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Mental Training in Surgical Education: A Systematic Review

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Abstract

Introduction

Pressures on surgical education from restricted working hours and increasing scrutiny of outcomes have been compounded by the development of highly technical surgical procedures requiring additional specialist training. Mental training (MT), the act of performing motor tasks in the "mind's eye", offers the potential for training outside the operating room. However, the technique is yet to be formally incorporated in surgical curricula. This study aims to review the available literature to determine the role of MT in surgical education.

Methods

EMBASE and Medline databases were searched. The primary outcome measure was surgical proficiency following training. Secondary analyses examined training duration, forms of MT and trainees level of experience. Study quality was assessed using CONSORT scores[18] or Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group[19].

Results

14 trials with 618 participants met the inclusion criteria, of which 11 were randomized and three longitudinal. 10 studies found MT to be beneficial. Mental rehearsal was the most commonly used form of training. No significant correlation was found between the length of MT and outcomes. MT benefitted expert surgeons more than medical students or novice surgeons.

Discussion

The majority studies demonstrate MT to be beneficial in surgical education especially amongst more experienced surgeons within a well-structured MT programme. However overall studies were low quality, lacked sufficient methodology and suffered from small sample sizes. For these reasons, further research is required to determine optimal role of MT as a supplementary educational tool within the surgical curriculum.

Abstract Word Count: 246

Introduction

In recent years, surgical training has faced various new challenges. Strict limitations in legal working hours have reduced training opportunities[1]. Furthermore, implementation of new technologies within the surgical field has grown rapidly with the development of minimally invasive surgery[2]. Lastly with growing concerns over outcomes and patient safety, the classic axiom of "see one, do one, teach one" is fast becoming an anachronism. To meet these new challenges, surgical education has been forced to seek alternative learning environments, including simulation training.

Studies have demonstrated that surgical residents engaged in simulation training require less time within the operating theatre to attain basic laparoscopic skills[5, 6]. Performance evaluation with box trainers remain limited by the lack of homogeny between assessment tools[7]. Virtual reality simulators (VRS) are expensive and require regular system upgrades and technical support[8]. Such limitations necessitate the development of additional teaching strategies.

Mental readiness was termed by McDonald and colleagues (1995)[9] whose research demonstrated 73% of surgeons carried out a series of mental tasks prior to the operation.
Mental training (MT) outlines the act of mentally rehearsing a sequence of motions in the absence of overt physical movement. MT is a well-recognised, validated educational tool in the fields of sport, music and flight training[10,11,12], but is yet to be validated for use in surgical education, despite obvious similarities.

Underlying neurophysiological correlates of MT in the acquisition of motor skills have been demonstrated. MT correlates with an increase in attentional stability[13] and self-confidence[14].

Activation of neural pathways associated with the motor system has been demonstrated[15] as well as similar neuroplastic changes following physical and MT[16,17].

The purpose of this review is to evaluate all studies that assess the use of MT in surgical education to determine whether it is feasible to incorporate it into the surgical curricula.

Methods

The study was performed according to the guidelines set out by the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement. PROSPERO registration number: CRD42016032869

The literature search was conducted from September 2015 to November 2015. EMBASE and Medline databases were searched. The following MESH search terms were used: “mental training”, “cognitive training”, “mental rehearsal” and “brain training”. These terms were combined with “surgery” to obtain the relevant articles.

Inclusion criteria:

- Randomized controlled trials and non-randomised controlled clinical trials assessing the role of MT in surgical education.
- Participants with a medical background ranging from first year medical students through to expert surgeons.
- Any form of MT in the context of surgical education, e.g. the use of descriptive leaflets, DVDs, MT educators.
- Studies originally written or translated into the English language.
- Full text available

Exclusion criteria:

- Case reports, case series and observational studies.

To ensure consistency with inclusion criteria, abstracts were reviewed by two authors (S.D & N.R). When texts were unavailable, authors were contacted directly. The steps used to identify relevant publications are represented in Figure 1.

