An ergonomic evaluation of the surgeon's workstation in a public hospital operating room- "The laparoscopy case"

Une évaluation ergonomique du poste de chirurgien en salle d'opération dans un hôpital public « cas de la coelioscopie »

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Abstract:

Surgeons encounter significant professional constraints during operating room procedures, which not only affect their well-being but also compromise their health and potentially their performance. Surgeons are exposed to a multitude of occupational hazards, primarily represented by the risk of blood exposure accidents, biological hazards, chemical risks, psychosocial risks, and biomechanical stress. A study assessing surgeons' professional exposure to biomechanical limitations was carried out in a hospital located in the Algiers region. The aim of this investigation was to identify the current work environment and suggest appropriate enhancement strategies to maintain the well-being and security of the surgeons.

The study concentrated on the function of a surgeon utilizing the laparoscopic approach in the operating room. Utilizing the REBA (Rapid Entire Body Assessment) method, which is a tool for evaluating the risk of musculoskeletal disorders (MSDs) associated with biomechanical limitations, a study of the position was conducted.

The research measured biomechanical risks, particularly uncomfortable postures, repetitive movements, and physical exertion. Inadequate positioning of surgical screens often leads the operator to adopt uncomfortable postures, promoting muscle fatigue and the risk of MSDs. Non-ergonomic tool handles increase pressure on the hands, while working in a prolonged standing position contributes to lower back fatigue. The upper limb is subjected to higher strain when one's arms

are raised above the shoulders. The necessity for a set of guidelines for the ergonomic enhancement of the role was brought to light by this study.

Keywords: MSD; Biomechanics; REBA; Ergonomics; Laparoscopy.

Résumé :

Les chirurgiens rencontrent d'importantes contraintes professionnelles lors des interventions au bloc opératoire, affectant, non seulement, leur bien-être mais compromettant aussi leur santé et potentiellement leur performance. En effet, les chirurgiens sont exposés à une multitude de risques professionnels qui se manifestent principalement sous la forme de risques liés aux accidents d'exposition au sang, aux dangers biologiques, aux substances chimiques, aux risques psychosociaux et aux troubles biomécaniques. Une évaluation de l'exposition professionnelle aux contraintes biomécaniques, a été réalisée chez des chirurgiens d'un hôpital dans la région d'Alger. Les objectifs de cette étude étaient de dresser un diagnostic de la situation de travail et de suggérer des mesures d'amélioration appropriées afin de permettre de préserver la santé et la sécurité des chirurgiens.

L'étude a concerné le poste de chirurgien au bloc opératoire utilisant la technique de cœlioscopie. Cette étude a utilisé la méthode REBA (Rapid Entire Body Assessment), un outil d'évaluation des risques de troubles musculo-squelettiques liés aux contraintes biomécaniques, pour analyser un poste de travail spécifique.

La méthode REBA permet de quantifier les risques biomécaniques tels que les postures inconfortables, les mouvements répétitifs et les efforts physiques. L'analyse a notamment mis en évidence le positionnement inadéquat des écrans chirurgicaux conduit souvent l'opérateur à adopter des postures inconfortables, favorisant la fatigue musculaire et le risque de TMS. Les poignées d'outils non ergonomiques augmentent la pression sur les mains, tandis que le travail en position debout prolongée contribue à la fatigue du bas du dos. Les positions des bras soulevés au-dessus des épaules induisent des tensions accrues sur le membre supérieur. Cette étude a permis de souligner la nécessité d'émettre une liste de recommandations visant l'amélioration ergonomique du poste.

Mots-clés : TMS ; REBA ; biomécanique ; ergonomie ; coelioscopie.

1. Introduction

Laparoscopy is a surgical technique performed in the abdominal cavity of patients through small incisions and involves observing the surgery on a screen. It is associated with a reduction in hospital stay duration, earlier return to work, less pain, better aesthetics, and improved postoperative immune function (Fuchs, 2002; Nilsson et al., 2000).

