Surgeon Strength: Ergonomics and Strength Training in Cardiothoracic Surgery

Mohammed I. Dairywala, BS,* Saurabh Gupta, MD, MSc,† Michael Salna, MD,‡ and Tom C. Nguyen, MD§

With the high prevalence of musculoskeletal pain in surgeons and interventionalists, it is critical to analyze the impact of ergonomics on cardiothoracic surgeon health. Here, we review the existing literature and propose recommendations to improve physical preparedness for surgery both in and outside the operating room. For decades, cardiothoracic surgeons have suffered from musculoskeletal pain, most commonly in the neck, and back due to a lack of proper ergonomics during surgery. A lack of dedicated ergonomics curriculum during training may leave surgeons at a high predisposition for work-related musculoskeletal disorders. We searched PubMed, Google Scholar, and other sources for studies relevant to surgical ergonomics and prevalence of musculoskeletal disease among surgeons and interventionalists. Whenever possible, data from quantitative studies, and meta-analyses are presented. We also contacted experts and propose an exercise routine to improve physical preparedness for demands of surgery. To date, many studies have reported astonishingly high rates of work-related pain in surgeons with rates as high as 87% in minimally-invasive surgeons. Several optimizations regarding correct table height, monitor positioning, and loupe angles have been discussed. Lastly, implementation of ergonomics training at some programs have been effective at reducing the rates of musculoskeletal pain among surgeons. Surgical work-related stress injuries are more common than we think. Many factors including smaller incisions and technological advancements have led to this plight. Ultimately, work-related injuries are underreported and understudied and the field of surgical ergonomics remains open for investigative study.

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Keywords: Surgical ergonomics, Work-related musculoskeletal injuries, Physical training, Stretching, Exercise, Surgical performance

Central Message
Surgical ergonomics remain understudied with many implications for surgeon health. Physical training and intraoperative modifications can help reduce musculoskeletal impacts of practicing surgery.

Perspective Statement
Ergonomics have a large impact on surgical performance. We review the existing literature surrounding ergonomics and discuss its importance in training and practice. Finally, we propose a set of recommendations for both in and outside the operating room to improve ergonomics and extend career longevity in cardiothoracic surgery.

Abbreviations: OR, operating room; MSK, musculoskeletal; MICS, minimally-invasive cardiothoracic surgery; EMG, electromyography; STS, Society of Thoracic Surgeons; SVS, Society for Vascular Surgery; CTS, cardiothoracic surgery; OSHA, United States Occupational Safety and Health Administration; SCM, sternocleidomastoid; IMU, inertial measurement units

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INTRODUCTION

Cardiothoracic surgery shares many characteristics with high-performance sports, demanding consistent excellence and stamina. In his 2017 John H. Gibbon, Jr Lecture, “The Elite Athlete…the Master Surgeon,” Dr Verrier elaborated upon this relationship by promoting the importance of deliberate practice, coaching, and other techniques utilized in high-performance athletics. As we recognize this role, we must also identify the challenges tied with that identity. Athletes place their bodies under tremendous physical stress, and so, fundamental to their training is the maintenance of good form and technique; that is, healthy ergonomics.

Unfortunately, surgical ergonomics has been constantly underappreciated, understudied, and underemphasized. Anecdotally, far too often we see surgeons with hunched necks, and poor postures. The progressive breakdown of the body from years of operating is an insidious process. As early as 1916, Dr Gilbreth advised surgeons and medical practitioners to study motion study and time study within the operating room (OR) to eliminate inefficiency and improve the longevity of a surgeon’s career. Over 100 years later, unfortunately not much has changed. Dr Dudley, who prolifically wrote about training surgeons, lamented that “looked at from the ergonomic point of view, most major operations are, at first sight, a mess.” The physical implications of this are bleak. Musculoskeletal (MSK) pain is very common among surgeons, with estimates ranging from 66%-94% among those performing open surgeries. A recent meta-analysis by Epstein et al. found that approximately 60% of surgeons report a neck pain at 12-month. Some must even undergo surgery to correct MSK problems; a study of spine surgeons reported 4.6% underwent corrective surgery for their MSK pain.

