Notable Grand Rounds
of the
Michael & Marian Ilitch Department of Surgery

Wayne State University
School of Medicine

Detroit, Michigan, USA

Ashley Malach, MD

"BACK" TO BASICS: ERGONOMICS AND THE OR

June 8, 2022

About Notable Grand Rounds

These assembled papers are edited transcripts of didactic lectures given by mainly senior residents, but also some distinguished attending and guests, at the Grand Rounds of the Michael and Marian Ilitch Department of Surgery at the Wayne State University School of Medicine.

Every week, approximately 50 faculty attending surgeons and surgical residents meet to conduct postmortems on cases that did not go well. That “Mortality and Morbidity” conference is followed immediately by Grand Rounds.

This collection is not intended as a scholarly journal, but in a significant way it is a peer reviewed publication by virtue of the fact that every presentation is examined in great detail by those 50 or so surgeons.

It serves to honor the presenters for their effort, to potentially serve as first draft for an article for submission to a medical journal, to let residents and potential residents see the high standard achieved by their peers and expected of them, and by no means least, to contribute to better patient care.

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"Back" to Basics: Ergonomics and the OR

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This paper is based on Dr. Malach's Surgical Grand Rounds presentation on June 8, 2022 at the Wayne State University School of Medicine.

Objectives

This paper defines ergonomics and discusses why it is important to surgeons as they operate in the OR using various operative approaches. It suggests how to improve overall ergonomic health in surgeons and discusses ergonomic training as part of the surgery curriculum.

The word *ergonomics* stems from the Greek words *ergon,* meaning work, and *nomos,* meaning natural laws or arrangements. Ergonomics is the study of people and efficiency in the working environment. It uses anatomy, physiology, psychology, and engineering to create a favorable environment that mitigates musculoskeletal complaints and optimizes performance and efficiency.

Figure 1 is the result of a Google image search for "ergonomics in the workplace." Most of the images show a desk or seated type of job. Why is ergonomics important to surgeons, who rarely sit at a desk? Their work environment and conditions have been described as similar to (if not worse than) certain industrial workers. As many as 80% of surgeons have reported experiencing pain, most often in the neck, back, shoulders and arms, when operating. In addition, 40% of surgeons have experienced one or more muscu-

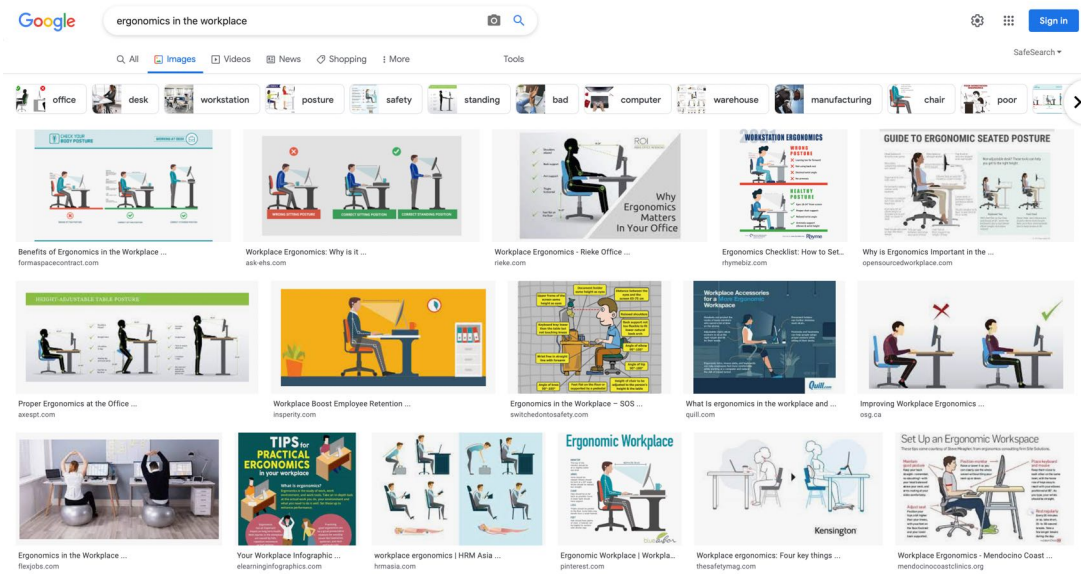

Fig. 1. Google view of workplace ergonomics

loskeletal injuries in the workplace during their career.

A 2018 review of the literature on surgeons' ergonomics and work-related musculoskeletal disorders[1] found that 66–94% of surgeons had a musculoskeletal injury or symptoms with open surgery; 73–100% during laparoscopic; and 23–80% during robotic surgery. Risk factors for open surgery included wearing loupes and headlamps. During laparoscopic surgery, risk factors included table and monitor positioning, long-shafted instruments, and poor instrument handle design.

Clearly, work-related musculoskeletal injuries are common among surgeons and across all types of operations. They result in missed work, reduced number of operations, and ultimately shortened careers. As well, the cost of medical treatment for occupational related injuries is over $100 billion annually.

