Mental Practice: Effective Stress Management Training for Novice Surgeons

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BACKGROUND: Surgeons are often subject to excessive levels of acute stress that can impair their performance. Mental practice (MP) is a strategy used in other high-performance industries to alleviate anxiety. This study investigated if MP reduces stress in novice surgeons.

STUDY DESIGN: A prospective, randomized controlled design was used with 20 novice surgeons recruited by random sampling. After baseline testing, participants underwent training on an evidence-based virtual reality (VR) curriculum. They then performed 5 VR laparoscopic cholecystectomies (LC) after being randomized to MP or control groups. The MP group performed 30 minutes of MP using a validated MP training protocol before each LC; control participants conducted an unrelated activity. Stress was assessed subjectively using the validated State-Trait Anxiety-Inventory (STAI) questionnaire and objectively with a continuous heart rate (HR) monitor and salivary cortisol. Mental imagery was assessed using the validated mental imagery questionnaire.

RESULTS: Eighteen participants completed the study. There were no intergroup differences in baseline stress, imagery, or technical ability. Comparing the MP group with controls, subjective stress (STAI) was lower for the MP group (median 8.40 vs 11.31, $p < 0.01$). Objective stress was also significantly reduced for the MP group in terms of the average HR (median 72 vs 88 beats/minute, $p < 0.0001$), maximum HR (median 102 vs 119 beats/minute, $p < 0.01$), and cortisol (median 2.26 vs 3.85 nmol/L, $p < 0.05$). Significant negative correlations were obtained between stress and imagery, indicating that improved imagery was associated with lower stress ($p < 0.05$).

CONCLUSIONS: A short period of MP reduces the subjective, cardiovascular, and neuroendocrine response to stress on a VR simulator. Additional research should determine whether this effect extends beyond novice surgeons and transfers to the operating room. (J Am Coll Surg 2011;212: 225–233. © 2011 by the American College of Surgeons)

Surgical science is rapidly advancing as new technologies and techniques continue to emerge at an unprecedented pace.[1] Developments such as laparoscopic surgery have significantly benefitted patients. However, they have also led to a paradoxical increase in the level of acute stress experienced by surgeons who must overcome new challenges in order to safely complete a procedure.[2-4] Compounded with the demands of managing critically ill patients, meeting service delivery targets, and making crucial decisions, it is easy to see why surgery is a stressful enterprise.[5,6] This is of particular concern to patient safety because the research literature outside of the surgical domain has shown that excessive stress adversely affects not only cognitive processes such as memory, attention, and concentration, but also performance of complex motor skills.[7-9] Within surgical research, there is growing evidence on the effects of chronic stress and burnout on both surgeons and the incidence of medical errors.[10,11] The construct of acute stress, however, has received far less attention. Although a small degree of acute stress can facilitate task execution (and may indeed be one of the attractions of a surgical career), excessive levels can have the opposite deleterious effect.[12-14] Importantly, evidence shows that surgeons are subject to ex-

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Abbreviations and Acronyms

HR = heart rate
ISAT = Imperial Stress Assessment Tool
LC = laparoscopic cholecystectomy
MIQ = Mental Imagery Questionnaire
MP = mental practice
OR = operating room
STAI = State Trait Anxiety Inventory
VR = virtual reality

cessive levels of stress in the operating room (OR) and believe it to be detrimental to their skills.[15,16]

A recent systematic review on the impact of stress concluded that it does impair surgical performance, most prominently in novice surgeons.[17] With further reductions in work hours, the notion of stress management training for surgeons is becoming increasingly popular. Although simulation techniques could be used to facilitate this (by providing additional experience), they rely on physical practice, which is costly and not widely available.[18,19] Interestingly, expert surgeons seem to have developed a variety of psychological coping strategies that have made them less prone to the effects of stress.[20,21] By examining such strategies, it may be possible to develop effective stress management programs for novice surgeons.