Perhaps driven by a proudly stoic culture, surgeons are reluctant to seek help and continue to suffer in silence because of poor ergonomics. A 2009 survey by Soueid et al. found that 65% of 130 British surgical consultants who experienced pain, never sought any help or advice. Of those that did, 54.5% obtained help from a colleague, 22.7% self-medicated, 13.6% from their general practitioner, 4.5% from a physiotherapist, and 4.5% merely informed the occupational health department at their practice. The hesitancy to seek help, compounded by long work hours, poor nutrition, and lack of sleep ultimately provide the perfect storm for injury and are the antithesis of elite athletic training.

Moreover, as cardiothoracic surgery increasingly adopts minimally invasive techniques, the need to twist, and contort into awkward angles is also increasing. Over time, repeatedly subjecting ourselves to ergonomically vulnerable positions and movements places serious stress on the body; likely that arms and back are placed at higher risk due to the longer telescopic surgical instruments. In fact, while somewhat different from minimally invasive cardiothoracic surgery (MICS), 87% of laparoscopic surgeons report MSK pain. Laparoscopic surgeons often use exaggerated ulnar deviation, wrist flexion and arm abduction to use these tools, which can lead to compression of the digital nerve ie “laparoscopic surgeon’s thumb.” An electromyography (EMG) study comparing open and laparoscopic surgeons found that the latter had higher EMG amplitudes in the thumb, forearm flexor, and deltoid. Body discomfort scores were also higher among laparoscopic surgeons. Essentially, complex manipulative tasks with minimally invasive techniques requires greater upper-extremity muscle effort.

Additionally, the growing use of transcatheter therapies in surgery has brought added ergonomic challenges with it, like donning heavy lead aprons. The progressive deleterious effects of wearing 40-pound suits unequally distributed across the body have been studied extensively by vascular surgeons, orthopedic surgeons, and interventional cardiologists and radiologists. Despite facing these challenges for years, an ergonomically sound solution remains far from reach.

Recently, surgical training has experienced a paradigm shift from one that ignores stress and discourages conversations around well-being and burnout, to a culture that is beginning to foster surgeon wellness. For example, in 2019, the Society of Thoracic Surgeons (STS) held a roundtable discussion around “Strategies for Surgeons to Prevent Burnout”. Similarly, the Society for Vascular Surgery (SVS) established a Wellness Task Force, which – in part – focuses on highlighting pain from performing operations, and its effects on surgeon wellness. Initiatives like these further highlight the need for research in ergonomics to ensure that a surgeon’s career does not break down over time.

While ergonomic analyses may seem expensive, a focus on motion studies can actually prove economically valuable. The ability to identify ergonomic weak points provides opportunities to create replicable systems with higher operative efficiency. Ergonomic breakthroughs can help reduce the surgical care cost on healthcare systems, providing a basis for systems that help effectively train surgeons in a more efficient way.

Overall, poor surgical ergonomics impacts several areas. Here, we outline some of the most common, first describing the prevalence of disorders along with a review of potential instigating factors. Then, we share intraoperative considerations followed by a set of recommendations outside of work to strengthen, and lessen the ergonomic risk to respective body areas. Later, we discuss the implementation of ergonomics within surgical education. Finally, we conclude with a set of exercise recommendations to establish a workout routine for the surgeon-athlete.

NEUTRAL BODY POSTURE

The neutral position for various body parts is that in which there is little or no harmful pressure exerted upon them. Moreover, neutral body posture is a position of ease that can be maintained for an extended period of time, supports the natural curvature of the spine, and provides the body with a biomechanical advantage to perform work. The United States Occupational Safety and Health Administration (OSHA) created ergonomic recommendations (Table 1) as positions...
deviating significantly from these are considered to be high ergonomic risk.

When considering the typical positions surgeons find themselves in while lost in focus operating, it is evident the surgical environment is severely under-optimized (Fig. 1). Currently, there are several operations where limitations in visualizations make achieving neutral posture very difficult. However, just as systems and guidelines are developed to minimize complications in surgery, further investigations can facilitate development of guidelines, and techniques to make surgery safer for surgeons.