Some studies have reported that only 20% of surgeons report their injuries; however, as Wohl and Hubbard have pointed out, surgeons "like a professional athlete… simply often choose to 'play through the pain.'"[2] The mentality of continuing to work and operate through the pain is not only harmful to the surgeon but can be detrimental to patients as well.

In sum, a lack of ergonomic training and lack of healthier ergonomics practice in the OR leads to discomfort and pain for the surgeon but also results in fatigue and can affect surgical speed, stamina and concentration.

Operative Approaches and Ergonomics

The three main approaches to surgery are open, laparoscopic, and robotic.

Open surgery requires long periods of standing, often in awkward body positions. Sometimes the surgeon must exert substantial force when retracting tissues. The surgeon's common posture is head and back bent forward, torso twisted. As well, open surgery generally requires more dynamic movement, which can lead to fatigue and disability. Ultimately, performing open surgery puts surgeons at risk for neck and back and lower back injury.

Meltzer et al assessed ergonomic risk amongst surgeons.[3] Fifty-three surgeons conducting a total of 115 cases wore sensors on their head, torso, and arms to measure deviations from standard neutral body positions. The study found that during open procedures surgeons averaged 65% of the operative time in a high-risk neck position, 30% in a high-risk torso position, and 11% in a high-risk shoulder position. It also reported that surgeons spent more time in these high risk neck positions during an open procedure compared to laparoscopic.

The study broke out the surgeons by specialty (**Table 1**, p. 5). Cardiothoracic surgeons averaged 52.7% of operative time in high-risk neck positions and 20% for the torso. General surgeons were higher at 59.6% for neck and 28.7% for torso. Vascular was even higher, at 71.5% for neck.

Errors in Ergonomic Posture

There are three common errors in ergonomic posture during open procedures.

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[1] Catanzarite, T, J Tan-Kim, EL Whitcomb, and S Menefee. Ergonomics in Surgery: A Review." *Female Pelvic Med Reconstr Surg*. Jan/Feb 2018;24(1):1-12. doi: 10.1097/SPV.0000000000000456. PMID: 28914699

[2] Wohl, DL, and T Hubbard. *Bulletin of the American Academy of Otolaryngology–Head and Neck Surgery* April 2019 – Vol. 38, No. 3.

[3] Meltzer, Andrew J et al. "Measuring Ergonomic Risk in Operating Surgeons by Using Wearable Technology." *JAMA surgery* vol. 155,5 (2020): 444-446. doi:10.1001/jamasurg.2019.6384

Surgical Specialty	Total Cases, No. (%)	Mean (SD) Time in High-Risk Position, %			
		Neck	Torso	Right Shoulder	Left Shoulder
Cardiothoracic	4 (3.5)	52.7 (32.0)	20.6 (26.9)	9.2 (9.2)	6.7 (7.1)
Colorectal	11 (9.6)	50.9 (18.5)	26.5 (17.5)	6.3 (3.2)	4.1 (4.8)
General	25 (21.7)	59.6 (28.8)	28.7 (22.5)	9 (15.1)	7.2 (12.5)
Gynecologic	10 (8.7)	61 (29.7)	32.1 (27.7)	13.2 (10.4)	5.4 (4.1)
Head and neck	6 (4.4)	77.6 (19.1)	25.7 (5.5)	9.3 (4.9)	6.1 (6.1)
Hepatobiliary	8 (7)	78.4 (27.1)	34 (15.6)	15.6 (17.4)	6.7 (11.9)
Neurosurgery	5 (4.4)	60.4 (27.7)	47.2 (35.0)	14.9 (10.8)	4.6 (4.4)
Orthopedic	7 (6.1)	69.1 (11.7)	50 (25.7)	13 (7.1)	8.2 (2.2)
Plastic	3 (2.6)	85.4 (9.8)	31.4 (25.1)	9.7 (4.8)	4.7 (0.8)
Urology	11 (9.6)	56.3 (23.1)	21 (25.0)	10.8 (14.7)	6.4 (5.1)
Vascular	25 (21.7)	71.5 (25.2)	28.2 (21.2)	7.3 (7.6)	5.4 (9.0)

Table 1. High-risk position time by surgical specialty.
Source: See footnote 3.

The first one is excessive forward head position: For every inch the head moves forward in space, it adds 10 pounds to the spine and can lead in the long term to degenerative disk changes in the cervical spine and also degenerative disease in the shoulder girdle. (**A** in **Figure 2**)