One of the most popular strategies to reduce stress is mental practice (MP).[16,22] MP is a systematic form of mental rehearsal in which people imagine themselves performing an action without engaging in the actual physical movements involved.[23] Research shows that MP not only enhances physical performance but can also improve cognitive skills.[24] Furthermore, responses to stressful stimuli can be moderated by visualization.[25] This latter finding may be due to the proposed overlap of neural representations between imagery, perception, and motor execution.[26] According to this hypothesis, imagining an emotional event may activate similar autonomic responses to those elicited by actually experiencing the imagined event or situation. Outside surgery, MP has been shown to be an effective strategy in reducing self-reported stress and anxiety in elite athletes.[27,28]

Within surgery, MP has been validated as a training strategy for laparoscopic surgery.[29] Evidence suggests MP enhances the mental imagery of both novice and experienced surgeons[29] and results in better technical performance. The consequences of mental imagery training on acute stress, however, are largely unknown. The aim of this study was to determine the effects of MP on surgeon stress. The hypothesis is that participants who mentally practice the task will be less stressed than those who do not when they actually perform it.

METHODS

Participants

Twenty novice surgeons were recruited by random sampling from one university hospital. Participants were deemed eligible to be included only if they had never performed any surgical procedure previously, but did have the opportunity to assist others in the OR. This ensured that they were true novices. To avoid potential confounding variables, participants who had any known systemic illness such as hypertension, diabetes mellitus, or affective disorders were not enrolled. In addition, only participants who were available during the study period (February 2008 to April 2008) were deemed eligible for inclusion. Approximately 45 (of 152) participants met all these inclusion criteria, all of whom were invited. The first 20 who responded were recruited to the study. Informed consent was obtained from all participants; ethical approval was obtained from St Mary's local ethics committee.

Materials

The following instruments were used in this study:

1. The LAP Mentor VR laparoscopic surgical simulator (Simbionix Corporation). This is a full procedural VR simulator that has been validated for laparoscopic cholecystectomy (LC).[30]
2. MP script and training protocol. A validated MP training strategy was used to provide MP training for participants in this group. Full details of this can be found elsewhere.[29] Briefly, participants watched a video of an expert surgeon performing a live LC to gain a mental representation of the task. Then, they practiced guided imagery with a facilitator using an MP "script." This script contained a sequence of procedural steps for the task but, in addition, a set of detailed and vivid imagery cues designed to enrich participants' mental representation of the skill being learned. Finally, participants were asked to independently mentally practice the procedure. A methodologic check on the efficacy of the MP was conducted using the Mental Imagery Questionnaire.
3. Imperial Stress Assessment Tool (ISAT). The ISAT is a reliable and validated (content, construct, and concurrent) instrument that captures stress in surgeons.[31] This multidimensional tool comprises 3 measures: heart rate (HR), salivary cortisol, and the State Trait Anxiety Inventory (STAI).[32] HR and cortisol capture objective stress; STAI is a self-report questionnaire that measures subjective levels of stress. It contains 6 items, each assessed on a 4-point Likert scale (minimum 6, which equates to lowest stress; maximum 24, which equates to highest stress).

3. Mental Imagery Questionnaire (MIQ). This is a validated self-report questionnaire designed to capture surgeons' private experience of their mental imagery.[29] It contains 8 items that measure visual and kinesthetic imagery as well as confidence. The MIQ acted as a "manipulation check," which empirically quantified whether the MP or control group had better imagery, rather than making biased assumptions.

Study procedure

Baseline levels of stress (STAI, cortisol, and HR) and technical skill (using the withdraw and insert task on the validated MIST-VR simulator [Mentice Inc])[33,34] were initially assessed to ensure that all participants were comparable. To ensure that all participants had a comparable level of baseline mental imagery ability, they were given the Group Mental Rotations Test (Vandenberg and Kuse, 1978).[35] The Group Mental Rotations Test is 20-item, psychometrically robust, objective test of imagery control that requires subjects to make judgments about the orientation of various 3-dimensional figures.

Next, in order to ascertain that all participants were equally familiar with the task that they were required to perform (ie, an LC), participants were trained to proficiency on a LapSim simulator (Surgical Science) using an evidence-based, validated VR curriculum.[36] This stepwise training of procedural skills further ensured that participants were comparable in terms of baseline psychomotor proficiencies.

