The New Ropanasuri Journal of Surgery

Volume 7 | Number 1 Article 3

6-23-2022

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Recommended Citation

Prasetyono, Theddeus OH; Andrian, Christopher R.; and Kinanthi, Elisabet LA (2022) "Risk of Upper Extremity Musculoskeletal Injury in Laparoscopy Training," *The New Ropanasuri Journal of Surgery*: Vol. 7: No. 1, Article 3.
DOI: 10.7454/nrjs.v7i1.1125
Available at: https://scholarhub.ui.ac.id/nrjs/vol7/iss1/3

The New Ropanasuri Journal of Surgery
OPEN ACCESS
Published by Department of Surgery
Faculty of Medicine, Universitas Indonesia

Risk of Upper Extremity Musculoskeletal Injury in Laparoscopy Training

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Corresponding author: theddeus.h@ui.ac.id Received: 27/Apr/2022 Accepted: 17/May/2022 Published: 23/Jun/2022
Website: https://scholarhub.ui.ac.id/nrjs/ DOI:10.7454/nrjs.v7i1.1125

Abstract

Introduction. The laparoscopy procedure still has an ergonomic burden that can increase the risk of musculoskeletal injury, especially in the upper extremity. Furthermore, the risk is compounded in laparoscopic training as the trainees have to repeat the same movements many times to achieve competencies. This study revealed the relation between the position and the risk of musculoskeletal injury in laparoscopy training.
Methods. A cross-sectional study on nine subjects was conducted during laparoscopy training. By fixing the table height at 77 cm, we measured the operator height and upper extremity positions to relate them to their VAS and DASH scores.
Results. The overall ratio of table height to subject height was <0.49. All subjects showed their wrist- deviation axis and flexion beyond the neutral zone while performing the tasks. Although the score stayed low, 7 out of 9 subjects experienced increased VAS after the training tasks. No subject had a significant DASH score.
Conclusions. There is a risk of upper extremity musculoskeletal injury without disabilities. The pain produced by laparoscopy activity has shown to be mild and needs no medication. The wrist position is considered the highest risk of initiating the upper extremity injury.

Keywords: hand; human engineering; laparoscopy; wrist

Introduction

Laparoscopy surgery is part of minimally invasive surgery methods which use optical technology and special instrumentation to gain access and perform the surgery inside the abdomen.[1,2] Laparoscopy has many benefits compared to open surgery for the patient, such as less operative pain, short and painless recovery, shorter hospital stay, and improved cosmetic results.[1,3,8,16] Gynaecology Laparoscopy in Indonesia has progressed rapidly over the last 30 years.[1,3] In 2013, 600 obstetric and gynecologist specialists in Indonesia performed laparoscopy for the therapeutic and diagnostic procedure.[3]
Despite its superiority, laparoscopic surgery presents some ergonomic difficulties for surgeons across multiple surgical specialties.[17] The long instrumentation, narrow operation field, and detached hand-eye coordination make a simple task more difficult.[1,4] Furthermore, during laparoscopic procedures, surgeons must adopt static body postures and perform repetitively and force exertion from the adverse position.[18] One study reported a musculoskeletal disorder (MSD) prevalence rate of 73-88% in minimally invasive surgery.[18] This preliminary study aims to discover the risk of musculoskeletal injury of the upper extremity while performing laparoscopy in training sessions.

Methods

A cross-sectional study was carried out in ICTEC (Indonesian Clinical Training and Education Center), Cipto Mangunkusumo Hospital/ Faculty of Medicine, Universitas Indonesia. The subjects are fellows in gynecology-oncology training and already have previous experience as an operator or assistants in laparoscopic surgery. They were enrolled by a convenient sampling method. Subjects who already have musculoskeletal pain or a history of upper extremity surgery are excluded.