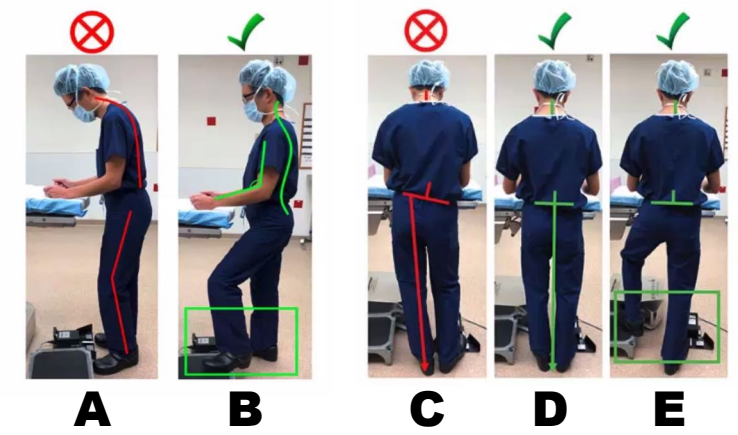

Fig. 2. Posture
Source: See footnote 2**.**

The second most common error is a sustained awkward torso position, and the third (also illustrated in **Figure 2**) is perhaps the most common: Asymmetrical weight bearing, which causes back and hip problems. Asymmetry in the weight on the feet (**C** in **Figure 2**) results in a non-neutral spine and the pelvis is tilted as well. In **D** and **E** the spine is straight and the pelvic lines are straight. It is okay to stand on a step as long as the pelvic line and spine are aligned.

Figure 3 shows pictures taken in an OR, with red circles indicating poor ergonomic positions. Correcting standing posture alone may not decrease the risk of injury. Other factors play into healthy surgical ergonomics.

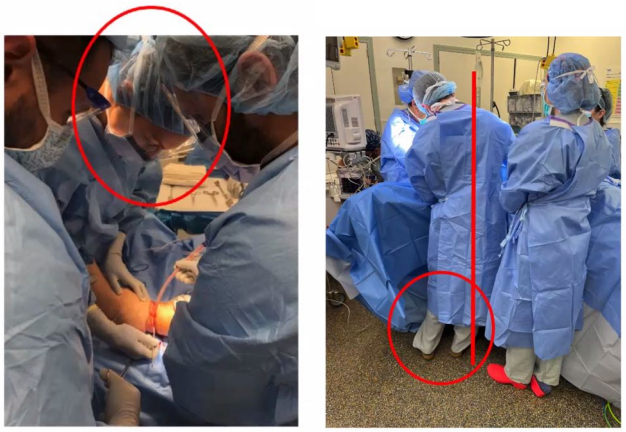

Fig. 3. Bad postures

Loupes and Headlamps

Loupes and headlamps help in the operating room, but they can cause harm. One study [REF] showed that both loupes and headlamps were associated with an increased time spent in an unfavorable neck position. **Figure 4** details the risk and shows the correct and incorrect angles for using them.

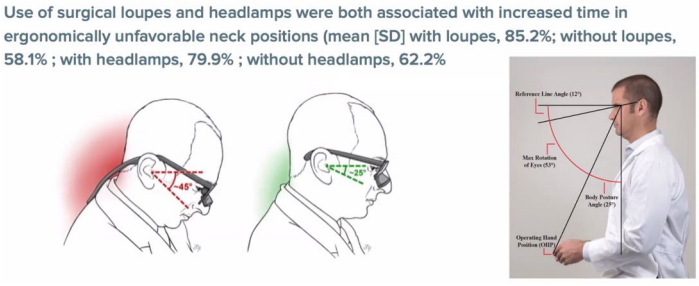

Fig. 4. Loupe and headlamp positioning
Source: LEFT: https://surgery.duke.edu/news/duke-surgery-introduces-ergonomics-program-improve-surgeon-health
RIGHT: https://www.surgitel.com/key-factors-for-ordering-custom-loupes-part-1-declination-angle-as-the-key-ergonomic-factor/