### PHYSICAL PLIGHT OF SURGERY

Some of the most common areas impacted by poor surgical ergonomics are presented in Figure 2. Below we describe the prevalence of disorders in these areas and review potential instigating factors. We then share intraoperative considerations followed by recommendations to mitigate the ergonomic risk to these respective body areas (Fig. 3).

**Table 1. Neutral Body Positions & OHSA Ergonomic Recommendations**

<table>
<thead>
<tr>
<th>Body Area</th>
<th>Neutral Position</th>
<th>OHSA Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and Neck</td>
<td>The head is rested on the spine and not twisted or rotated in any direction</td>
<td>The head should be vertical and should not be tilted more than 15 degrees</td>
</tr>
<tr>
<td>Back</td>
<td>Neutrally positioned in an S-shaped curve with no flexion or extension</td>
<td>Should sit or stand upright without bending the joints into extreme positions. Torso flexion should be limited to 6-10 degrees from vertical</td>
</tr>
<tr>
<td>Arms</td>
<td>Hanging straight to the sides of the body pronated</td>
<td>Should hang normally at the side of the body without reaching forward farther than 16-18 inches. Hands should be maintained vertically between the waist and the middle of the chest when reaching out</td>
</tr>
<tr>
<td>Lower Body</td>
<td>Flexed fetal position</td>
<td>Standing upright, shifting weight occasionally from one leg to the other</td>
</tr>
</tbody>
</table>

**Head and Neck**

Neck pain is one of the most common MSK disorders among surgeons with rates ranging from 6%–74%. Multiple factors are at play, including headwear, eyewear, table positioning, and monitor placement in the OR.

While the routine uses of surgical loupes enhance visibility, their use can cause uncomfortable head, and neck flexion. Several studies correlate the use of loupes with high incidences of neck discomfort. Their weight can significantly strain neck muscles in the long-term, which is further compounded by the neck flexion angle extending significantly beyond neutral body position. One study suggested that when getting fitted for loupes, surgeons should do so while simulating their use in the OR, rather than in a seated position, unless, of course, the surgeon performs a majority of their operations seated to attempt to prevent focal length discrepancies, and excessive neck flexion. Headlights have been found to exacerbate the issue of excessive neck flexion. A single-center study from Sahni et al. found that 68% of high-frequency headlight users experienced

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![Figure 1. Poor vs improved surgical ergonomics. Two surgeons are depicted representing the difference between poor and improved ergonomics. Note the first surgeon hunched over the operating field, comprising his cervical, and lumbar spine. In contrast the female surgeon on the right has improved posture with a safer cervical angle of less than 25 degrees. Additionally, she demonstrates a slight blend in the knees with an equal weight distribution.](image-url)
aggravated neck symptoms.\textsuperscript{18} Another study of ophthalmic plastic surgeons found that headlamps and loupes were one of the primary concerns for surgeon pain during operations. Additionally, an alarming 10\% of these surgeons said that they stopped operating due to neck discomfort.\textsuperscript{19} Many companies now advertise cushioning and weight distribution systems to improve the surgeon experience. The use of a cervical brace and maintenance of neck flexion at less than or equal to 25 degrees has been suggested to prevent spine and neck strain in the OR.\textsuperscript{20}

The growing use of monitors has led to an increased incidence of eye strain among surgeons. As cardiothoracic surgery evolves to include more robotic, minimally invasive, and transcatheter techniques, it is critical to evaluate the ophthalmic impact of viewing screens at a distance along with constantly switching between close sight with the instruments and patients against far sight on the screen.\textsuperscript{4,16} Placement and use of high-definition monitors, and optimal OR light setup are important to reduce eye strain. Usually, monitors are placed too high (38\%) or too far away (28\%).\textsuperscript{21} Instead, monitors should be positioned with a slight declination angle of 0-15 degrees, between the eye and hand level.\textsuperscript{21} and a distance of 80-120cm — which has been has been shown to considerably reduce eye strain.\textsuperscript{22}

Back

Back pain is another common area of MSK pain among surgeons. A 2017 review by Epstein et al. reported the prevalence of degenerative lumbar spine disease among “at-risk” surgeons and interventionalists had increased by a staggering 9\% between 1997 and 2015.\textsuperscript{5} However, this study did not include cardiothoracic surgeons. Unfortunately, despite being at equally high risk for such injuries, ergonomic analysis of our specialty remains woefully absent from the literature, highlighting the serious need for research in this area.