All 20 participants were then randomly allocated either to the intervention condition (ie, MP) or to the control condition using the closed envelope technique. This resulted in 10 participants per study group. Each participant performed 5 LCs (1 LC/day for 5 consecutive days on the Lap Mentor simulator at around the same time each day). Before performing each LC, each participant in the MP group completed 30 minutes of MP using the validated MP training protocol; the control group completed 30 minutes of an unrelated online activity (watching a pathology lecture). After assignment either to MP or control group, each participant completed the MIQ. Participants were also explicitly asked to keep the details of their sessions confidential to minimize cross-contamination.

Because the participants were all novices, no extraneous stressors were imposed; the inexperience with the task itself was designed to act as the stressor. Subjective stress was assessed by asking participants to complete the validated STAI questionnaire before and after each LC. At the end of each LC, participants rated how stressed they felt during the LC (retrospective assessment) and how they felt at the present moment, ie, after performing the task. Cortisol was measured by asking the participant to chew on a salivette (Sarstedt) for 1 minute immediately before and after completing each LC. Saliva was stored at –20 °C until biochemical analysis took place. Finally, HR was measured by asking surgeons to wear a wireless Polar S710i continuous heart rate monitor (Polar-Electro Inc) throughout the task. Data were captured by a wireless data recorder worn on the surgeon's wrist in the form of a sports watch. It was then transferred to a personal computer by infrared, and the mean and maximum HRs were analyzed using Polar precision performance software. Figure 1 shows the procedure for each of the 5 LC sessions.

Outcomes measures

The primary outcomes measure was the surgeons' stress level, as measured by STAI, HR, and cortisol (ISAT). The secondary outcomes measure was mental imagery, as assessed by the validated MIQ.

Statistical analysis

SPSS v 16.0 (SPSS) was used for descriptive analyses. In accordance with the nonparametric nature of the data, a Mann-Whitney U test was used to test for significant differences in baseline measures between the 2 groups. The same test was used to determine if there was any difference between the MP and control groups in terms of imagery and stress indices. Here the individual trials were analyzed separately without any consideration of correlations within person across trials.

In addition, the overall mean and maximum HRs were computed by taking a median of the 5 sessions, giving a single measurement for each participant across the 5 trials. The overall pre- and post-task cortisol was calculated in a similar manner. In addition, a score for "total STAI" per participant was computed by taking the median across the pre-, intra-, and post-task phases. This was important in giving a measure of subjective stress across each entire session, as opposed to just the individual discrete phases. These metrics were subsequently aggregated across participants by examining the median HR/cortisol concentration/STAI score of the entire group (mental practice vs control). A Mann-Whitney test was again used to test for any significant differences between the 9 summary variables (overall mean/maximum HR, overall pre-/post-task cortisol, total STAI) between the MP group and the control group. Spearman rho correlations were used to test for the relationship between imagery and stress for each of the 5 sessions. Spearman rho correlations were also used to test for the relationships between the stress measures to ensure concurrent validity. For all tests, a criterion level of $p < 0.05$ was set for establishing statistical significance.