However, laparoscopic staff members encounter additional physical and psychological limitations compared to their counterparts in open surgery (Alarcon & Berguer, 1996; Park et al., 2010; Schwaitzberg et al., 2009; Szeto et al., 2009). Larger and more numerous pieces of equipment are used during laparoscopic surgery, taking up more floor area and restricting range of motion and encouraging static postures (Alarcon & Berguer, 1996; Wauben et al., 2009). The technical and mechanical nature of the equipment causes significant additional restrictions, such as the loss of natural hand-eye coordination, haptic feedback and dexterity (Coles et al., 2011; Satava et al., 2001).

Studies indicate that several factors, including the design of the surgical tools, the height of the operating table, the usage of pedals, and the location of the primary screen, affect the surgeon's body posture during laparoscopic procedures (Berguer, 1998; Supe et al., 2010).

But there isn't much information on study findings in the area of laparoscopic tool ergonomics in the literature. However, they unequivocally highlight the issues in this field. Thus, the aim of this research was to examine and analyze the ergonomic hazards related to laparoscopic surgery. and its consequences on the health of surgeons.

2. **Material and Methods**

Our study focused on a population of surgeons practicing laparoscopy at a healthcare facility in the Eastern Algiers region. The study took place from November to December 2023. The ergonomic study, which integrated the REBA (Rapid Entire Body Assessment) tool into the observation approach, was accompanied by a self-administered questionnaire medical survey. (Hignett & McAtamney, 2000)

The "Nordic" questionnaire is a standardized tool used to screen for work-related musculoskeletal disorders (MSDs) (Kuorinka et al., 1987, 1994). The Nordic questionnaire can be used in an interview or as a self-administered tool with its closed-ended questions. The initial edition consists of three sections that are specifically targeted at the neck, shoulders, and lumbar spine, after a series of general inquiries. The purpose of the questionnaire was to respond to the following query: "Does the specified population have a musculoskeletal pathology? and if so, which region of the body does it affect?"

A representation of the body, originally categorized into nine distinct anatomical areas and viewed from the back, is included in the Nordic questionnaire. The query: "In the past year or the past week, have you experienced any health issues such as pain, discomfort, inconvenience, or numbness?" is asked for each anatomical region. These regions were, in the original version, those for which symptoms are most frequent. However, derived versions have been developed with additional questions regarding upper limb pathologies.

A simple way to evaluate ergonomic risks associated with work postures is to apply the REBA approach. It examines the entire body, considering the postures of the trunk, upper limbs, and lower limbs. This technique was created to quantify the degree to which workers are exposed to risk factors linked to MSDs by considering the biomechanical and postural demands that their jobs place on their entire body. Because the surgeon's work involves mobilizing all body segments to complete the numerous tasks that make up their activity, their choice of tool was dictated by this activity.

It was possible to evaluate different tasks and analyze the joint ranges of motion of distinct body segments by using video recordings of varied grip postures.

Interpretation of Results

Nordic Questionnaire

Socio-demographic data were interpreted by calculating the mean for quantitative variables and considering how frequently qualitative factors occur.

Rapid Entire Body Assessment, or REBA

The REBA tool makes it possible to calculate scores according to the various body segments' placements. The posture of the legs, trunk, and neck are examined in the first score (score A). The second score, or score B, examines how the wrists, elbows, and shoulders are positioned. The activity score makes up the third score.

After adding these scores together, a score between 1 and 15 is produced, with a score of "1" denoting minimal risk and suggests no action is necessary, while low risks (2-3) indicate that a change could be beneficial. Moderate risks (4-7) signal the need for caution and consideration of improvements.

High risks (8-10) highlight the need for substantial improvements, while a very high risk (+11) demands immediate intervention. It was determined by the most difficult positions, professional tasks, or the posture kept for the greatest amount of time.

3. **Results presentation and analysis**

3.1 Findings from the survey using the questionnaire

The distributed surveys received responses from every surgical practitioner (07). The majority of participating surgeons, with an average age of 49 years, were male (4 males, 3 females). The average height of surgeons was 171 cm, with an average weight of 81 kg, all being right-handed. In the scope of our study, 14.29% (01) of surgeons had between 5 and 10 years of experience, while 85.71% (06) had more than 10 years of experience. All surgeons practiced an average of 4 hours of laparoscopic surgery per week. All participants were in permanent employment, working full-time with regular schedules. The average working hours were 46 hours; all surgeons worked at least once a week for more than 10 hours per day.