The most obvious intraoperative ergonomic consideration to reduce prevalence of back pain is to operate at the appropriate table height. Matern et al. reported that the OR table was too high for 95\% of laparoscopic surgeons.\textsuperscript{23} Accordingly, van Veen\textsuperscript{el et al.} suggested a table height of about 70\%-80\% of

**Figure 2.** Physical plight of surgery. Several studies have surveyed surgeons across various specialties regarding musculoskeletal pain. Here we highlight a few of the most alarming findings. The 3 most common problems reported by Epstein et al. in 2017 were degenerative cervical spine disease in 17\%, degenerative lumbar spine disease in 19\%, and rotator cuff pathology in 18\%. Additionally, Park et al found that 87\% of surgeons regularly performing minimally-invasive operations experienced musculoskeletal pain. These data highlight how prevalent these issues are among our colleagues. MSK, musculoskeletal.
elbow height, stating that movements remain in the neutral posture over 90% of the time with this position. Furthermore, stools are a poor ergonomic compromise as the additional height can over or under-compensate. The small stepping areas can also compromise balance.

Shoulders and Arms

Shoulders comprise a common area of discomfort among surgeons. A 2012 study surveying European thoracic surgeons found that 76.3% suffered from shoulder pain, and 94.4% were unaware of any ergonomic guidelines and did not practice them regarding table height, monitor, or instrument position. The rotator-cuff is one specific area of injury, with up to 18% of surgeons suffering from degenerative rotator-cuff disease. Suprascapular nerve injury is an additional factor to consider, as entrapment of this nerve is common among overhead athletes.

It is plausible that cardiothoracic surgeons are also susceptible to this condition since tying down into deep holes involves having the arms cocked high.

Proper arm and elbow placement also plays a role in reducing upper extremity discomfort. In a study of the optimum operating table height for laparoscopic surgery, Berquer et al. suggested that the optimum table height for laparoscopic surgery should position the laparoscopic instrument handles close to surgeons’ elbow level to minimize discomfort as well as upper arm and shoulder muscle work. Optimal positioning should keep the elbows at a 90°-120° angle.

INCORPORATION INTO SURGICAL EDUCATION

The Need for an Ergonomics Curriculum

The key to robustly improving surgical ergonomics perhaps lies in its incorporation into surgical training programs. In a 2007 survey, 97% of the surveyed surgeons believed that improving ergonomics in the OR was necessary. More recently, a study focused on ergonomics in otolaryngology had 2 critical findings: first, only 24% of surgeons had any prior ergonomic training or education and second, residents were equally affected by MSK disorders when compared to senior surgeons. Similar data was collected by surgeons at Duke University, who reported that 78% of medical students rated their posture during surgical tasks as poor or very poor. And, more than half reported that they regularly experience MSK pain while performing surgical tasks. While previous studies have suggested that ergonomic problems develop over the course of a surgeon’s career, significant challenges are obviously present at start of surgical practice. These findings call for urgent implementation of ergonomics training into surgical training programs. In a study of 42 robotic surgeons, 88% improved their practice after an in-person ergonomics training session, and 74% reported decreased strain afterwards. The
implemented changes included proper chair positioning allowing for 90-degree flexion at the knee, forearm placement parallel to the ground with tucked elbows, head flexion <20 degrees, placing little pressure on the headrest, and clutching frequently.\textsuperscript{29} Overall, however, a recent study highlighted the rarity of formal surgical ergonomics training programs. Of 130 program directors who responded to their survey, only 2 (1.5\%) had a formal ergonomics program. Trainees across the board felt that learning ergonomic skills was a worthwhile investment of their time.\textsuperscript{30} As such, we should aim to implement an ergonomics program as early as surgical rotations during clinical years of medical school.

