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Mastering Surgical Techniques: The Role of Hand Anatomy and Posture for Trainee Surgeons

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Abstract

Developing surgical techniques is crucial for trainee surgeons, and understanding hand anatomy and posture plays a vital role. This paper explores the intricate relationship between the anatomical posture of the hand and the precision required in surgical procedures. The intrinsic muscles of the hand, especially the lumbricals, are crucial for extending the distal interphalangeal (DIP) _ joints without interference from the long flexor muscles of the forearm. Along with the opponens pollicis, these muscles allow the fingertips to touch lightly, enabling delicate surgical manoeuvres. Proper handling of surgical instruments requires better teaching, focusing on grip modulation and tactile feedback. The flexor digitorum profundus (FDP) and flexor pollicis longus (FPL) are the largest muscles in the forearm, generating significant pinch force that can cause tissue damage if not managed properly. The extension of the proximal interphalangeal (PIP) joints and DIP joints, along with the flexion of the metacarpophalangeal (MCP) joints and the action of the opponens pollicis, maximises the contact area of the fingertips, defining the precision grip. The lumbricals adjust tension between the extensor and flexor systems during fine pinching, highlighting human adaptability in tool use, especially in surgery. The tactile and visual elements of precision are vital, ensuring that the surgical instrument functions as a seamless extension of the surgeon's fingers. This article aims to equip trainee surgeons with essential knowledge and techniques to improve their surgical skills by gaining a deeper understanding of hand anatomy and posture.

Mini abstract: Understanding of the functional anatomy of the upper limb improves fine motor skills and reduces career risk of musculoskeletal degeneration.

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Introduction

Posture impacts surgery in both professional and personal ways. This issue is common in certain specialties, worsened by head-mounted cameras or loupes. Open surgery is recognised to take more effort, with head inclination impacting on the trapezius muscles [1] but it is also recognised in laparoscopic surgery [2].

The function of the upper limb is considered in a domestic setting. The kitchen counter height is calculated to match the function of the upper limb for the median height of the population, but this does not mitigate for lower back pain especially if you are tall and standing for prolonged periods l [3]. Likewise, the domestic ironing board height is adjustable to ease the process of ironing and correcting the table height is important to ensure the optimum function of the upper limb.

Less than a quarter of surgeons have had education in ergonomics [4]. Execution of ergonomics recommendations does not require a trade-off between good ergonomics and the ability to efficiently complete surgical tasks [5]. Understanding functional anatomy enhances the appreciation of good ergonomics.

Twenty-three years of observation and teaching notes that the majority trainee surgeons do not adjust the height of table when operating in theatre or the skills lab, unless prompted. This can be uncomfortable (literally and figuratively) if there is a disparity in the heights of the surgeon and assistant. All parties should be aware of the correct standing position and the functional anatomy of the arm. This paper explores the functional anatomy of the upper limb to raise awareness, improve dexterity and reduce the risk of musculoskeletal degeneration.

The motion of the shoulder is complex, involving each of the four shoulder joints, especially when raising the arm overhead. The predominant joints are the scapulothoracic and the glenohumeral joints. Flexion and abduction of the humerus are common movements for the surgeon, but each of these requires moving and fixing the scapula to the chest wall. The middle deltoid, the subscapularis, supraspinatus, infraspinatus and the anterior deltoid are involved generating considerable force [6]. This is increased by hunching forward over the table, i.e. failing to stand correctly, because of increased scapula rotation and anterior tilt [7], requiring the scapula to be fixed to the chest wall by predominantly serratus anterior, especially with reaching out and reaching across scenarios [8]. Shoulder flexion and abduction increase muscle activity [9], leading to fatigue that may also increase tremor and is not conducive to a lightness of touch.

Most surgeons stand to operate, and the surgical instrument often works at depth with the hand and wrist lower than the elbow. The ergonomics and the movement of the instruments in the operative field are acquired through practice [10]. In yesteryear, skills acquisition was on the job [10], but today, simulation can compensate for the lack of volume [11]. The benefits are clear, but for the practice to be deliberate and purposeful, it must mimic the prescribed ergonomics of the procedure [12]. As part of that practice, it is essential to emphasise the correctness of posture and instrument handling to reduce the incidence of musculoskeletal problems and improve tissue handling. Unfortunately, we continue to teach surgical skills sitting down [13]. The upper limb works optimally when elbows are close to the body, slightly extended, and hands are palmar flexed. This effectively isolates the major muscles of the upper limb in a resting position [14], and this neutral functional position of the upper limb mitigates fatigue and potential tremor [15].