All participants were queried about potential symptoms in the neck, shoulders, elbows, wrists, hands, back, hips, thighs, knees, ankles, or feet. All participating surgeons (07) experienced musculoskeletal problems related to laparoscopic surgery. Among surgeons, the neck and lower back accounted for the bulk of reported pain or discomfort (71.43%), with the upper back and both shoulders coming in second (57.14%), then both elbows (28.57%), in descending order. Other joint pains were also reported, as indicated in Table 1. To address these mentioned physical discomforts, surgeons received treatments (24.24%) such as massages, physiotherapy, ultrasound stimulation, and oral analgesics.

Table 1. Results of the Nordic questionnaire

	Yes	No	Total
Neck	5/7	2/7	7/7
Upper arm	5/7	2/7	7/7
lower arm	4/7	3/7	7/7
Wrist/hand	1/7	6/7	7/7
Upper back	4/7	3/7	7/7
Lower back	5/7	2/7	7/7
Hips/thighs	1/7	6/7	7/7
Knee	3/7	4/7	7/7
Ankle/feet	1/7	6/7	7/7

3.2 Ergonomic Analysis Results

3.2.1 Observation Results

According to the Algerian Classification of Activities (NAA), surgeons' activity falls under section Q, division 86, group 86.2 "Activities of Physicians and Dentists", class 86.22 "Specialist Medical Activities".

There is a single laparoscopy room equipped with necessary equipment, including a monitor, an operating table, a cabinet for material storage, as well as cauterization and insufflation systems under the surgeon's permanent supervision.

The floor is cluttered with electrical cables and tubing, thereby increasing the risk of workplace accidents. Lighting is exclusively artificial, with an unsatisfactory average general illumination level. The noise level varies between 20 and 45 dB due to the sound produced by foot switch usage and the alarm signalling the lack of gas used to maintain pneumoperitoneum.

The main surgeon's activity begins with reviewing the medical record. Subsequently, they disinfect their upper limbs in a room adjacent to the operating theatre. They don personal protective equipment (PPE) and then access the operating room by pushing the door with their foot while keeping their forearms flexed. The scrub nurse assists in donning the gown and gloves. Meanwhile, the lead surgeon marks the incision site before ensuring complete patient preparation, including checking the availability of necessary instruments.

In collaboration with the anaesthesiologist, the surgeon participates in sedating the patient, ensuring their secure unconscious state all through the intervention.

As directed by the surgeon, the scrub nurse adapts the operating table. Three tiny incisions are made to start the intervention once the table is at the patient's navel level, allowing trocar insertion with assisting surgeons in well-defined areas. They instruct the scrub nurses to readjust the operating table to a more declivitous position after they have reached the target location. In our case, the table is generally positioned at a different height from the surgeon's pubic line due to limitations in adjusting its height.

Indeed, before making the incision, it is essential to create pneumoperitoneum to inflate the abdomen, enhance visibility, and shift the bowels upward from the pelvic area.

The surgeon adheres to the established surgical protocol, tailored to the specific case, executing procedures with meticulous precision while maintaining unwavering visual focus on the monitoring apparatus. The screen is placed on equipment trolley, at one meter from the surgeon (recommended distance between 0.9 and 3 meters). It is situated at a height of approximately two meters above the floor, suggesting a sagittal plane extension of the surgeon's neck. Since it is frequently located on the surgeon's right side, the spinal column must be rotated axially. The surgeon views a low-resolution monocular video image of the operating field, which is frequently obstructed by the assistant's movements with the camera and the varying lighting within body cavities. Compared to direct binocular vision, surgeons spend more time carrying out different activities under such visual situations. This entails a two-dimensional vision and a protracted, limited static posture that causes a loss of physical contact with the operational field, impairing depth perception and complicating the procedure.