Outcome measures were decided by consensus by the authors a priori. Principle domains were surgical skill outcome measures, training techniques and duration of training. Primary analysis evaluated the effect of MT on surgical performance. Sub-analyses assessed high quality RCTs using a Consolidated Standards of Reporting Trials (CONSORT) score[18] and longitudinal studies using a Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group[19]. Outcomes of higher quality studies were evaluated separately to determine whether their conclusions were consistent with all studies. Techniques of MT e.g. mental rehearsal vs non-mental rehearsal and time engaged within MT will also be evaluated to determine the effective way of implementing MT in surgical education. Finally, outcomes will be correlated with level of participant expertise.

Results

General study characteristics

14 studies were identified, of which 11 were randomised controlled trials (RCTs) [20,21,22,23,24,25,26,27,28,29,30]. The remaining 3 were longitudinal trials[32,33]. Studies were published between 2004 and 2015. Median sample size was 44 (range 11 to 98). Studies involved participants with various degrees of medical experience ranging from first year medical students to expert surgeons. Most groups studied the role of MT alone as the intervention[21,22,24,25,26,28,30,31,32,33] whilst three studies combined MT as part of a wider training regime[20, 23, 29]. Eldred-Evans et al[23] combined the MT with either box training or VRS whilst Bathalon et al[29] studied the effect of MT as an additional intervention to kinesiology. Wetzel et al[20] explored the effect of stress management training with a MT component on surgical

performance. Lastly one study compared different ratios of physical and MT to assess which proportion of MT, if any, correlated with better outcomes[27].

12 studies involved mental rehearsal as a component of their MT programme alongside other techniques[20,21,22,23,24,26,27,28,29,30,32,33]. Of the remaining studies, one familiarized participants with MT techniques using a hand-out and CD-ROM[25]. Another induced a state of relaxation using breathing exercises and hypnosis by a trained clinical psychologist who offered specific mental suggestions.

Three studies assessed participants using a VRS[21, 23, 32], whilst three studies scored participants using a box trainer[20, 26, 29]. Participants demonstrated surgical skills on both the VRS and box trainer in three further studies[21, 23,32]. Four studies used real life surgery to assess skill, two using live anaesthetised rabbits[24, 27], a cystoscopy[28] and a vaginal hysterectomy[30]. The remaining study used a 'MT Questionnaire' to determine the effect of the MT intervention[33]. Outcome measures were also very variable, although time, precision, accuracy and surgical performance were common measures.

3.2 Outcomes

Overall, 10 studies concluded that MT demonstrated a greater improvement in surgical skill[20 ,22 ,23 ,24 ,26 ,28 ,29 ,31 ,32 ,33] whilst four studies indicated no improvement[21, 25, 27, 30]. One study measured surgical performance using an OSATS-based global rating scale during five laparoscopic cholecystectomy VRS sessions. The MT group achieved consistently superior results with an 8-point difference by the 5th simulation session (p=0.001)[22]. Immenroth et al found that trainees engaged in MT achieved significantly better Modified Task-Specific Checklist scores (p=0.001)[26]. One study found that the MT enhanced group scored higher than the control group in terms of overall performance on the VRS (87.3% vs 81.3%) and box trainer (90.4% vs 77.9%)[23]. Another study found the MT group outperformed the control group in terms of overall performance

(17.05 vs 14.71)[28]. Whilst two studies[25,30] found no difference between control and MT groups using various performance measures, Mulla et al reported a poorer overall performance of the MT group compared to the control group on the box trainer and VRS[21].

In one study the mental imagery relaxation group performed significantly better than the group assigned to textbook learning (0.29 vs -0.26)[24]. However, the same team compared different proportions of MT and physical training sessions with inconclusive results[27].

In two studies, participants engaged in MT alongside other forms of training. One group compared MT with kinesiology to kinesiology alone and to advanced trauma life support training. It was concluded that MT and kinesiology when practised together yielded statistically superior results to the control group[29]. One longitudinal trial found that hypnosis-induced MT decreased peg transfer time significantly more than a music session[31].