The ability of the forearm to produce muscle torque about the elbow joint is an important measure to gauge the ability to perform related workplace tasks. The Biceps and brachioradialis are very effective supinators of the forearm when held at a ninety-degree angle to the arm [16,17]. Still, these are not needed, and minimised when the elbow is partially extended when operating, and the minimal forces of the pronator teres and supinator muscles are all required [18].

Pronation and supination of the forearm is around an axis between the first and second fingers and the common flexor origin, i.e. the medial epicondyle of the ulna, and is not affected by the flexion of the elbow [19]. The needle holder needs to be aligned with the axis of pronation and supination to ensure smooth rotation [20] akin to using a screwdriver, but without the biceps

Forearm position does not affect the range of movement of the wrist [21] due to the coupled function of the carpals. Partial extension of the wrist is necessary to maximise the function of the long flexors [22] and increase grip strength, especially for manual workers, [23] together with flexion of the distal interphalangeal joints by flexor digitorum profundus and flexor pollicis longus. These are the two largest muscles of the forearm, which give the 'popeye' bulge and enable climbers. Slight extension at the elbow with palmar flexion at the wrist reduces forearm interference and optimises the use of the intrinsic muscles of the hand.

The lumbricals are fundamental to the function of the surgical hand. Because they are spindle-rich, the lumbrical muscles play a vital role in the sensory feedback of the distal interphalangeal, proximal interphalangeal, and metacarpophalangeal joints of the fingers. They have a high number of muscle spindles, specialised sensory receptors, found richly in many human muscles that are involved in precision movements, and are especially prevalent in the lumbricals of the index and middle fingers supplied by the median nerve, which also innervates the thenar muscles [24].

The intrinsic muscles of the hand especially the lumbricals, that extend the distal interphalangeal joints without interruption by the long flexor muscles of the forearm, which together with the opponens policies enable the pulps of the fingers to be opposed, thereby exercising the lightest of touches and resulting in the caress of tissues described by Lord Berkley Moynihan. From an anthropological point of view this could be the considered the most sophistic grip of hominids defining our ability to make and use tools [25].

The detail of instrument handling is poorly taught, and it is clear from photographs that trainees lack instruction how to hold the surgical instrument properly. This was particularly true of forceps. The flexor digitorum profundus and flexor pollicis longus, in the deep flexor compartment, are the two biggest muscles of the forearm. The pinch force, generated by these long flexors as they flex the distal interphalangeal joints, is between 25 N and 50 N [26]. If the surface area of the end of a pair of forceps is assumed to be 5 mm^2 (5 × 10 -6 m^2), the pressure exerted on tissue by pinching the forceps is more than 5 million Nm^2 (Pressure = Force (N)/Area (m^2) or the equivalent of 725 psi. Tissue damage is inevitable [27].

The extension of the PIP DIP joints and flexion of the MCP joints, together with the opponens pollicis, maximise the contact area of the pulp of the fingers and the thumb and characterise the precision grip using the first three digits [28]. The lumbrical has evolved into a highly specialised structure that modulates the tension between the extensor and flexor systems during fine pinch and is identified with a human's adaptability in using tools, especially for surgeons [24]. The tactile and visual elements of precision feel [29] mean that the surgical instrument becomes an extension of the fingers.

Feedback in surgical instruments plays a crucial role in enhancing precision, control, and safety during procedures. Tactile feedback enables surgeons to accurately evaluate tissue roughness and texture, especially when visual inputs are insufficient (Brydges R. 2005). Tactile sensors in laparoscopic instruments improve surgical accuracy. Instruments with tactile sensors can simulate the surgeon's sense of touch, making them feel like an extension of the surgeon's fingers (Ottermo MV. 2004). Tactile feedback is essential for avoiding excessive force, reducing tissue damage, and ensuring the safety and effectiveness of minimally invasive surgeries (MIS) (Othman, W., 2022). Visual feedback enhances tactile feedback by offering cues that help correct significant deviations, improving precision in instrument navigation. In minimally invasive surgery, the lack of direct tactile sensation makes visual feedback essential for guiding hand movements and instruments. Tactile and visual feedback significantly boost surgeons' performance, enhancing precision and speed in task execution. Technologies like piezoelectric sensors, optical fibre tactile sensors, and force-sensitive resistors provide surgeons with real-time feedback, effectively improving the accuracy and safety of surgical procedures (Wottawa CR. 2013).

Conclusion

To master surgical techniques, surgeons must understand hand anatomy, maintain proper posture, and continuously develop their skills using innovative training methods and ergonomic practices. These factors improve efficiency, precision, and well-being in trainee surgeons this reducing the significant lifetime risk of musculoskeletal degeneration [30].

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