Endoscopic surgical instruments typically consist of an axial or pistol-style grip, a circular rod with a diameter of 5 to 12 mm that houses the actuation mechanism, and a double-action spinning tip that rotates to manipulate tissue. The instrument tip's internal movement is restricted to four degrees of freedom by the pivot point formed by the trocars that are implanted into the body wall. Instruments used in video endoscopic surgery have an unfavourable force transfer ratio from the handle to the tip and a markedly reduced tactile feedback as a result of their internal mechanical construction.

Further impairing the surgeon's capacity to sense tissue properties carefully is the nonlinear relationship between input and output forces demonstrated by laparoscopic devices. Overall, it has been shown that the same task may be completed with 4–6 times more force using video endoscopic surgery devices than open surgery instruments. The surgeon clutches the tools tighter as a result, which reduces the efficiency of the energy transmission from the handle to the tip. Surgeons may suffer from increased upper limb fatigue when using these less effective equipment, especially in the shoulder, elbow, wrist, and hand areas.

Through trocars affixed to the abdominal wall, laparoscopic instruments traverse, producing a paradoxical pivot effect in which the intracorporeal portion of the instrument rotates in the opposite direction from the surgeon's hand.

Uncomfortable working angles may arise from a surgeon's limited capacity to modify their body posture around the tools due to fixed trocar locations.

While bending around a patient who is extremely obese or has a thick abdominal wall, the surgeon's body could be put under dangerous strain.

Furthermore, the non-perpendicular placement of trocars between the skin and the peritoneal cavity requires excessive force on the instruments, which can lead to discomfort in the upper limbs. Most laparoscopic handles are fixed, and others include difficult-to-use locking mechanisms. Depending on hand size, several of these instruments require an excessive amount of force to open and close with the thumb.

Because instruments are not made to fit the surgeon's hand proportions, there may be discomfort, nerve compression, and restricted range of motion.

In addition to manipulating instruments, the surgeon is principally responsible of simultaneously activating foot control pedals for procedures including suction, irrigation, electrical cutting, and coagulation. The presence of pedals restricts space under the operating table, sometimes leading to constraints related to the height of required platforms. Therefore, the surgeon may find themselves performing precise surgical movements while standing on one foot, requiring intense concentration to avoid misuse of instruments and pedals during the operation. This not only results in biomechanical constraints but also increases mental workload, increasing the risk of musculoskeletal disorders.

Working closely with the surgical team, including nurses, technicians, and anesthesiologists, the surgeon ensures effective communication, especially with assisting surgeons, whose smooth coordination is paramount.

The surgeon often has to make crucial decisions in real-time, adapting the procedure based on unexpected findings or potential complications, requiring responsiveness and rapid judgment.

Most surgeons acknowledge that they become more tense and frustrated during complicated laparoscopies.

Once the procedure is completed, the surgeon meticulously sutures the incision, aiming to minimize scars and ensure optimal healing.

Data from video recordings of each participant's posture were analyzed using the REBA method to obtain the overall score.

3.2.2 REBA Tool Analysis Results

Analysis of different working postures during interventions was based on video recordings made by the investigator. Result tables summarize the value ranges for each limb and the overall REBA score of the participants.

3.2.2.1 Individual Results per Intervention

TABLE 2: REBA Results for group A

Body segment		Score
A. Neck, Trunk and Leg Analysis	Neck	1-2
	Trunk	1-2
	Leg	1-2
	Force/load score	1
B: Arms and Wrist Analysis	Upper arm	2-3
	Lower arm	2
	Wrist	2-3
	Coupling score	1-2
activity Score		1
REBA score		4-7

TABLE 3: REBA Results for group B

A. Neck, Trunk and Leg Analysis	Neck	1-3
	Trunk	1-4
	Leg	1-2
	Force/load score	1
B: Arms and Wrist Analysis	Upper arm	2-4
	Lower arm	2
	Wrist	1-3
	Coupling score	1-2
activity Score		1
REBA score		8-10

4. **Discussion:**

The goals outlined in this study have been made possible by the researchers' research approach. It facilitated diagnosing the work situation and proposing appropriate improvement measures that would help preserve the health and safety of laparoscopic surgeons.