Before the training, subjects were given a brief lecture about the ergonomic position in laparoscopic procedure and their height measured. The two-level stepladder was provided to allow the subjects to adjust their position. (Figure 1) Level 1 height was 12 cm, while level 2 height was 32 cm. Total subject height is the subject's height added by the height level of the stepladder they used. The table height was fixed at 77 cm from the floor, while the pelvic trainer (the abdominal-like model) height was 22 cm from the table surface and had a nine entrance port position. The table height to subject height is the ratio between table height and total subject height.

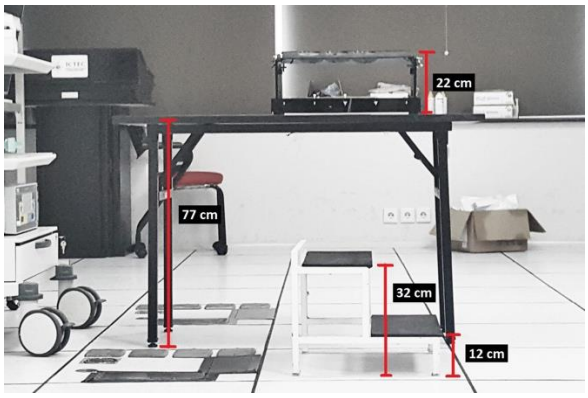

Figure 1. Laparoscopic table training. The table height is fixed at 77cm; a two-level step ladder is set at a total height of 32 cm with 12 cm at its lower level, and the pelvic trainer is 22cm from the table surface. The pelvic trainer height was excluded in the calculation of the ratio of table height to subject height.

The data collected during laparoscopic training was when the subjects were given the task of performing dissection of the artery of the chicken thigh and suturing in vagina-like 'plas chamois' models with pistol and shank handle instruments. While performing the task, photos of the shoulders in P.A. (posteroanterior) view, lateral view of elbows, and sagittal and lateral views of the wrists were taken. These photos were taken at the most extreme position of the joint. Then, the angle of those joint images was measured using the mobile android application PROTRACTOR® (Android Pandaz – Seoul, South Korea). The angles that were taken are (1) shoulder abduction angle, as seen in Figure 2; (2) elbow flexion angle, as indicated in Figure 3; (3) wrist angles to see wrist flexion and deviation (Figure 4). First, we drew the lines adjacent to the measured part of the extremity that produced the various angles, i.e., shoulder abduction angle, elbow angle, and wrist angles. Later, the full angles were compared with the Van Veelen neutral zone of the upper extremity joint to measure the possible risk.

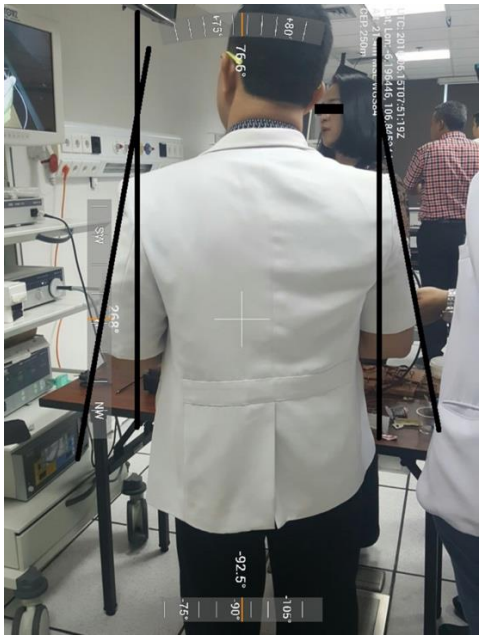

Figure 2. Shoulder abduction angle. In measuring the angle of shoulder abduction, a true vertical line was drawn adjacent to the line that the axis of the humerus was made, as shown by the black lines.

Figure 3. Elbow flexion angle. A line following the forearm axis was drawn, crossing the vertical line, following the axis of the humerus to form the elbow flexion angle.

The line made wrist flexion angles following the axis of the forearm, which draw ahead of the lateral epicondyle, and the line following the axis of the 3rd metacarpal of the hand. The line made wrist deviations following the axis of the forearm and the line following the axis of the 3rd metacarpal of the hand. This measurement method is an improvement from the previous study, which used two lines following the tip of the skin of the forearm and the hand to create an angle[9]. Using the bone axis, we could measure the joint angle without being compromised by the thickness of the fat tissue.