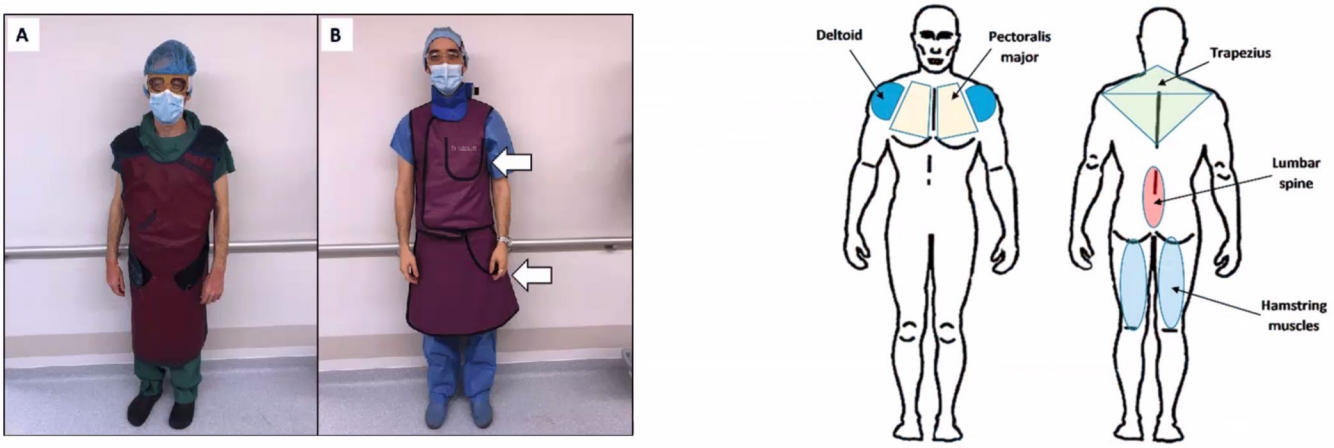

Fig. 5. Lead aprons and their ergonomic effects

Lead Aprons

Lead aprons that protect against radiation can also cause musculoskeletal strain. Two-piece aprons are better than one-piece aprons at distributing the weight across the shoulders and the waist. A study that looked at muscle fatigue while wearing lead aprons found fatigue in the deltoids, the pectorals, the trapezoids, and the lower back and legs (**Figure 5**).

Laparoscopic Surgery

Laparoscopic surgery allows the surgeon to be in an upright position without leaning forward over the incision. **Figure 6** shows proper ergonomic positioning during laparoscopy. Table height, should be set at 66 to 77 centimeters above the floor depending on the surgeon's height, with the monitor positioned in line of sight and such that the neck is not flexed forward more than 25 degrees. The shoulders should be slightly retroverted, and the arms and elbows should be bent between 90 and 120 degrees and slightly abducted.

Laparoscopy appear superior, ergonomically, to open surgery, but it does have its limitations, including the fulcrum effect, a lack of articulating instruments, and a more static position. A study

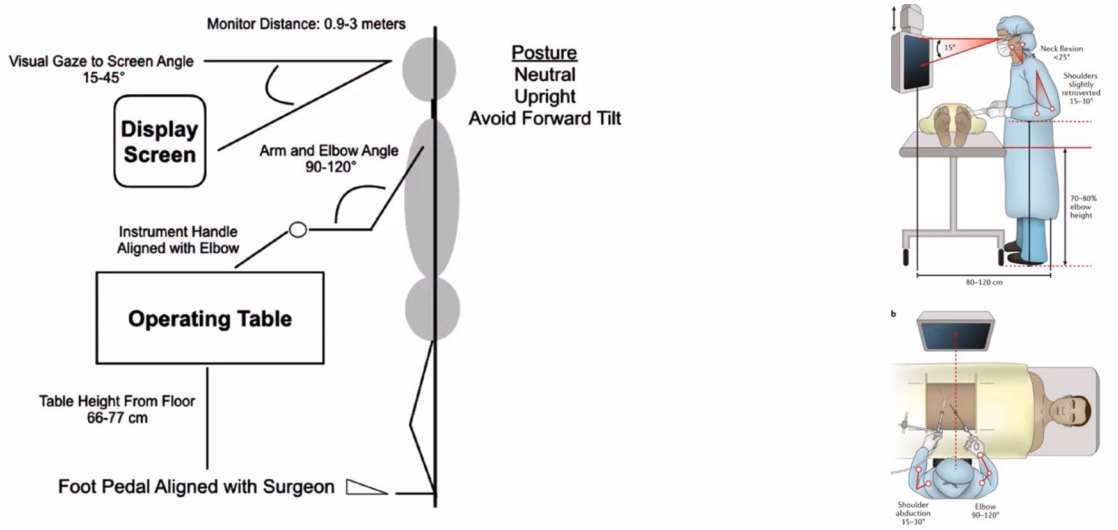

Fig. 6. Ergonomics of Laparoscopic Surgery
Source: Meltzer, Andrew J, and Susan Hallbeck. "Measuring ergonomic risk in operating surgeons by using wearable technology." JAMA Surg. 2020; 155(5):444-446

to find out whether laparoscopy causes less ergonomic strain than open surgery[4] measured upper body muscle activation during laparoscopic and open portions of five sigmoid colectomies conducted by a single surgeon. The study authors had hypothesized that laparoscopic caused more ergonomic strain, but they found that there was an ergonomic benefit to several upper body muscles during the laparoscopic portions.

Is laparoscopic surgery really better than open surgery, from the ergonomic perspective? The Catanzarite et al. study (see footnote 1) reported that laparoscopic surgery resulted in 73–100% musculoskeletal injuries among surgeons compared to 66–94% for open surgery. So what's causing musculoskeletal symptoms during laparoscopic surgery?

During laparoscopic surgery, the surgeon's neck is often rotated, looking at a screen that is often not positioned in the direct line of sight. The upper extremities are also often in awkward postures, the arms placed in a continuous abducted position internally rotated. There is often an asymmetrical loading between the surgeon's dominant and non dominant shoulders.

As well, laparoscopic surgery requires repetitive motion in inserting and taking out the instruments, which is harmful to the joints. And compared to open surgery, it's a more static position, which leads to a build-up of lactic acid in the muscles.