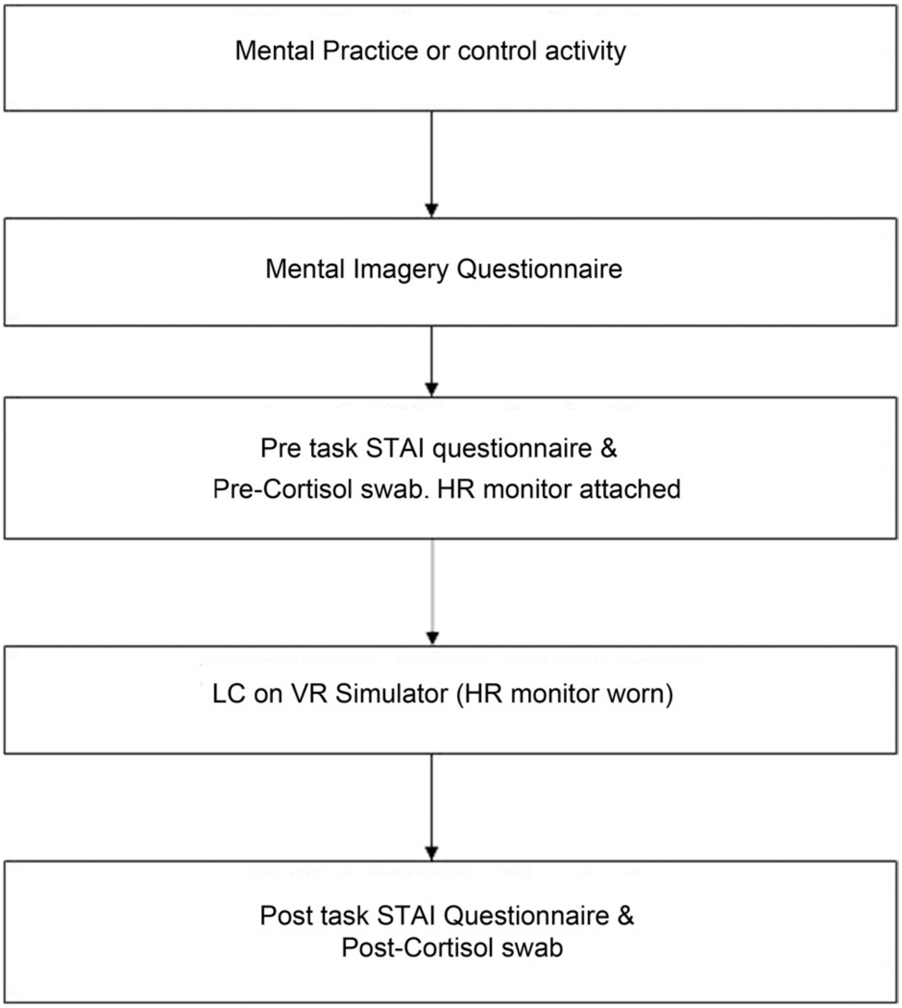

Figure 1. Experimental procedure within each session. HR, heart rate; LC, laparoscopic cholecystectomy; STAI, State Trait Anxiety Inventory; VR, virtual reality.

RESULTS

Baseline skills assessment

Eighteen participants completed the study (all 5 LCs). Two withdrew due to scheduling difficulties. There were no intergroup differences detected in terms of baseline technical ability, stress, or imagery ability at the start of the study (Table 1).

Physiologic outcomes measures: heart rate

The MP group had lower mean ($p < 0.001$) and maximum HRs ($p = 0.008$) overall compared with the control group. More detailed analysis revealed that the mean HR was significantly lower for each of the 5 LCs performed (Fig. 2A); first LC (77 vs 96 beats/minute, $p = 0.001$), second LC (76 vs 92 beats/minute, $p = 0.001$), third LC (74 vs 88 beats/minute, $p = 0.003$), fourth LC (78 vs 87 beats/minute, $p = 0.042$), and fifth LC (71 vs 88 beats/minute, $p = 0.007$). For the MP group, the maximum HR was also significantly lower for all LCs performed except the first (Fig. 2B). Here the effect was in the expected direction (MP 110 vs control 118 beats/minute), but not statistically significant ($p = 0.18$).

Physiologic outcomes measures: cortisol

Overall, there was a significant difference in the pretask cortisol for the MP group compared with the control group ($p = 0.011$). This suggested that members of the MP group were less stressed at the start of the task. Detailed analysis of results for all 5 sessions revealed that this effect was significant for the first LC (2.02 vs 3.57 nmol/L, $p = 0.013$), second LC (1.98 vs 3.66 nmol/L, $p = 0.021$), and third LC (2.26 vs 3.99 nmol/L, $p = 0.012$). The same beneficial effect was seen for the fourth LC (2.26 vs 2.45 nmol/L,

Table 1. Demographics and Baseline Measures across Mental Practice and Control Groups