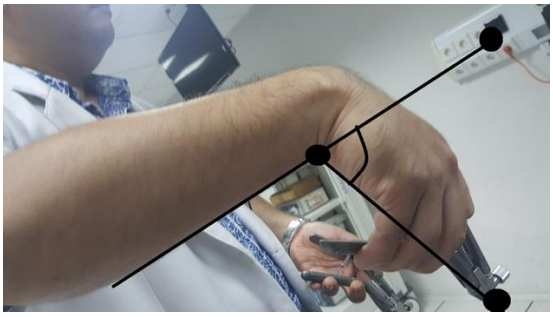

Figure 4. Wrist angles. Two wrist angles were measured i.e., (A) wrist flexion, which was measured in the dorso-palmar angle, and (B) ulnar deviation, which was measured in the radio-ulnar plane.

The risk of musculoskeletal injury was measured using VAS (visual analog scale) and DASH (disability of the arm, shoulder, and hand). Subjects recorded their VAS before and after the training. VAS is a measurement that consists of a continuous line of 100 mm where zero represents no pain, and ten is the worst pain ever expressed subjectively by the subjects.[11,12] DASH score is a questionnaire consisting of 38 questions regarding the degree of functionality of the upper extremity.[13]

Results

Characteristics

All characteristics of the subjects are shown in Table 1. There were eight male subjects, and only one subject was female. They are Obstetrics & Gynaecology specialist doctors trained to be a consultant. All of the subjects had experience doing laparoscopy training as operators or assistants. The duration of the subjects being operators or assistants or taking rest varied among them as there was no rule to manage each participant's role. The subjects could perform as operators, camera assistants, or take rest at will.

Table 1. Subjects' characteristics

Characteristics	
Subjects	
– Male (n)	8
– Female (n)	1
Total	9
Age (in years), mean ± SD	38.5 (33–42)
Body height (in centimeters) (without step ladder), mean ± SD	164 (154–172)
Duration of operator (in minutes), mean ± SD	28.9 ± 1.36
Duration of assistant (in minutes), mean ± SD	27.1 ± 2.07
Duration of rest (in minutes), mean ± SD	8.7 ± 5.23

The ratio of table height to subject height

Table 2 shows the height of each subject added by their own chosen stepladder height and the ratio of table height to subject height. In the study,

Table 2. Ratio of subject height and table height

Subjects	Height (using step ladder)	Ratio of table height to subject height
A	164 cm	0.47
B	186 cm	0.41
C	182 cm	0.42
D	179 cm	0.43
E	177 cm	0.44
F	174 cm	0.44
G	184 cm	0.42
H	176 cm	0.44
I	172 cm	0.45

the ratio of the table height to subject height was 0.41 at the lowest, and the highest ratio was 0.47, with a mean ratio of 0.43, which is slightly lower than the ratio proposed in other studies.[9,20]

The angle of upper extremities

In table 3, most subjects had shoulder position in the neutral zone while doing laparoscopy, with only two subjects having shoulder abduction angles of 40,3º and 35.7º. Moreover, most of them had a neutral axis in elbow flexion, with only two subjects having 130.2º and 131.4º elbow flexion. Nonetheless, all subjects had a greater risk of musculoskeletal injury because of wrist deviation and flexion position. For example, in ulnar-radial deviation, most of the subjects' right hands are outside the neutral zone, with only three of the left hand being outside the neutral zone. Unfortunately, there are only two of the dorso-palmar flexion angles inside the neutral zone.