In **Figure 7A**, the surgeon's elbows are bent too much. Wrists are at an awkward angle and head is bent forward. 7B reveals asymmetrical loading between the dominant and non-dominant shoulders.
Musculoskeletal symptoms and injuries reported by laparoscopic surgeons include increased

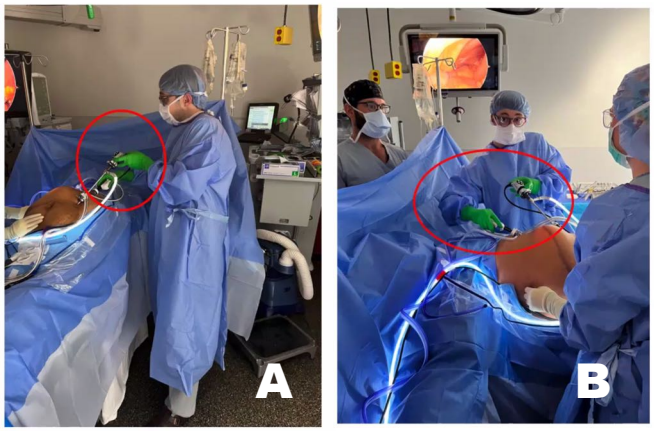

Fig. 7. Bad laparoscopic ergonomics examples
Source: LEFT: https://www.thieme-connect.com/products/ejournals/pdf/10.1055/s-0039-1693026.pdf
RIGHT: https://www.nature.com/articles/s41585-020-00414-4

shoulder, wrist, and hand pain or numbness in addition to the neck and back pain seen in open surgery. They also report transient thenar neuropathies and digital nerve injuries due to the ring-handled instruments. The force necessary to grasp a laparoscopic instrument has been calculated to be up six times greater than what it is for open surgery. Finally, they have also reported carpal tunnel, eyestrain, and cervical spondylosis during laparoscopy.

BMI
Patient BMI might be thought to be another factor in OR ergonomics; however, one study has found that a BMI >= 30 compared to < 30 does not cause an increased ergonomic stress or workload during laparoscopic surgery.[5]

Robotic Surgery
Robotic surgery has the advantages (over open and laparoscopic surgery) of being able to adjust the console to fit the surgeon, and being seated in a supportive chair (**Figure 8**, p. 6). The console angle and height of the viewer (the red ar-

[4] Wang R, et al. "Which causes more ergonomic stress: Laparoscopic or open surgery?" *Surg Endosc.* 2017 Aug;31(8):3286-3290. doi: 10.1007/s00464-016-5360-5.

[5] Liang Z, et al "Effect of Patient Body Mass Index on Laparoscopic Surgical Ergonomics." *Obes Surg*. 2019 Jun;29(6):1709-1713. doi: 10.1007/s11695-019-03748-0. PMID: 30712169.

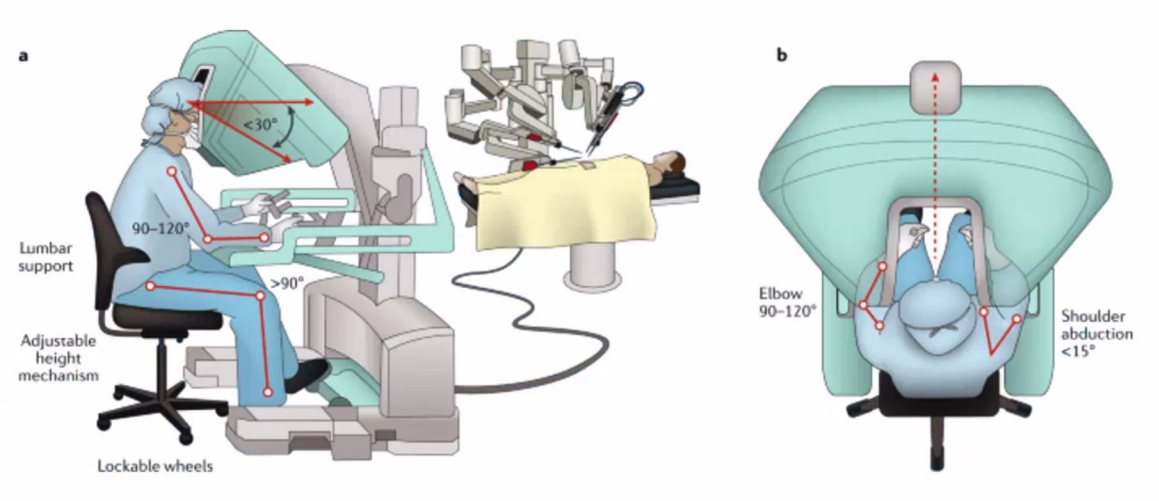

Fig. 8. Robotic surgery ergonomic advantages

rows in **Figure 9**), the arm rest height, (the blue) and the foot pedals are all adjustable.