Measurement and Progress Tracking
Earlier reviews demonstrate that the biggest barrier to establishing surgical ergonomics programs is the lack of an evidence-based framework. Previously, evidence on surgical ergonomics has been collected through a variety of subjective tools such as surveys, questionnaires, pictures, and video analysis, as well as objective tools like EMGs, skin conductance sensors, and most recently, inertial measurement units (IMUs). The advent of wearable IMUs which combine accelerometer, gyroscope, and magnetometer measurements has made it significantly easier to collect data needed to establish an evidence-based framework for ergonomics. They are non-obstructive, wireless, and can be worn under surgical gowns. Some software can even record movement data from standard camera footage, avoiding intra-operative sterility concerns that come with using physical sensors. These new technologies can be used by experts diagnostically to identify weak points in an operator’s technique. Used over time, these data can help develop an evidence-based framework for surgical ergonomics training. These technologies are available at a reasonable cost from companies such as wearNotch, mbientlab, BOSCH, Noraxon, KineticLabs, and others, making establishing a surgical ergonomics lab inexpensive to implement at surgical programs.

Proposed Integration Into Training Programs
In a survey of program directors of 14 surgical and interventional medical specialties, none of the surveyed integrated cardiothoracic surgery residencies had any formal or informal ergonomics education.\textsuperscript{30} Given the broad range of areas that fall under surgical ergonomics, it can seem difficult for program directors to begin incorporating it into an already packed surgical curriculum. However, a basic ergonomics module can be composed of 2-3 instances of education totaling 1-3 hours of both didactic and hands-on training by an ergonomist, physical therapist, or surgeon. Attendance should mandatory, with periodic in-person skill assessments as well as information about how to prevent common musculoskeletal injuries.

SURGEON STRENGTH
There is compelling evidence that regular resistance training is protective against development of MSK disease, and improves quality of life for those already suffering from these disorders.\textsuperscript{31} One study reported that irrespective of lower back pain duration, exercises that strengthen core muscles, gluteus maximus, and improve lumbar flexibility are an effective rehabilitation technique.\textsuperscript{32} Surgeons often work long, stressful, and unpredictable hours, making it difficult to build consistent exercise habits. Here, we aim to initiate the conversation around exercising for performing surgery by describing a routine built specifically for surgeons. Additionally, we provide a set of recommendations as a resource for surgeons looking to expand beyond the core routine.

The Core Routine
We designed a basic routine that surgeons everywhere can easily use to improve their MSK health (Table 2). The routine is designed to be conducted within 12-15 minutes at any location, without equipment, and includes elements of stretches, cardiovascular exercise, and strength training. The workout begins with 3 stretch movements, followed by 3 core exercises. These core exercises (steps 4-6) should be repeated 3 times, with 30 seconds rest between each set. The routine is then concluded with another 3 stretch positions. The total allotted time (including rest) is 11.5 minutes but can be extended to 15 minutes. As a standard disclaimer, we recommend consulting a physician or other healthcare professional before starting this or any other fitness program.

Additional Recommendations
Table 3 outlines stretch that are useful for reducing MSK burden on the body during surgery. The forced cervical flexion required by surgery leads to shortening of the sternocleidomastoid (SCM) and anterior scalene muscles resulting in a characteristic “forward head posture” (hunch back) seen in many surgeons. This poor posture can also tighten the suboccipital muscles, causing migraine headaches.\textsuperscript{33} Stretching these “tight” muscles may alleviate neck pain.\textsuperscript{34} Some stretches have been suggested specifically for back pain due to prolonged sitting. One is to arch the spine forward and backward. Side bends and twists can also help release compression on the vertebrae.\textsuperscript{32} These can be implemented into a full stretching routine or incorporated into mini-breaks during surgery to reduce overall back fatigue. Intraoperative “micro breaks” with targeted stretching have been shown to reduce surgeon postprocedural pain without affecting operative duration.\textsuperscript{35} Proper weight management is another area of focus for preventing back discomfort.