Variable	Parameter	MP	Control	MP versus control, p value
Demographics	Age, y, median (range)	22 (21–23)	22 (20–23)	—
	Handedness, n	R:L 8:1	R:L 9:0	—
	Experience	<1 LC	<1 LC	—
Technical skill	Time, sec median (range)	53.9 (29.9–86.1)	50.0 (42.0–147.1)	0.51
	Economy of motion, path length median (range)	4.7 (3.0–7.0)	5.1 (3.6–11.6)	0.38
	Errors, n median (range)	88 (9–139)	75 (48–240)	0.57
Stress	Heart rate, median beats/min (range)	84 (62–90)	76 (62–86)	0.14
	Cortisol, median nmol/L (range)	2.40 (1.48–7.62)	2.56 (1.58–4.88)	0.61
	STAI median (range)	7.5 (6–14)	10 (6–13)	0.82
Imagery ability	Mental rotations score, median (range)	20 (8–25)	20 (14–28)	0.23

Mann-Whitney U test was used to test for differences between groups.
MP, mental practice; STAI, State Trait Anxiety Inventory.

p = 0.37) and fifth LC (2.85 vs 3.59 nmol/L, p = 0.82), although this did not reach statistical significance (Fig. 3A).

A similar pattern was obtained for the cortisol sample taken immediately after task performance. The MP group had a significantly lower cortisol for the first LC (1.45 vs 2.31 nmol/L, p = 0.015), second LC (1.78 vs 3.36 nmol/L, p =.012), and third LC (1.42 vs 4.41 nmol/L, p = 0.027). Again within the MP group, cortisol was lower for the fourth LC (1.89 vs 1.71 nmol/L, p = 0.60) and fifth LC (2.00 vs 2.68 nmol/L, p = 0.42), although not significantly so (Fig. 3B).

Subjective outcomes measures: STAI

The MP group reported statistically lower levels of stress during the task for all 5 sessions (Table 2). Immediately before and after completing the task, subjective stress was still lower for the MP group, but this difference was

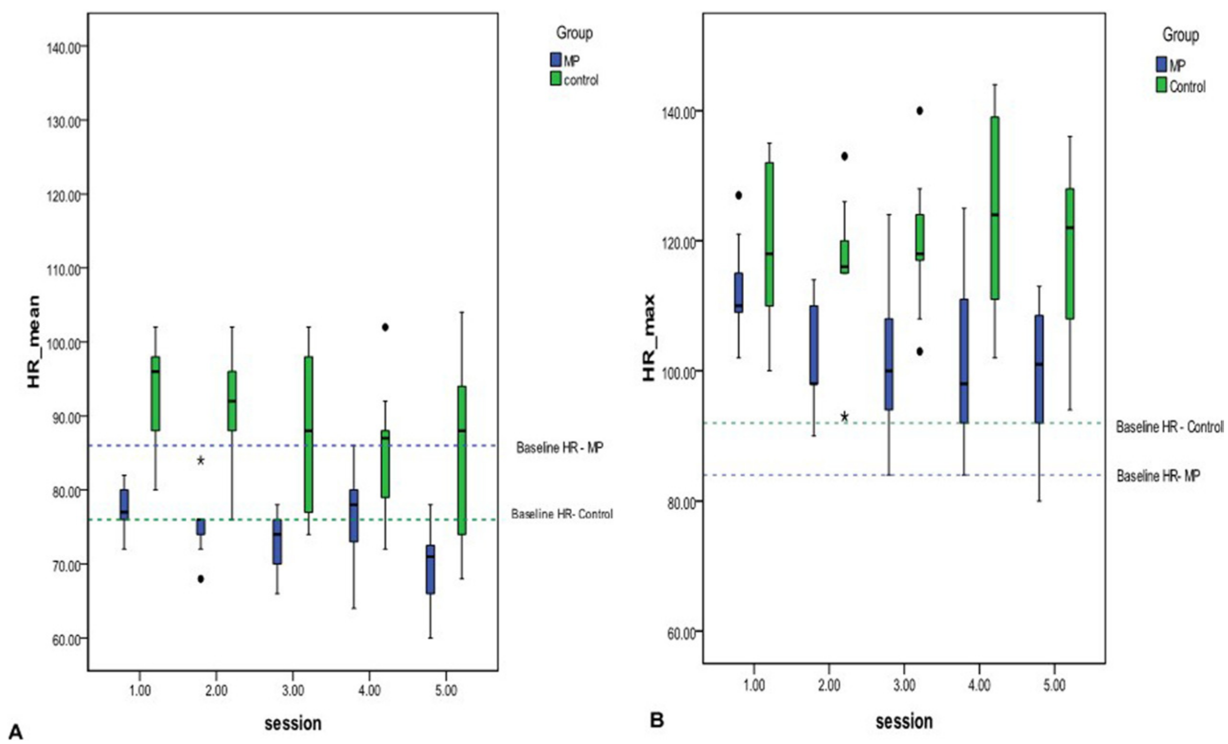

Figure 2. (A) Mean heart rate (HR) across 5 sessions for mental practice and control groups. (B) Maximum HR across 5 sessions for mental practice and control groups.