This study looked at laparoscopic and robotic procedures and they used EMG to compare activation of the back and arm muscles. And they found that there was statistically significant elevated level of muscle activation in the biceps, triceps and deltoids but not the trapezius muscles during laparoscopy and compared to robotic surgery. And they thought that it was not statistically significant between the two for the traps

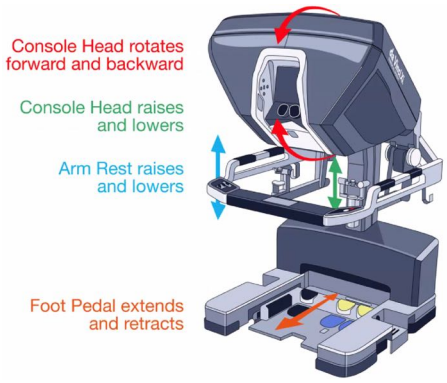

Fig. 9. Robotic surgery console adjustments

because of the anterior tilt of the head and neck when looking down into the robotic Viewer.

A study[6] that looked at surgeons body posture while operating robotically with the DaVinci system measured trunk, neck, shoulder, elbow, hip, and knee angles (from photos) and compared them to a preferable joint angle. It found that there was a greater risk of neck strain during robotic surgery but less discomfort in the arms, forearms and wrists.

In another study,[7] after undergoing ergonomic training for the robotic console, surgeons reported a 74% decrease in strain. It seems that before training, they had tended to lean forward and did not use the supportive chair provided with the console.

Summary

Open surgery can result in neck and back injuries, laparoscopic surgery in neck, shoulder, and upper extremity injuries, and robotic surgery can cause injury to the neck. So surgeons are put at risk with all types of surgery no matter what approach they take.

[6] Zihni, Ahmed M et al. “Ergonomic analysis of robot-assisted and traditional laparoscopic procedures.” *Surgical endoscopy* vol. 28,12 (2014): 3379-84. doi:10.1007/s00464-014-3604-9

[7] Franasiak, Jason et al. “Feasibility and acceptance of a robotic surgery ergonomic training program.” *JSLS : Journal of the Society of Laparoendoscopic Surgeons* vol. 18,4 (2014): e2014.00166. doi:10.4293/JSLS.2014.00166

How to Achieve Healthy Ergonomics
There are components of healthy ergonomics in the OR:

1. Body positioning,
2. OR equipment (especially monitors),
3. Preparation and recovery outside of the OR, and
4. Targeted stretching micro breaks in the OR.

While operating, the surgeon should maintain as neutral a body position as possible. It is important to avoid rotating the neck and avoid flexing it greater than 25 degrees or extending it to look up at a monitor. The back should be straight so the spine is not flexed or extended. The legs should bear equal weight, with occasionally shifting to avoid remaining too long in a static posture.

For the upper extremities, hand reach should be a maximum of 16–18" and the hands should be positioned between the waist and the middle of the chest, with the elbows bent from 90°–120°.

For the equipment, table height should be adjusted to the surgeon's height. Loupes should be lightweight and fitted properly so that the surgeon's neck is not bent greater than 25 degrees. The monitors should be high definition and placed 80 to 120 centimeters distant from the surgeon's eyes. The neck should not have to turn, flex, or extend to look at the monitors. If using a lead apron, the two-piece is preferable.

Gel-filled or other anti-fatigue mats and compression socks are also beneficial. Gel mats cause a decrease in foot and knee and back pain and compression socks decreased leg swelling. A study that looked at the calf circumference and leg volume when wearing and not wearing compression socks and when using and not using mats found that using a combination of both decreased calf circumference and leg volume goes significantly. (See **Figure 10**).

It is important to prepare outside and recover outside of the operating room. All three types of surgeries affect the neck, so neck stretches should be done before and after performing surgery. Squats, lunges, bridges, planks are beneficial for strengthening the cores.

Surgeons are generally busy and may not have time to stretch at home, so should perform "targeted micro stretching breaks" on rounds and