The method of gathering medical information regarding MSD complaints through a validated international questionnaire provided insight into the health profile of participants regarding musculoskeletal disorders.

The ergonomic risks associated with laparoscopic surgery on surgeons' health were analyzed and evaluated using the

REBA method.

However, this methodology has certain limitations inherent in the subjective component in result analysis by the investigator and the self-administered questionnaire responses by participants, which could compromise the quality of the results.

A score of 1 to 3 was assigned to neck and trunk positions due to the height of the screen and the constraints on moving the operating table's positions in different directions do not allow adaptation to operators' sizes.

Surgeons made incisions and positioned trocars with the operating table set at the navel level, considered the optimal height for open surgery. Throughout the rest of the laparoscopic procedure, the majority of surgeons altered the operating table's height, positioning it at various levels different from the pubic-level setting, resulting in uncomfortable positions (arms spread, shoulders raised/flexed, wrists deviated towards the ulna), exposing them to biomechanical constraints with non-ergonomic and sustained positions for a considerable duration. This could partly explain the operators' complaints, which mainly consisted of MSDs in the neck, back, shoulders, arms, wrists, and hands (Koneczny, 2009). Indeed, 5 out of 7 operators experienced neck, shoulder, and lower back pain.

Van Veelen et al (2002) suggest that for laparoscopic surgery, the ideal table height should be between 0.7 and 0.8 times the distance from the floor to the elbow height of the surgeon. To make measuring each person's elbow height simpler, the recommended optimal location is at the pubic level (van Veelen et al., 2002), promoting a neutral posture for the surgeon. This configuration helps place laparoscopic instruments near the elbow, minimizing joint movements and discomfort in the arms and shoulders during the precise gestures required by such procedures.

The axial rotation of surgeons' spines in the horizontal plane would explain the back pain manifested by this population. The misalignment of monitors directly in front of surgeons forces them to adopt these poor working postures, thus accelerating the development of MSDs in this population.

The neck pain reported by 5 out of 7 surgeons would, in part, be related to the screens not aligning with their eye level. This screen positioning forces an extension of the operator's neck in the sagittal plane.

A REBA score between 1 and 2 was assigned to leg position. The use of switches requiring monopodial support was the reason for this evaluation.

The repetition of tasks and actions supported the effort and load score of 1.

For arm position, the score ranged from 2 to 4 depending on the degree of flexion. During the procedure, participants flexed their upper arms between 20° and 50°, with the upper arms often in abduction. In this study, most of the time, the lower arm was flexed between 60° and 95°.

Wrist position was scored between 1 and 3, as there was excessive flexion, extension, and torsion of the wrist (i.e., greater than ±15°) when manipulating scissors and forceps during the procedure. This could be due to the limited space for the laparoscopic device, requiring surgeons to excessively move their wrists.

The ease of gripping score ranged from 1 to 2 as the grip is acceptable to possible.

It was observed that equipment and tools with sharp edges and high-pressure contact areas were being used. When an instrument lacks ratchets, trigger locks, or other characteristics that reduce the need for constant gripping and squeezing, as well as the inefficient use of force grip on instruments, exacerbates the risk of MSDs in this professional category.

Furthermore, since all laparoscopic surgeries are performed while surgeons stand statically for more than 20 minutes, the activity score was 1. Prolonged standing has been linked to a number of potentially dangerous health conditions, including discomfort, weariness, cardiovascular difficulties, lower back and leg pain, and exhaustion.(Waters & Dick, 2015).

This result is consistent with previous studies concluding that performing laparoscopy places strain on various muscle groups and often requires surgeons to adopt non-ergonomic and uncomfortable postures (Berguer et al., 1999; Uhrich et al., 2002).

After adding up all the scores, an overall REBA score between 4 and 7 was obtained for all participants. This score indicates the need to implement a prevention strategy and improvement measures to preserve the health and safety of operators.

