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Surgical ergonomics. Analysis of technical skills, simulation models and assessment methods

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HIGHLIGHTS

- Competence in surgery is not an achievement but rather a habit of lifelong learning.
- The core elements of a training model build on the basic foundations of gross and fine motor skills.
- Low fidelity models can be used to achieve significant progress through the early stages of the learning curve.
- Deliberate practice is necessary to account for why some people become experts and others fail to do so, but not sufficient.
- Accurate skills assessment at an early stage may be critical in determining an individual's chances of becoming an expert.

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ABSTRACT

Introduction: Over the past two centuries the surgical profession has undergone a profound evolution in terms of efficiency and outcomes. Societal concerns in relation to quality assurance, patient safety and cost reduction have highlighted the issue of training expert surgeons. The core elements of a training model build on the basic foundations of gross and fine motor skills. In this paper we provide an analysis of the ergonomic principles involved and propose relevant training techniques. We have endeavored to provide both the trainer and trainee perspectives.

Methods: This paper is structured into four sections: 1) Pre-operative preparation issues, 2) technical skills and instrument handling, 3) low fidelity simulation models and 4) discussion of current concepts in crew resource management, deliberate practice and assessment.

Discussion: Rehearsal, warm-up and motivation-enhancing techniques aid concentration and focus. Appropriate posture, comprehension of ergonomic principles in relation to surgical instruments and utilisation of the non-dominant hand are essential skills to master. Low fidelity models can be used to achieve significant progress through the early stages of the learning curve. Deliberate practice and innate ability are complementary to each other and may be considered useful adjuncts to surgical skills development.

Conclusion: Safe medical care requires that complex patient interventions be performed by highly skilled operators supported by reliable teams. Surgical ergonomics lie at the heart of any training model that aims to produce professionals able to function as leaders of a patient safety oriented culture.

1. Introduction

Surgery is a profession defined by its authority to cure by means of bodily invasion [1].

Over the past two centuries surgery has become radically more effective and its invasiveness substantially reduced. This profound evolution has brought new societal concerns including how to ensure the quality and appropriateness of the procedures performed, how to reduce adverse events and risks, and how to improve outcomes whilst managing relevant costs. At the heart of this worldwide revolutionary concept lies the issue of training competent surgeons of tomorrow.

Competence in medicine is the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning,

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emotions, values and reflection in daily practice for the benefit of the individuals being served [2]. These values are consistently observed in expert surgeons' practice. Competence in surgery is not an achievement but rather a habit of lifelong learning.

In this paper we aim to discuss relevant skills required for expert surgical performance. We include a detailed analysis of the ergonomic principles involved and propose relevant simulation techniques. We have endeavored to provide both the trainer and trainee perspectives.

1.1. Proper prior preparation

1.1.1. Physical and mental well-being

Surgeons ensure they are physically and mentally fit prior to operating. The majority considers abstinence from alcohol and other drugs or substances that may impair performance, alongside adequate rest, as mandatory. They are certainly expected and often requested by the patient.

Published evidence on the relationship between performance and sleep deprivation/fatigue is significant. A recent meta-analysis found that individuals with insomnia performed poorly on tasks dependent on working memory and problem solving [3,4]. The Institute Of Medicine's review of resident working patterns and the European Working Time Directive echo this cultural change in health care provision [5]. Cognition and emotion interact with problem solving abilities [6]. Surgery requires precision. It is this paradigm that invites consideration of the surgeon's own physical and emotional status. The latter is recognized by all interested in sports science and coaching as contributing to success. Many top athletes employ nutritionalists and psychologists. Performance at that level is dependent on physical and mental well being.

The comparison of surgery and flying is often made. The briefing process at Naval Air Station Fallon, the 'top gun' school for USA fighter pilots, allows the individual pilots to declare themselves 'unfit for flight' without prejudice.