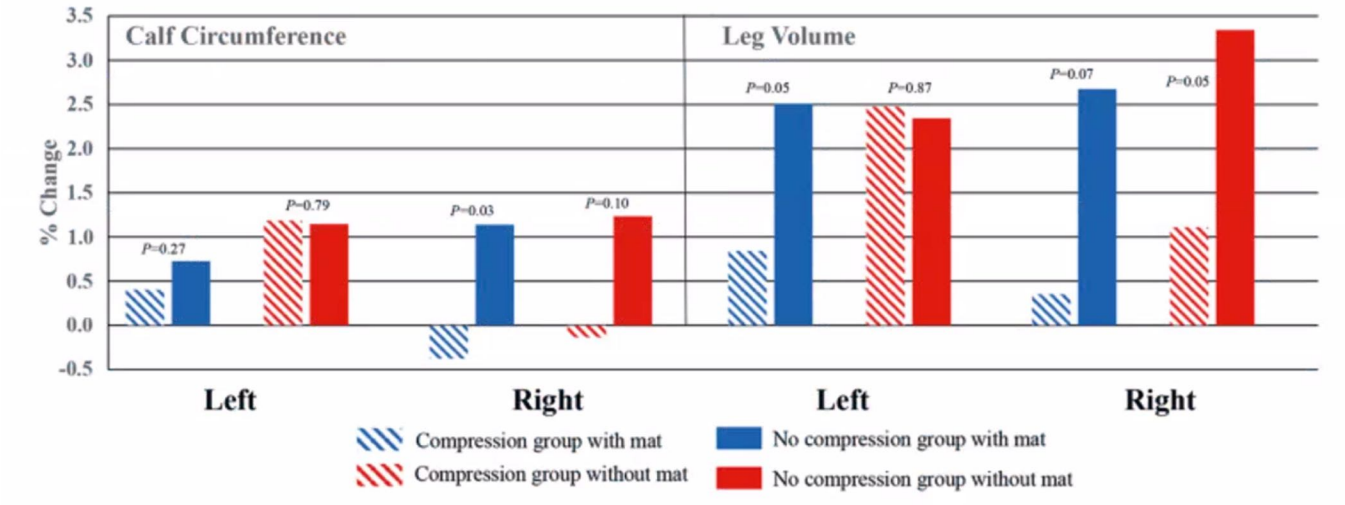

Fig. 10. Decreased pain and lower leg swelling through ergonomic adjuncts in the OR
Source: https://pubmed.ncbi.nlm.nih.gov/9322173/

even in the OR. They take only 20 seconds and should be performed every 20 minutes after being in the operating room for two hours.

A study that measured self-reported pain and fatigue and physical and mental performance over two operative days compared surgeons who performed targeted stretching micro breaks with surgeons who did not. The study found that post-procedure pain scores in the neck, back, shoulders, and upper and lower extremities for the targeted stretching micro breaks group were lower, and interestingly the breaks did not affect overall operative time. Nearly 90% of surgeons who performed the breaks said they planned to adopt them into their operative routine.

Figure 11a (p. 9) shows some targeted stretching micro breaks done while standing and **Figure 11b** (p. 9) shows targeted stretching micro breaks that can be done while seated.

Ergonomics as Part of Surgical Residency

Eighty percent of surgeons experience pain while operating. Musculoskeletal workplace injuries result in a reduced number of operations and ultimately a shortened career. Surgeons spent a long time getting to be a surgeon so having to shorten a career because of an avoidable injury sustained while operating would be tragic.

In two studies of surgical ergonomic education incorporated into surgical residency curricula,[8,9] residents reported musculoskeletal injuries they thought was from their training and they thought it would be valuable to incorporate training into the residency.

Duke University has done just that, setting up a peer based program run by the chief resident, with senior residents coaching and mentoring their juniors. Each resident attends ergonomic labs where they are properly fitted for loupes. The junior residents do one-on-one observation with the senior residents. Gel mats and targeted stretching micro breaks have been introduced. Not least, the program targets medical students to teach good posture and ergonomics practice in the OR at an early stage.

The Mayo Clinic has created an app that leads the surgeon through stretches. A timer alerts the surgeon when it is time to take a 20-second stretching break and shows video clips of the stretches to be performed. At the end of the day, the surgeon records any muscle aches or other pain in the app, which can then show the progress being made (or not).

* * *

[8] Jensen, Megan J et al. “Incorporating Surgical Ergonomics Education into Surgical Residency Curriculum.” *Journal of surgical education* vol. 78,4 (2021): 1209-1215. doi:10.1016/j.jsurg.2020.11.004

[9] Allespach, Heidi et al. “Practice Longer and Stronger: Maximizing the Physical Well-Being of Surgical Residents with Targeted Ergonomics Training.” *Journal of surgical education* vol. 77,5 (2020): 1024-1027. doi:10.1016/j.jsurg.2020.04.001