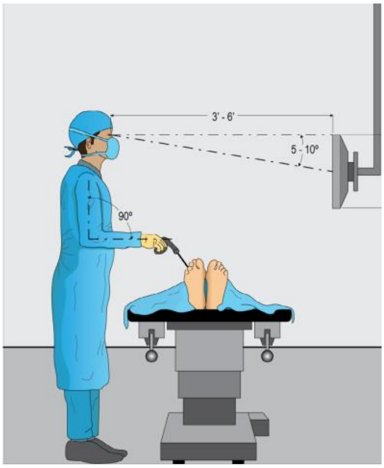

Figure 1 Monitor placement and table height for laparoscopy (American College, 2022)

The results of this study confirm the non-ergonomic design of laparoscopic instruments in the operating room, particularly their installation and positioning within the room. This positioning is associated with work postures that do not adhere to the comfortable angles of different joints, thereby accelerating the development of MSDs among operators. The constrained work postures maintained during the surgical procedure are associated with higher wrist flexion and torsion, flexion of the upper limbs, and an increased risk of MSD development.

5. **Recommendations**

Following this study, improvement recommendations based on identified dysfunctions have been formulated. They mostly cover the requirement to:

- Make improvements to the table's height adjustment to better accommodate surgeons' statures and ensure that different body segments are positioned comfortably, particularly the neck, trunk, shoulders, upper limbs, and lower limbs (figure 1).

- Provide platforms when there are differences in surgeons' heights to ensure ergonomic comfort for all team members by adjusting the table height to accommodate the tallest surgeon's level.

- Put the display monitor squarely in front of the user, with the center of the screen just below eye level and the top border of the screen at eye level, in order to preserve a neutral cervical posture (figure 1).

- - Consider the work and the characteristics of the operator when choosing the size and form of the instruments.

- Incorporate ergonomic switching devices that do not require monopodial support, thus reducing pressure on a single part of the body.

- Propose task rotation techniques among surgeons to diversify arm positions and allow for positional changes.

- Design instruments with ergonomic handles to minimize excessive wrist bending.

- Provide a variety of instruments suited for different tasks, thereby reducing the need for wrist twisting and extension.

- Integrate locking mechanisms, ratchets, or other features on instruments to minimize the need for prolonged gripping.

- Educate surgeons on the importance of proper grip strength to avoid excessive pressure on contact areas (figure 2).

- Introduce adjustable sit/stand workstations to allow surgeons to vary their posture during procedures.

- Encourage short breaks to relieve fatigue from prolonged static standing and to prevent repetitive motions.

- Implement a storage system for equipment and various cables to reduce the risk of workplace accidents.

- Ensure sufficient lighting in surgical environments to improve task visibility.

- Implement adjustable lighting systems to adapt brightness and orientation according to individual needs.

- Ensure strong brightness of the surgical field during incision using two or more surgical lamps at different angles.

- Prefer flat screens and high-definition televisions (HDTV) with increased brightness and detailed images to enhance visual quality in the operating room (Brown et al., 2003; Szold, 2005).

- Promote and encourage the sharing of surgeons' expertise within the team.

- Identify the best ergonomic practices and ensure their dissemination and transmission to new generations and within the team.

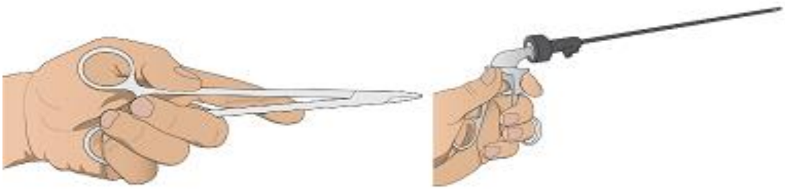

Figure 2. open and lap grip (American College, 2022)

6. Conclusion:

The risk of musculoskeletal disorders among laparoscopic surgeons is a scientifically accepted reality. Our study has identified the biomechanical constraints connected to the design of some items that require for ergonomic adjustments and the significance of the practitioner's experience in reducing some constraints through the application of acquired knowledge and the adoption of procedures offering better comfort to the surgeon, thus preserving their health. It would be desirable to conduct ergonomic studies comparing laparoscopic surgery to innovative new surgical procedures and to consider their ergonomic design from the outset.

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