Suggeriamo un importante miglioramento degli aspetti ergonomici sia della sala operatoria che dello strumentario chirurgico, in quanto soprattutto nelle procedure laparoscopiche più complesse che richiedono tempi operativi più lunghi e comprendono più di un quadrante addominale, un maggior comfort corrisponde ad un minore stress psico-fisico da parte del chirurgo.

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