1.2. Rehearsal and warm-up

Rehearsal is the deliberate practice of technical and non-technical skills specific to a procedure [7]. It is not uncommon for the surgeon to rehearse and visualise the steps of a complex operation prior to surgery. Many have conscious or subconscious rituals that get them 'in the zone' for optimal performance. Visualization and ritual are well-established motivation-enhancing techniques that aid concentration and focus.

Warm-up is the act or process of warming up for a contest by light exercise or practice. Two recent studies showed that warm-up prior to laparoscopic cholecystectomy and renal surgery improved the technical performance of the operators [8,9]. We are all familiar with sports players eg golfers who spend time on the practice range prior to a tournament and the warm-up session prior to a tennis tournament.

Indeed the concept of rehearsal and warm up transcends many disciplines and is widely practiced within most professions.

2. Technical skills

There is a saying in cardiac surgery that 'if you are away from the table for one week you notice it, two weeks and your assistant notices it and after three weeks your patient notices it'. This is because surgery is a motor exercise that must be practiced. A recent randomized trial involving twenty bariatric surgeons in the US provides compelling evidence: Investigators found that surgical skill was not related to years in bariatric surgery practice, completion of a fellowship in advanced laparoscopy, or practice at a teaching or non-teaching hospital. Surgical skill was, however, strongly related to procedure volume. Another significant finding was that surgical skill was a strong predictor of clinical outcomes [10].

There are many implications for learning, based on the way our bodies acquire new motor skills. To achieve greatest success it has to start with the proper technique. This then requires plenty of hands-on time. Repetition develops a motor memory that brings harmony to thought process and technique.

Consideration of this learning and understanding invites us to consider and reflect how we train a surgeon.

2.1. No hesitation, deviation, interruption or repetition. (Operating speed)

Skillful surgeons do not appear to hurry or rush movements. Time seems to flow-by as each movement is deliberate and advances the procedure. They use the natural pauses during the procedure to attend to other areas. There is no hesitation, deviation, interruption or repetition. Deliberate purposeful movement appears slow but smooth and smooth is 'fast'.

We describe this using the metaphor of the cardiac cycle - the contraction of the heart ie systole occurs over a fixed period - this does not shorten however fast the heart is beating. It is the relaxation phase i.e. diastole that shortens with increased heart rate. The time it takes for the needle to pass through the tissue is much the same for the expert and the novice but it is the time it takes to execute that movement that makes the difference. The latter is dependent on posture, the manner in which instruments are handled and the angles of the needle on the needle-holder.

2.2. Posture

Posture is fundamental to reduce risk of injury and fatigue as well as optimise function. The golfing posture is a good example. It appears awkward and to the novice strange that you stand and deliberately stick you posterior out, however, a 'pro' recently stated that eighty percent of golf is posture and if you get that right, the swing of the club will look after itself.

Posture is important to enable relaxed upper limb movement. You cannot operate with your chin below the level of your shoulders nor can you effect a comfortable movement with the elbows in the air and the shoulders fixed. The position of the limbs is akin to that of string puppets - floppy and relaxed. This is very personal and dependent on the surgeon's body habitus.

Furthermore, it is important that the surgeon understands and utilizes the function of the operation table. The height of the table complements the posture and likewise the tilt effects the angles. Appropriate and timely adjustments throughout the operation in combination with changing posture ensure that the end movement, like the rotation of the needle, is accurate.

2.3. Needle handling

All needles are made on the curve of a circumference of a circle. The perfect needle movement enables the needle to pass through the tissue on this circumference. The suture that follows the needle will therefore sit snug within the tissue i.e. on a tangential section the suture will fill the perfect hole in the tissue. Failure to insert and deliver the needle at right angles to the tissue results in a suture sitting in an elliptical hole. In cardiac surgery, this may be at best seen as 'sweating' from an anastomosis.

The needle angle can be demonstrated prior to stitching and is akin to aligning the body with a golf club for a golf swing. Once that alignment has occurred the surgeon is in the appropriate position