Table 3. Angle of Upper Extremities

Subjects	Angle (degree)							
	Shoulder Abduction		Elbow Flexion		Ulnar-radial Deviation		Dorso-palmar flexion	
	Right	Left	Right	Left	Right	Left	Right	Left
A	21.1	20	76.5	67.2	27.7*	12.3	43.3*	23.1*
B	40.3*	5.9	109.4	118.7	33*	10.6	63.2*	30*
C	18	16.1	125.1	130.2*	29.9*	47.7*	37.1*	48*
D	6.6	7.5	84.4	84.9	23.7*	5.5	24.3*	44*
E	13.4	13.8	53.2	49.7	37*	22.3*	12.4	50.3*
F	35.7*	13.5	128.6	131.4*	24.1*	3.4	21.3*	13.8
G	11.4	9.4	90.3	93.3	5.1	16.5*	58.9*	49.3*
H	8.5	8.5	112.3	76.7	1.3	3.7	56.9*	31.3*
I	4.6	16.7	93.7	98.7	12.3	-7.8	43.9*	44*

Pain and disability of upper extremities

Seven of nine respondents felt the increasing pain after laparoscopy, as shown by the inclined VAS score. In contrast, one respondent felt no change in pain, and another respondent had a decreased pain score, as seen in Figures 5 & 6. Most of the respondents had no disability in using upper extremities with their experiences in laparoscopy shown by the DASH score (Figure 6). Based on the result, the VAS score changed in 7 subjects. However, the VAS score stayed low (≤ 40). No subject had a significant DASH score.

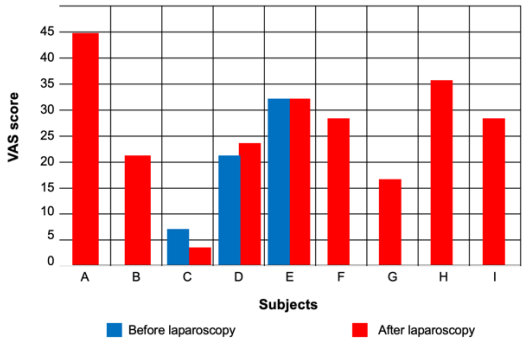

Figure 1. VAS before and after laparoscopy. This figure shows that 7 subjects experienced in increased pain intensity while the other two rather felt no change at all or decreased pain intensity.

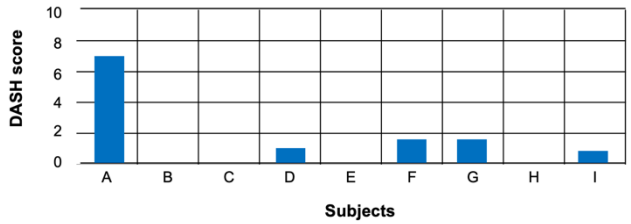

Figure 2. DASH Score. This figure shows all subjects had low score and considered no disability.

Discussion

In this study, we distributed the VAS and DASH score questioners to measure the risk of upper extremity musculoskeletal. The pain intensity increased in 7 subjects after the laparoscopy activity, with one subject having the same pain intensity before and after the training; one subject had a decreased VAS. The results reveal a prevalence of 78% in trainees practicing in this study. However, the pain has shown to be mild. The increased pain intensity was considered the result of upper extremities' position that was not in the neutral zone, particularly the wrist. In addition, only one subject whose upper extremities were furthest from the neutral zone had the highest DASH score amongst the others (6,67 of 100). Subjects from Obstetric and Gynecologic Laparoscopy Training were chosen to accentuate the procedure's ergonomics strain. First, the subject had not adapted to the laparoscopy ergonomics. Second, each subject was expected to do the same procedure around the same time. Third, the subjects' experiences did not differ to provide homogenous results.

The prevalence in our study is similar to other prevalence from another study. For instance, 26 articles reported MSD prevalence of an average of 74% in minimally invasive abdominal surgery. In the upper extremity, shoulder with 51%, hands with 33% prevalence.[18] In the study conducted by Berguer et al., 8-12% of surgeons complained about pain in the upper extremity after laparoscopic surgery.[1] Another study stated the percentage of surgeons reporting MSD was 90% in at least one part of their body, with the lower back being the most common (54-57%), followed by the neck (46-51%), upper back (44%), lower limbs (42%), right shoulder (29-33%) and right hand (28-30%).[19] This problem raises another issue, such as decreased surgical practice (reduced caseload) and sick leave, even though surgeons tend to accept pain as a natural consequence of their work.[18,19] This risk of musculoskeletal injury is becoming more prominent in laparoscopic training as the surgeon residents/trainees have to repeat the same movements many times.