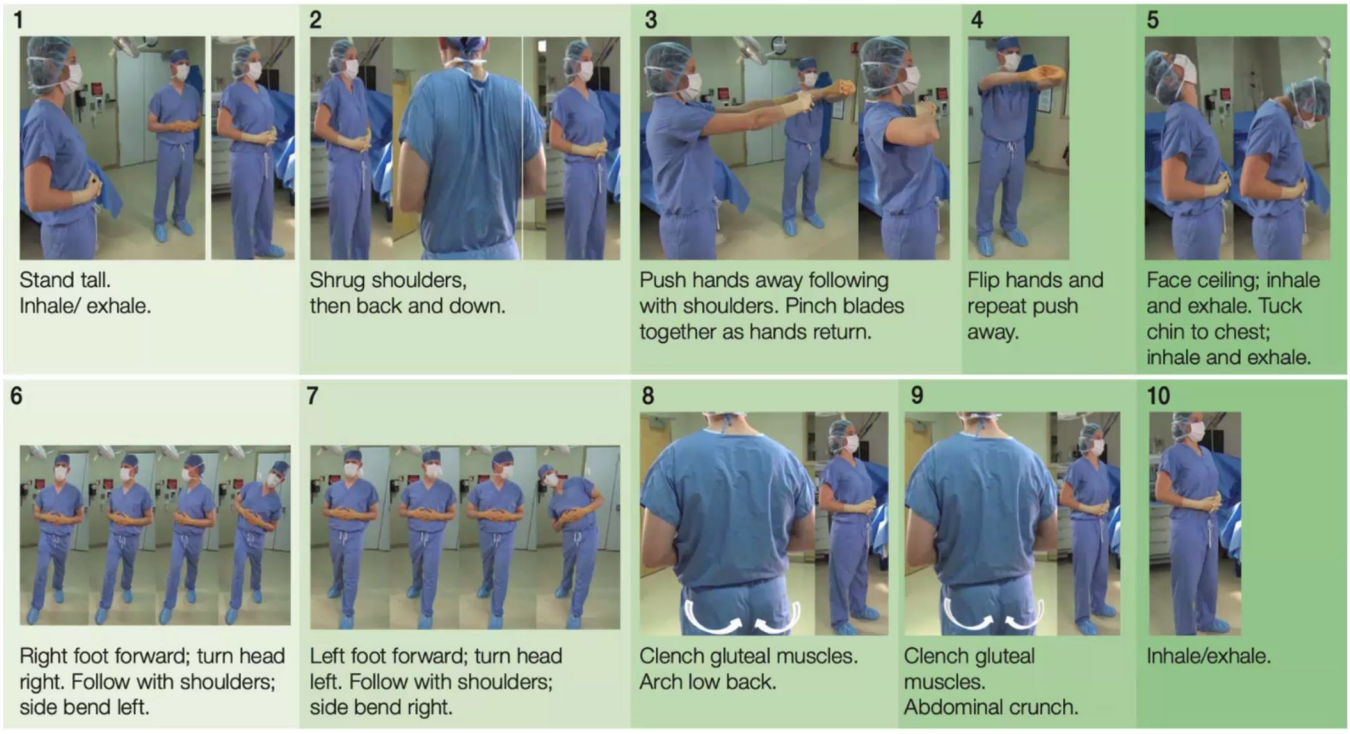

Fig. 11a. Targeted stretching micro breaks done while standing

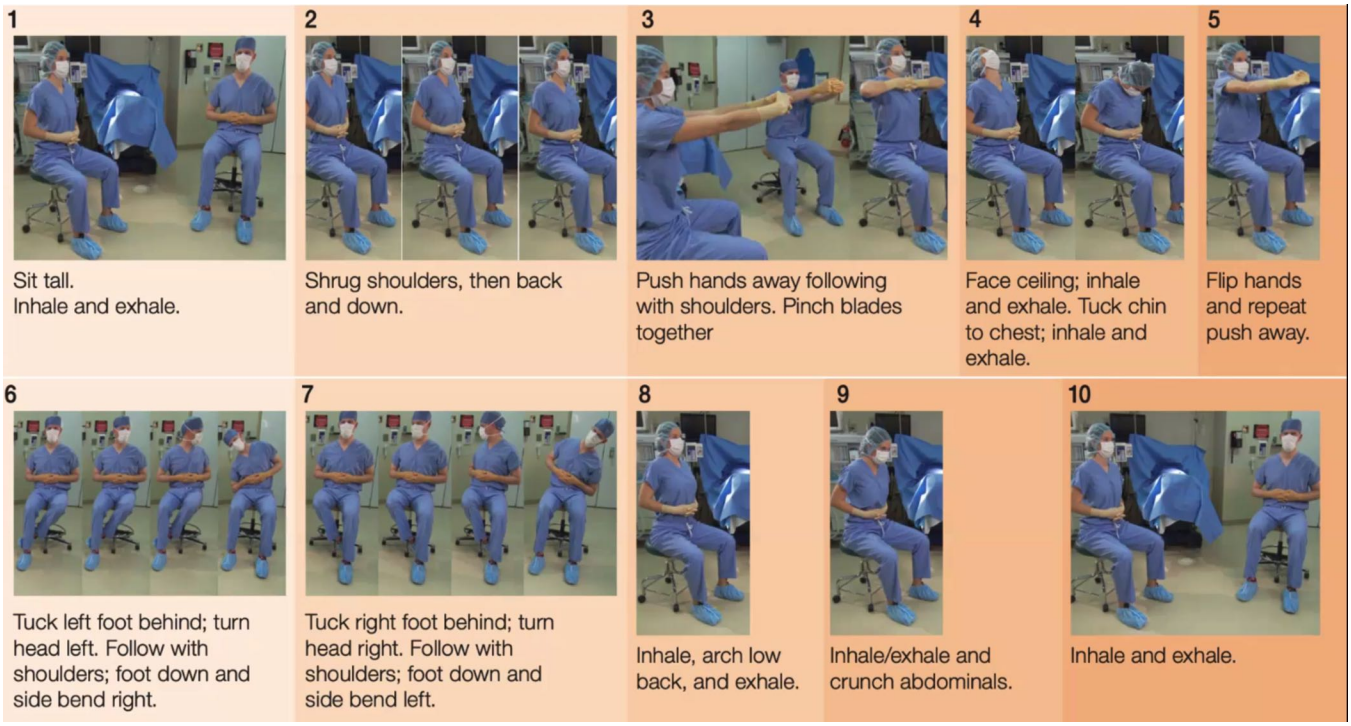

Figure 11b. Targeted stretching micro breaks done while seated