Regarding participants' experience of MT, 87.5% of participants in one study found it beneficial[20] whilst another study reported a decrease in anxiety levels[31]. Another study found that 4 items of the mental imagery questionnaire (MIQ) significantly improved following MT with greater self-confidence and knowledge of the procedure. However, 4 items yielded non-significant results[32]. In another study, MIQ scores improved significantly in both novice surgeons (15 vs 42; p=0.005) and experienced surgeons (48 vs 53; p=0.007)[33]. Arora et al found a significant correlation between the MIQ scores and surgical performance as measured by OSATS scores[22].

Subgroup Analyses

High Quality Randomized Controlled Trials

Study quality of the 11 RCTs was assessed using the CONSORT score. Mean score was 13.4 /25 ranging from 6.5[29] to 18[25]. The relatively low mean scores emphasise the overall low quality of the studies. A CONSORT score of 16 or above was set as representing a higher quality study which 3 studies attained[26, 28, 30]. In this subgroup, 1 study found no significant difference between the MT intervention group and control[30], whilst 2 found MT to be beneficial[26, 28].

Longitudinal Trials

To qualitatively assess the 3 longitudinal studies, a 'Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group' was used[19]. Out of a maximum score of 11, two studies scored 6[31, 33] and the other scored 8[32]. These values also suggest studies of lower quality. Additionally Arora et al[33] did not test surgical performance directly following MT but instead carried out a mental imagery questionnaire to assess learning. All 3 studies concluded that MT was an effective educational tool.

Techniques for Mental Rehearsal Training

Mental rehearsal was used as part of the intervention in 12 studies of which 9 were within a group setting[20, 21, 22, 23, 24, 27, 29, 32, 33] and 3 were one-on-one with a MT educator[26, 28, 30]. Collating results from group mental rehearsal training, 7 studies found a significant benefit[20, 22, 23, 24, 29, 32, 33] whilst 2 found no significant benefit[21, 27].

Of the one-on-one training sessions, two studies concluded that mental rehearsal was significantly beneficial for surgical technique[26, 28]. On the other hand, Geoffrion et al 2012[30] reported similar findings between the MT and control groups.

Alternative MT Techniques

Jungmann et al [25] presented participants with an educational leaflet and CD-ROM on MT techniques and tying surgical knots with groups scoring similarly[25]. Sroka et al compared MT induced by hypnosis to a musical relaxation session[31]. Mental suggestions were used to aid visualization of the smooth peg transfer across a board. MT induced by hypnosis significantly decreased the time required to complete the peg transfer.

Duration of MT

Four studies provided limited or no information regarding the duration of MT sessions[20, 30, 32, 33]. The shortest MT session was only 5 minutes long but successfully improved simulated emergency cricothyrotomy performance[29]. Another MT programme advised participants to practice MT for 3 minutes at least 4 times a week. This programme yielded non-significant results[25]. Another study successfully engaged participants in 5, 30 minutes sessions of MT as opposed to an unrelated online activities carried out by the control group. [22].

Comparative analyses were performed based on duration of MT training programmes. Six studies included MT programmes that involved ≥30 minutes of engagement[21, 22, 23, 24, 26, 27] and 4 studies involved <30 minutes of MT engagement[25, 28, 29, 31]. 4/6 of the longer MT programmes[22, 23, 24, 26] and ¾ of the shorter MT programmes[28, 29, 31] found positive results.

Participant Experience

Results demonstrated a rising trend between level of expertise and the effect of MT. 6 studies enlisted medical students in their preclinical years[21, 23, 24, 25, 27, 29]. 3 studies demonstrated a significant benefit[23,24, 29]. Six studies enlisted novice surgeons[22, 28, 30, 31, 32, 33]. 5 studies found MT to be of significant benefit[22, 28, 31, 32, 33]. Three studies that recruited experienced surgeons concluded MT to be a beneficial training tool[20, 31, 33].

Discussion

This systematic review has analysed all RCTs and longitudinal trials assessing the role of MT in surgical education. Ten studies demonstrated MT to be beneficial and four found no marked effect. These results could suggest a MT to be a beneficial component of surgical education.

