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ORIGINAL SCIENTIFIC REPORT

Cognitive Assessment of Surgeons During Surgical Procedures: Influence of Time and Intraoperative Complications

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Abstract

Introduction Surgeon's performance may be influenced by several factors that may affect skills and judgement, which ultimately represents surgeon´s cognition. Cognition refers to all forms of knowing and awareness, such as perceiving, conceiving, remembering, reasoning, judging, imagining, and problem solving. This report aims to evaluate the effect of operative time and operative complications on surgeon´s cognition.

Methods Forty-six surgeons (mean age 31 years, 78% males) assigned to an operation expected to last for at least 2 h, volunteered for the study. All participants underwent 3 cognitive tests at the beginning of the operation and hourly, until the end of the procedure: (a) concentration (serial sevens, counting down from 100 by sevens); (b) visual (fast counting, counting the number of circles with the same color among a series of circles); and (c) motor (trail making, connecting a set of numbered dots). Intraoperative complications were recorded.

Results The visual test had a stable behavior along time. Concentration and motor tests tend to be performed faster. Intraoperative complications occurred in 5 (11%) cases (3 hemorrhage and 2 organ injuries). Performance time was stable for concentration and motor tests but visual test tends to be performed faster in cases with an intraoperative complication.

Conclusion Our results showed that (1) time does not jeopardize surgeons' cognition, but rather surgeons learned to perform the tests faster, and (2) complications do not decrease surgeons' cognition.

Introduction

Cognition refers to all forms of knowing and awareness, such as perceiving, conceiving, remembering, reasoning, judging, imagining, and problem solving [1]. Surgeons' performance may be influenced by several factors, from sleep deprivation [2] to operating room noise [3]. These and other distractors [4] may affect surgeons' skills and judgement [5], which ultimately represents surgeons' cognition. The evaluation of cognition may thus be an adequate tool to measure surgeons' performance.

Different tests have been used to evaluate surgeons' cognition: levels of tremor, proficiency, manual dexterity, errors, movement smoothness, accuracy, economy of movement, speed of movements, body axis stability, alertness, spatiotemporal coordination, etc. [5]. Most of these abilities, however, have been measured in a simulation setting. Moreover, the impact of long procedures and intraoperative complications on surgeons' cognition has not been fully studied. We hypothesized that the fatigue

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associated with long operations and the psychological burden of intraoperative adverse events could jeopardize surgeons' cognition measured by non-technical skills through learning, concentration, attention, memory, visual and motor abilities, and mental function.

This study aims to evaluate the effect of operative time and operative complications on surgeons' cognition.

Methods

Population

Forty-six surgeons (Table 1) assigned as the primary surgeon to an elective operation expected to last for at least 2 h volunteered for the study (Table 2). Each surgeon participated only once. If the procedure was performed by a junior surgeon, a more senior attending functioned as first assistant.

Exclusion criteria were: refusal to participate ($n = 8$) and color blindness ($n = 1$).

Cognitive tests

All participants underwent 3 cognitive tasks:

(1) *Concentration test (Serial sevens test)*. Individuals had to count down from 100 to 0 by sevens [6]. Wrong answer prevents continuation.
(2) *Visual test (Fast counting test)*. Individuals were asked to count the number of same-color circles among a series of 4 different colors circles in a 9 columns × 11 lines chart. Color was randomly chosen each time.
(3) *Motor test*: Trail making test A [7]. Individuals had to connect a set of 24 randomly dispersed numbered dots in a 6 columns × 4 lines chart. Sterilized pencils were used for the task.

Participants were instructed to perform the tests as fast as possible. The time for each test was recorded. All tests were applied at the beginning of the operation and hourly until the end of the procedure.

Table 1 Participants demographics and specialty

Age (years)	31.7 ± 6.5 [26–59]
Gender	78% males
Time from MD certification (years)	8.0 ± 6.5 [2–34]
Surgical specialty	
Head and neck	11 (24%)
Gastrointestinal	10 (22%)
Plastic	9 (20%)
Urology	3 (6%)
Gynecology	3 (6%)
Transplantation	2 (4%)
Ophthalmology	2 (4%)
ENT	2 (4%)
Orthopedics	1 (2%)
Thoracic	1 (2%)
Vascular	1 (2%)
Pediatric	1 (2%)

Variables presented as mean ± standard deviation [range]

Table 2 List of operations

Specialty	Procedure	*n*
Gastrointestinal	Gastrectomy	5
	Proctosimoidectomy	2
	Laparotomy	3
	Inguinal hernia	1
	Esophagectomy	1
Head and neck	Mandibulectomy	3
	Parathyroidectomy	2
	Thyroidectomy	2
	Pharyngealcutaneous fistula closure	2
	Cervical lymphadenectomy	1
	Laryngectomy	1
Plastic	Dermolipectomy	5
	Rhinoseptoplasty	2
	Inguinal lymphadenectomy	2
Urology	Prostatectomy	3
Gynecology	Hysterectomy	
Transplantation	Liver harvesting	2
Orthopedics	femoral osteosynthesis	1
Ophthalmology	Orbitectomy	2
ENT	Nasopharyngeal angiofibroma resection	1
	Tympanoplasty	1
Thoracic	Sternochondroplasty	1
Vascular	Saphenectomy	1
Pediatric	Colonic pull-through	1

Intraoperative complications

Intraoperative complications were considered as grade II or higher from the CLASSIC classification [8]. In summary, excessive bleeding, organ damage needing repair, and severe hemodynamic changes were defined as intraoperative complications.