CONCLUSION
Surgical work-related stress injuries are underreported and underdiscussed. Many factors, including technological advancements, smaller incisions, and systemic lack of ergonomics training have led to the current plight (Fig. 4). This is all compounded by the fact that surgeons maybe hesitant to openly discuss their physical injuries. Much like an athlete, we must train and prepare ourselves for the long journey of our
careers. As a surgical collective, we must heed the wisdom of entrepreneurs not to scale too quickly (adding new technologies, new procedures, new techniques) without ensuring that our fundamentals are grounded and our training paradigms can handle the pace of growth. Additionally, beyond personal physical interventions, we must look to our environment, and try to modify it to help us be our best, for as long as possible. Ideally, this needs to be a conversation at individual centers.

Overall, this review highlights the need for greater emphasis on the impact of poor ergonomics on cardiothoracic surgeons. Surgical ergonomics represents a rich field for investigative study and innovative disruption, with the potential to

Table 2. Surgeon Strength Workout Routine

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Time (s)</th>
<th>Instructions</th>
<th>Video Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sternocleidomastoid Stretch</td>
<td>60</td>
<td>Sit or stand forward. Tilt your ear toward your shoulder until you feel a deep stretch. Take 5-10 deep breaths per side.</td>
<td><a href="https://www.youtube.com/watch?v=isGmJ146Cc">https://www.youtube.com/watch?v=isGmJ146Cc</a></td>
</tr>
<tr>
<td>2. Chin Tucks</td>
<td>30</td>
<td>Face forward and pull back your chin without tilting the face down. Perform stretch 5-10 times</td>
<td><a href="https://www.youtube.com/watch?v=vhFGQxDVzF8">https://www.youtube.com/watch?v=vhFGQxDVzF8</a></td>
</tr>
<tr>
<td>3. Posterior Shoulder Stretch</td>
<td>30</td>
<td>Pull your arm across your body and rest it along the opposite shoulder. Gently push the elbow back until you feel a stretch. Take 2-5 deep breaths and repeat on the opposite side</td>
<td><a href="https://www.youtube.com/watch?v=dploxuw7uJSzA">https://www.youtube.com/watch?v=dploxuw7uJSzA</a></td>
</tr>
<tr>
<td>4. Bodyweight Squats</td>
<td>30</td>
<td>Stand with feet roughly shoulder width and toes slightly outward. Lower your body until thighs are parallel to the floor. Complete 15 reps. Add isometric hold to modify</td>
<td><a href="https://www.youtube.com/watch?v=LyidZ42ly9Q">https://www.youtube.com/watch?v=LyidZ42ly9Q</a></td>
</tr>
<tr>
<td>5. Mountain Climbers</td>
<td>60</td>
<td>Setup in plank position and engage your core. Alternate bringing your knee to the chest. Perform at high-intensity to rapidly increase HR</td>
<td><a href="https://www.youtube.com/watch?v=nmWgirgXLYM">https://www.youtube.com/watch?v=nmWgirgXLYM</a></td>
</tr>
<tr>
<td>6. Glute Bridge</td>
<td>30</td>
<td>Lie face up on the floor with your knees bent and feet flat. Keep your arms to the side and raise your hips until your knees, hips, and shoulders are in a straight line. Complete 15 reps. Add resistance to modify</td>
<td><a href="https://www.youtube.com/watch?v=wPM8icPu6H8">https://www.youtube.com/watch?v=wPM8icPu6H8</a></td>
</tr>
<tr>
<td>7. Trapezius Stretch</td>
<td>30</td>
<td>Start seated on a chair. Use one arm to hold the seat of the chair, and use the other arm to pull the head toward the opposite side, stretching the levator scapulae. 15 s on each side</td>
<td><a href="https://www.youtube.com/watch?v=-r0eoFS7_5Q">https://www.youtube.com/watch?v=-r0eoFS7_5Q</a></td>
</tr>
<tr>
<td>8. Levator Scapulae Stretch</td>
<td>30</td>
<td>Bring the arm up and place your hand on the shoulder blade so that the elbow is pointing up. Place your other hand on the back of your head and pull forward gently toward the knee. 15 s on each side</td>
<td><a href="https://www.youtube.com/watch?v=GSoXPJRnR6E">https://www.youtube.com/watch?v=GSoXPJRnR6E</a></td>
</tr>
<tr>
<td>9. Cat-Cow Stretch</td>
<td>60</td>
<td>Start on your hands and knees. Inhale and arch your back for the “cow” pose. Exhale and round your back for the “cat” pose. Perform slowly.</td>
<td><a href="https://www.youtube.com/watch?v=wPM8icPu6H8">https://www.youtube.com/watch?v=wPM8icPu6H8</a></td>
</tr>
</tbody>
</table>