MT has been validated in sport and music to facilitate skill-learning and performance[34, 35]. Whilst MT has shown to induce similar neuroplastic changes as physical training[16, 17], it has been suggested that MT targets the cognitive component of a task whilst physical practice improves motor components e.g. coordination and power[35, 36]. Similar findings can be extracted from studies concerning surgical education. Immenroth et al observed greater task-specific checklist scores (cognitive component) in the MT group whilst the practical training group achieved greater global rating scores (motor component) [26].

Mental rehearsal was the commonest form of MT utilised. Participants were given a script or engaged in group or one-on-one MT with a MT expert. Sensory cues and detailed instructions facilitate a more accurate representation of the mental task[37].

In order to capture all available data, both RCT and longitudinal trials were included in this review. As demonstrated by their qualitative assessment scores, these studies were generally of lower quality with main limitations pertaining to lack of randomisation and blinding methodology and small study sizes. Only five studies provided sufficient detail to allow replication[21, 22, 23, 26, 28] whilst many studies alluded to a MT protocol or script without elaboration. In 2 cases, medical students were advised to practise MT at home for a set duration of time[21, 25]. These tasks were not followed up and therefore results may not represent the duration and quality of MT as described in the methodology.

Heterogeneity of outcome measures prevented direct comparison between studies. Whilst various validated global rating scales were utilized to assess the surgical skill of participants, 5 studies based their assessment on metrics such as peg transfer time which may not correlate with overall surgical performance[21,23,24,25,31]. Furthermore, 9 studies evaluated performance through the use of assessor scores [20,22,24,26,27,28,29,30,32]. These subjective results may not be reliable, especially as two studies used a single assessor to evaluate performance [20,27].

Conflicting data exists around best practice in MT. One review assessed MT across a number of disciplines involving education, music, sports, medicine and psychology to evaluate the most effective design structure. Longer and more frequent MT programmes were most effective[38]. However another meta-analysis concluded no significant relationship between the number of MT trials and overall performance. There was also a negative correlation between MT duration and cumulative improvement in performance[35]. It may be that time engaged in MT is less important than programme quality, a variable that was difficult to measure with inadequate information.

The results of this systematic review have demonstrated a rising trend between level of expertise and the benefit yielded from MT suggesting a greater effect when introduced further along the educational ladder. However, definitions of expertise varied between studies. Sroka et al defined expert surgeons having completed >2000 LP[31] whilst expert surgeons had completed >100 LP in another study[33]. Taking results at face value may therefore be affected by these contrasting definitions. Most studies focused on skill acquisition amongst lesser-qualified medical personnel, despite much evidence that elite athletes benefit most from MT in comparison to novice athletes who risk practicing and reinforcing a poor technique[35,39].

Whilst three studies specified the inclusion of medical students with no prior laparoscopic experience[21,23,25], only two groups were able to practice the surgical skill prior to assessment[23,25]. The remaining study did not allow students the opportunity to learn the physical procedural steps prior to MT[21]. In this case, the term mental 'rehearsal' may not be appropriate, as subjects had no physical experience to mentally simulate.

More recent studies used electroencephalogram recordings to compare the cognitive engagement and mental workload in novice and expert surgeons. They found that novices employed high-level engagement and high mental workload whilst experts tended towards low-level engagement and a lower mental workload[40, 41]. A high mental workload could correlate to the amount of focus a surgeon directs towards their physical movements throughout a procedure. As procedures become more familiar, automated movements allow expert surgeons to perform surgery with minimal mental effort whilst concurrently responding to other stimuli in the operating theatre.

Conclusion

Overall the literature regarding MT in surgical education is of low quality and methodological differences make it difficult to compare results. However, amongst more experienced surgeons, evidence for the role of MT within surgical training is seen. Addressing higher quality studies in isolation, they were all one-on-one training and recruited participants enrolled in higher training. When delivered appropriately to a suitable cohort, MT has the potential to form an inexpensive but effective component of the surgical curriculum. Based on current evidence, the authors advocate incorporation of MT into the current modular training pathway for surgery. Following basic virtual reality and dry lab training, MT should be used to support procedure specific training and modular training within the OR (figure 2). However, more research is required to determine how best to incorporate MT into the surgical curricula.

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Table and Legends

Figure 1. PRISMA Flow Diagram

Figure 2. Proposed Surgical curriculum incorporating Mental Training