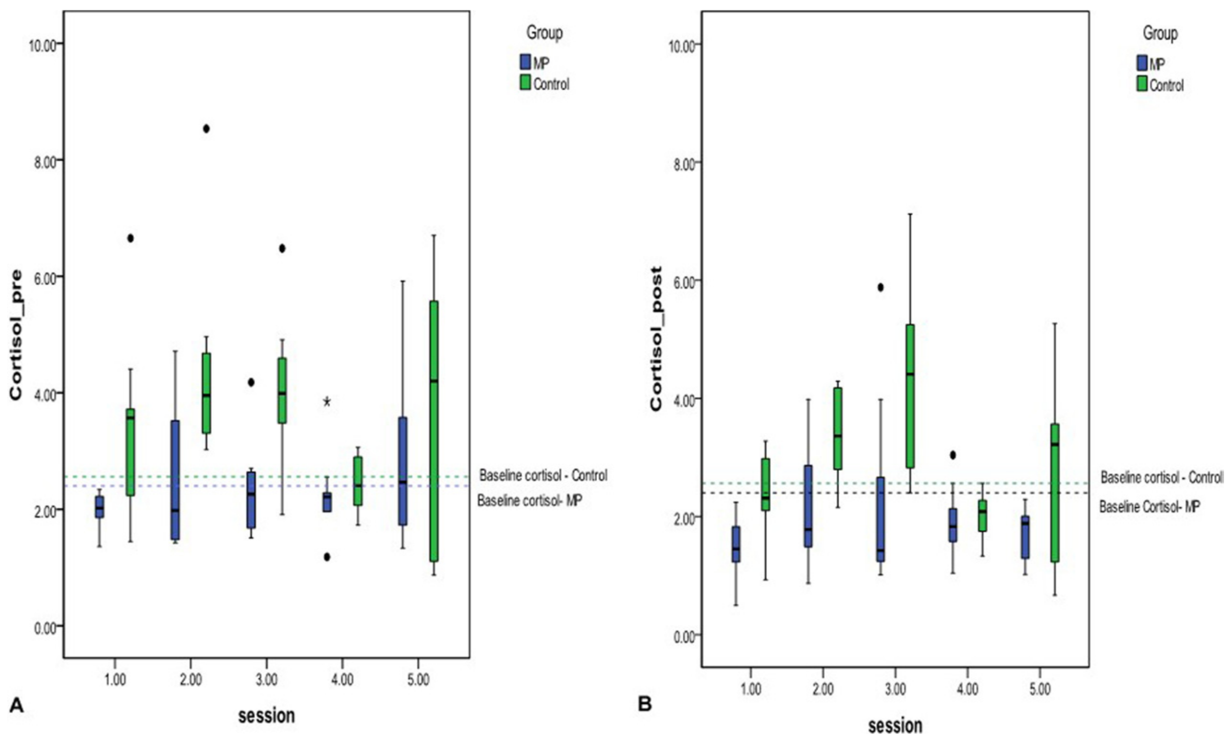

Figure 3. (A) Precortisol across 5 sessions for mental practice and control groups. (B) Postcortisol across 5 sessions for mental practice and control groups.

statistically significant for only the first, third, and fourth LCs. Regarding total stress across the procedure, the MP group was significantly superior for all except the final LC (session 5).