Steps 4-6 should be repeated 3 times, with 30 seconds rest between each set.
<table>
<thead>
<tr>
<th>Exercise (Muscle Group)</th>
<th>Instructions</th>
</tr>
</thead>
</table>
| Anterior Scalene Stretch | To stretch the right side:  
1. Gently depress right chest with the left hand  
2. Bring left ear to your left shoulder  
3. Slowly rotate your head to the right and point your chin to the ceiling until you feel a stretch in the front of your neck  
4. Hold for 10 deep breaths and switch sides |
| Suboccipital Release | You will need a tennis ball for this  
1. Lie on the ground with the tennis ball on one side of the back of the neck at the base of the skull  
2. Holding the ball in place, tuck your chin up, and down for 10 deep breaths on each side |
| Horizontal Plank (Abdominals) | On a yoga mat or the floor:  
1. Get into the pushup position, and drop down to your forearms  
2. Keeping your neck and spine aligned, squeeze your glutes, and contract your abdominal muscles  
3. Hold this position for 30 s |
| Superman Extension (mid-lower back) | On a yoga mat or the floor:  
1. Lie flat on the floor  
2. Inhale as you lift your arms and legs off the floor  
3. Focus on using your lower back muscles to maintain this position |
| Pectoral Stretch | Standing in an open doorway  
1. Raise each arm up to the side, bent at 90 degrees  
2. Rest palms on the door frame and slowly step forward with one foot  
3. Stand upright and feel stretch in shoulders and chest  
4. Hold for 30 s then relax  
5. Repeat 3 times |
| Shoulder Protraction (Serratus anterior) | Anchor a resistance band at the level of your mid back:  
1. Starting facing away from the resistance band with your arm at your side  
2. Slowly press your arm forward as if punching, making sure to extend through the shoulder blade at the end of the punch  
3. Return your arm back to your side  
4. Hold the resistance band out in front of you  
5. Repeat 10 times per side |
| Cable Row (Rhomboids, Latissimus Dorsi, upper trapezius) | Using a resistance band:  
1. Hold the resistance band out in front of you  
2. Focusing on using your mid-back, pull the resistance band back toward your chest  
3. Hold in the contracted position for 1 s, squeezing your shoulder blades tougher  
4. Slowly extend your arms back to the starting position  
Perform 3 sets of 15 |
| Internal and External Rotation (Rotator cuff muscles) | Using a resistance band:  
1. Stand at a distance equal to the length of the band and pivot your body perpendicular to the band  
2. Take the opposite end of the band and hold it with the arm that is farthest away  
3. Keeping your elbow bent at 90 degrees and fixed to the side of your body, slowly move your forearm outward to the side and slowly return to start  
4. Repeat this 10 times on each side |
| Internal Rotation |  
1. Standing in the same position as above, hold the resistance band with the arm closest to the band  
2. Slowly move your forearm inward until it reaches just past midline, then slowly return to the start  
3. Repeat this 10 times on each side |
immensely impact our performance, and longevity. Let us no longer suffer in silence.

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Figure 4. Overview of Surgical Ergonomics in Cardiothoracic Surgery. This figure depicts a graphical summary of the manuscript. In the left box we highlight concerning data from the existing literature. Prior studies have reported that the majority of surgeons (estimates between 66%-94%).4 A survey of European thoracic surgeons found that the majority were not aware of any ergonomic safety guidelines.25 The middle box highlights a few of the risk factors for ergonomic injuries cited in other studies that we believe apply to our specialty. 1) CT surgical operations are often long and technically complex 2) CT surgeons often use heavy loupes and headlights, and operate in deep cavities 3) minimally-invasive and transcatheter techniques come with their own added risk factors (limited visualization, lead aprons, etc). Lastly, we recommend a 3-pronged approach with physical exercise, intraoperative changes, and formal training to improve the state of surgical ergonomics in our specialty.