Ergonomic in laparoscopy is one of the important aspects when performing the procedure.[1] Ergonomic guideline in laparoscopic surgery has been studied for a long time.[1,5–8] Table height, the position of the monitor, and laparoscopic instruments, age, and sex contribute to the ergonomic aspects of body positions in laparoscopy, mainly at the upper extremities such as shoulders, elbows, and wrists. Table height has to be proportional to the operator's height to determine the elbow position.[9] Several instruments that differ in length and shape of the handle will impact the wrists' and fingers' position.[7] The monitor position has nothing to do with the upper extremities other than the neck position.[10,14] Different ages and experiences also contribute to MSD while the studies contradict each other.[18,19] Female surgeons are more prone to the risk of musculoskeletal injury. This is caused by the difference in muscle mass and hand size compared to a male surgeon.[19] One previous study has shown that most surgeons (66%) complained about the pain in the arm or shoulder associated with laparoscopic surgery, although the ergonomic guideline had been applied.[5]

An optimal ergonomic position should be applied to minimize musculoskeletal injury risk in laparoscopy. The laparoscopic table has to be maintained so that the elbow angle is between 90º-120º.[1,20] Studies suggest that the table height should be 0,49 times the operator's height.[9] Another study state that table height is -0.199+0.45x operator height(cm).[20] Monitor should be placed as in line as possible with the eye of the operator, so the neck is flexed approximately 15º-45º.[1,10] To achieve an ergonomic operating position, it is highly recommended to maintain the neutral position while performing laparoscopic surgery.

Van Veelen describes the neutral position zone of the upper extremity are shoulder abduction and adduction as less than 30º, elbow flexion between 30º to 130º, and wrist movements including ulnar-radial deviation palmar-dorso flexion should be less than 15º.[9]

Almost all of the subject's shoulder positions in this study were in the neutral zone, with one side of two subjects being slightly above normal. The type of procedure might cause this result in training (tissue dissection and suturing). The instruments we used in this study were a shank and pistol handle to dissect and suture the tissue dummy. These instruments naturally allow ulnar deviation and flexion of the wrists while manipulating the movement.[4,5] The subjects were allowed to select which port to insert the instruments.

Interestingly, we discovered that most wrist movements were exceptionally not in the neutral zone, especially the dorso-palmar flexion of the wrist. It also indicates that the ratio of table-subject height affects elbow angle and wrist movement. Another study has demonstrated that forced deviation of the wrist away from the neutral position may increase the risk of musculoskeletal injury. It will decrease the efficiency of the used muscle, increase carpal tunnel pressure and eventually result in fatigue and discomfort.[4] Yet, our study showed no functional impact based on VAS and DASH evaluation.

There were several limitations in this study. First is that the duration of training varied among subjects. We did not regulate the instruction to arrange an equal duration of training and rest. Thus the subjects were allowed to rest or continue practicing based on each call. Secondly, the height of the table could not be adjusted besides using a stepladder for the operator. Thirdly, the subjects in this study were less than the appropriate number to investigate the association between ergonomic positions and the risk of musculoskeletal injury.

Conclusions

Risk of upper extremity musculoskeletal injury without any disabilities in laparoscopy training. The pain produced by laparoscopy activity has shown to be mild and needs no medication. The wrist position is considered the highest risk of upper extremities injury. This preliminary study concluded that best ergonomic practice is not applied in laparoscopy training and most likely increases the chance of injury in the upper extremities. Table height and instrument handle design contribute most to laparoscopy surgery's ergonomics. Further studies are needed to compare the position and musculoskeletal injury in laparoscopy training.

Disclosure

The authors declare no conflict of interest. There was no funding provided for this work. None of the authors have a commercial interest in any product mentioned in this article.

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