Intercorrelations of stress indices (concurrent validity)

Correlational analyses between the stress indices across all 5 LCs revealed that total subjective stress (total STAI) correlated significantly positively with the objective measures (cortisol and mean HR). Furthermore, the 2 objective measures significantly correlated with each other, suggesting that we were indeed measuring acute mental stress (Table 3). This provides additional evidence for the concurrent validity of ISAT in a simulation setting (having been previously tested in a real OR).[31]

Mental imagery

The mental imagery score for the MP group was significantly higher than for the control group for every session: first LC (46 vs 26, $p = 0.002$), second LC (49 vs 34, $p = 0.003$), third LC (50 vs 39, $p = 0.001$), fourth LC (52 vs 38, $p < 0.001$), and fifth LC (53 vs 39, $p < 0.001$). A correlational analysis demonstrated that changes in stress levels were inversely related to imagery. That is, the higher the imagery scores, the lower the level of stress experienced by participants (Table 4).

DISCUSSION

Acute intraoperative stress impairs surgical performance and may compromise patient safety.[17] This study is the first to show that a short period of MP training can attenuate the psychological, neuroendocrine, and cardiovascular re-

Table 2. Subjective Stress Experienced by Mental Practice and Control Groups across 5 Study Sessions

	Session (LC) mental practice versus control (median values)				
Variable	**1**	**2**	**3**	**4**	**5**
STAI pre-LC	9 vs 12†	6 vs 10	6 vs 10†	6 vs 8†	6 vs 8
STAI during LC	9 vs 13†	9 vs 14†	7 vs 12†	6 vs 10*	6 vs 9*
STAI post-LC	6 vs 10†	7 vs 10	6 vs 10*	6 vs 8*	6 vs 10
STAI total	8.33 vs 12‡	7.66 vs 10*	6.33 vs 10.66†	6 vs 8.66*	6 vs 9

Mann-Whitney U test used to test for differences between groups. Statistical significance as follows: * $p < 0.05$; † $p < 0.01$; ‡ $p < 0.001$.
STAI, State Trait Anxiety Inventory; LC, laparoscopic cholecystectomy.

Table 3. Spearman Correlation Coefficients between Subjective (STAI) and Objective Stress Indicators

Variable	STAI total	Cortisol, pre	Cortisol, post	HR, mean	HR, maximum
STAI total	1				
Cortisol, pre	0.83†	1			
Cortisol, post	0.68*	0.86†	1		
HR, mean	0.73†	0.72†	0.65*	1	
HR, maximum	0.44	0.46	0.34	0.72†	1

Statistical significance as follows: * $p < 0.05$; † $p < 0.01$.
HR, heart rate; STAI, State Trait Anxiety Inventory.

sponse to acute stress in novice surgeons in a simulation-based setting.

In this study, the data regarding HR, cortisol, and STAI are analogous to those found in other studies involving surgeons under stress.[37,38] Furthermore, the reduction in the neuroendocrine and cardiovascular response to stress is comparable to that found by others who used a stress management intervention, confirming that these indices can be influenced by stress reduction strategies.[39,40] With regard to the fact that both the subjective and physiologic responses differed between the intervention and control groups, it seems appropriate to conclude that the MP intervention program acted as an effective stress reduction strategy. This conclusion mirrors the findings in the sport psychology literature, which suggest that apart from improving cognitive skills, MP can lead to measurable psychophysiologic changes.[26,41] Clues to the possible mechanisms underlying this latter effect come from the bioinformational theory of MP.[42] This theory postulates that the psychophysiologic effects of MP training are due to the visualization triggering the same signs of emotional arousal as actual perception.[25] So MP may have acted as a form of stress inoculation training for the surgeons in our study. If this is correct, then the stronger one's imagery of the task, the better the mental experience and the less the stress. Significant correlations between imagery and stress indicate that this was the case, lending support to this claim.

Several methodologic issues related to this investigation need to be discussed. First, care was taken to obtain all relevant baseline measures. This strategy ensured that our participants were truly comparable in terms of skill, stress, and imagery ability. Second, the use of a prospective randomized design, conducted in carefully controlled conditions, provides a robust platform for confidence in our findings that MP reduces stress in a surgeon while performing an LC. Put simply, such a design makes it very unlikely that the reported results were influenced by pre-existing individual differences between the groups. In addition, care was taken to ensure that both groups remained unaware as to whether they were in the intervention arm because all participants conducted some form of an activity with faculty presence. This helped minimize reporting bias. Furthermore, although the control group had lower levels of stress during the later procedures (indicating a trend toward stress reduction by virtue of participation alone), they still remained statistically inferior to the MP group. This suggests that MP may shorten the learning curve and distill the benefits of experience to novice surgeons. The significant correlations obtained between the 3 stress indices further corroborate this claim. Finally, the use of a clear and explicit MP protocol with a manipulation check overcame many of the previous limitations of research in this field. As well as revalidating its use to improve imagery, this protocol renders our training transparent, allowing for reproduction of our methods and the benefits of this approach to be available to others.

Because the procedure was conducted on a simulator and with novice participants in a single institution, more data will need to be collected in order to determine the degree to which this positive effect of MP transfers to the OR and to expert surgeons. Evidence suggests that the OR is plagued by potential stressors, making it a rich test-bed for studies on MP.[15] Moreover, although we took care to choose an index procedure (LC), additional studies will be

Table 4. Spearman Correlations Between Total Stress (STAI) and Mental Imagery Scores across Study Sessions

	STAI 1	STAI 2	STAI 3	STAI 4	STAI 5
Imagery 1	−0.82†	−0.58*	−0.57*	−0.58*	−0.57*
Imagery 2	−0.73†	−0.66*	−0.54*	−0.66†	−0.61†
Imagery 3	−0.68†	−0.63**	−0.61†	−0.62†	−0.47*
Imagery 4	−0.78†	−0.53*	−0.65†	−0.53*	−0.49*
Imagery 5	−0.71†	−0.53*	−0.58†	−0.61†	−0.55*

Statistical significance as follows: * $p < 0.05$; † $p < 0.01$.
STAI, State Trait Anxiety Inventory.

required to investigate whether the reduction in stress using MP applies to more complex procedures. Further work should also note whether the supervision of trainees, as usually provided in the OR, moderates this effect. It should also be noted that although a positive effect of MP was found overall, when examining the individual sessions, there was no significant difference between the 2 groups in terms of cortisol for the final session. An explanation for this could be that the effect of MP may have decreased as the novices went up their learning curves, ie, gained more experience, or that a larger sample size may have allowed for an effect to be statistically demonstrated, as it was for STAI and HR. Further work should determine whether MP can also reduce stress in experienced surgeons. Finally, within the sports literature, it has been noted that the positive effects of MP tend to decline sharply over time.[23] A retention study would establish the degree to which the same holds true in surgery.

Regarding the wider implications of our findings, it must be emphasized that evidence on the detrimental effects of acute stress on surgeons and their performance is rapidly mounting.[17,43] Despite ongoing calls for stress management training, however, surgical trainees still typically learn from their mentors how to deal with stress informally, at best, or by trial and error at worst. Although such primary stress management is useful, its efficacy is largely dependent on minimizing external demands to reduce stress, which may not always be possible given the inherent unpredictability of the surgical setting. An alternative approach is to focus instead on increasing surgeons' perceived resources to cope with the challenges that they face. In this response-based approach, MP could be used as a secondary stress management strategy that could help prepare trainees to perform optimally under highly stressful conditions. Apart from its undoubted efficacy in this latter regard, MP training has the additional appeal of being relatively inexpensive and easy to run — features that make it an attractive option for surgical training in the current economic climate. Finally, integration of MP into the surgical curriculum may also help reduce stress in the long-term, minimizing the chronic effects of stress, including cardiovascular risk, on surgeons.

CONCLUSIONS

A short period of MP reduces the subjective, cardiovascular, and neuroendocrine responses to stress in novice surgeons on a VR simulator. More research should determine whether this effect extends beyond novice surgeons and transfers to the real operating room. If so, mental practice may be an inexpensive strategy that could be used to provide stress management training at all levels of surgical education.

Author Contributions

Study conception and design: Arora, Sevdalis, Aggarwal, Moran, Kneebone, Darzi

Acquisition of data: Sirimanna, Arora, Crochet

Analysis and interpretation of data: Arora, Sirimanna, Sevdalis, Aggarwal, Crochet, Moran, Kneebone, Darzi

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Critical revision: Arora, Sevdalis, Kneebone, Moran, Sirimanna, Crochet, Aggarwal, Darzi

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