Statistical analysis

Variables are presented as mean ± standard deviation [range]. $p < 0.05$ was considered significant. Mann–Kendall test was used to assess temporal trend.

Ethics

The study protocol was approved by the local ethics committee, and the written informed consent was obtained from each subject.

If surgeons were not able to leave the operative field at the moment of the tests, the tests were postponed to a safer moment in order to avoid harm to patients.

No conflict of interest was present. All authors contributed sufficiently to be named as authors and are responsible for the manuscript. No professional or ghost writer was hired.

Results

All individuals completed the tests. The duration of the operations was 1, 2, 3, 4, and 5 h in 7 (15%), 23 (50%), 16 (35%), 7 (15%), and 2 (4%), respectively.

Cognitive tests and operative time

The time to perform the tasks according to operative time is shown in Fig. 1. The visual test had a stable behavior during the operation (coefficient of variation 0.14, Mann–Kendall statistics −3, confidence factor 64%). Concentration and motor tests tend to be performed significantly faster along time (coefficient of variation 0.30 and 0.14, Mann–Kendall statistics −15 and −11, and confidence factor 99.9 and 97.2%, respectively).

Cognitive tests and intraoperative complications

Intraoperative complications occurred in 5 (11%) cases: 3 excessive hemorrhage and 2 inadvertent organ injuries. One occurred between the beginning of the operation and the first hour, and the other 4 between the first and second hour of the operation. The mean operative time in the cases with adverse events was 170 ± 53 [70–192] min.

The time to perform the tasks according to operative time and moment of complications is shown in Fig. 2. Performance time was stable for concentration (coefficient of variation 0.34, Mann–Kendall statistics −4, and confidence factor 83%) and motor (coefficient of variation 0.12, Mann–Kendall statistics −4, and confidence factor 83%) tests. Visual tests tend to be performed significantly faster (coefficient of variation 0.06, Mann-Kendall statistics −6, and confidence factor 96%). Tests were postponed in 4 out of 5 cases due to the occurrence of complications. The mean delay was 31 ± 7 [20–35] min.

Discussion

Our results showed that (1) time did not jeopardize surgeons' cognition, but rather surgeons learned to perform cognitive tests faster and (2) complications also did not decrease surgeons' cognition.

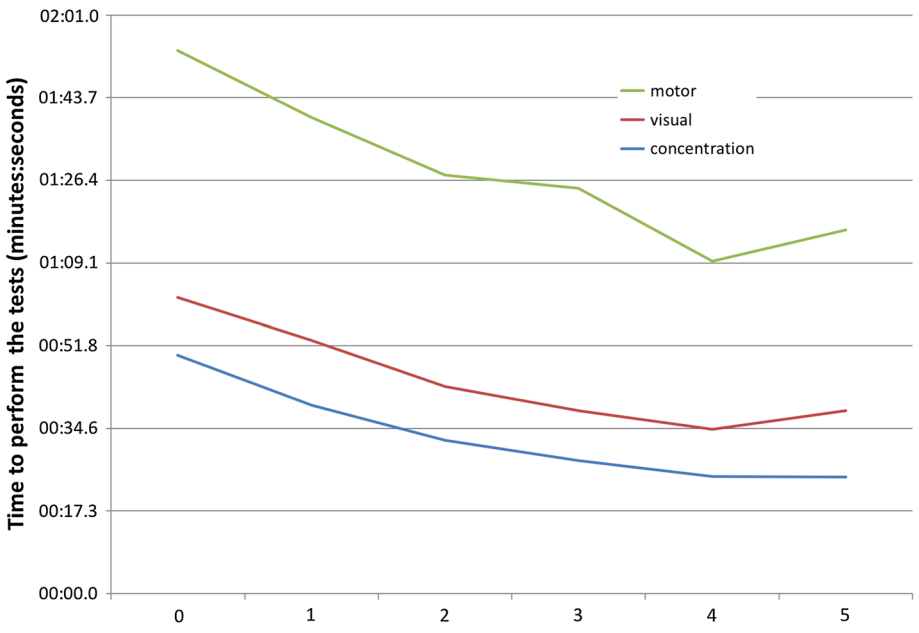

Fig. 1 Time to perform cognitive tasks according to operative time

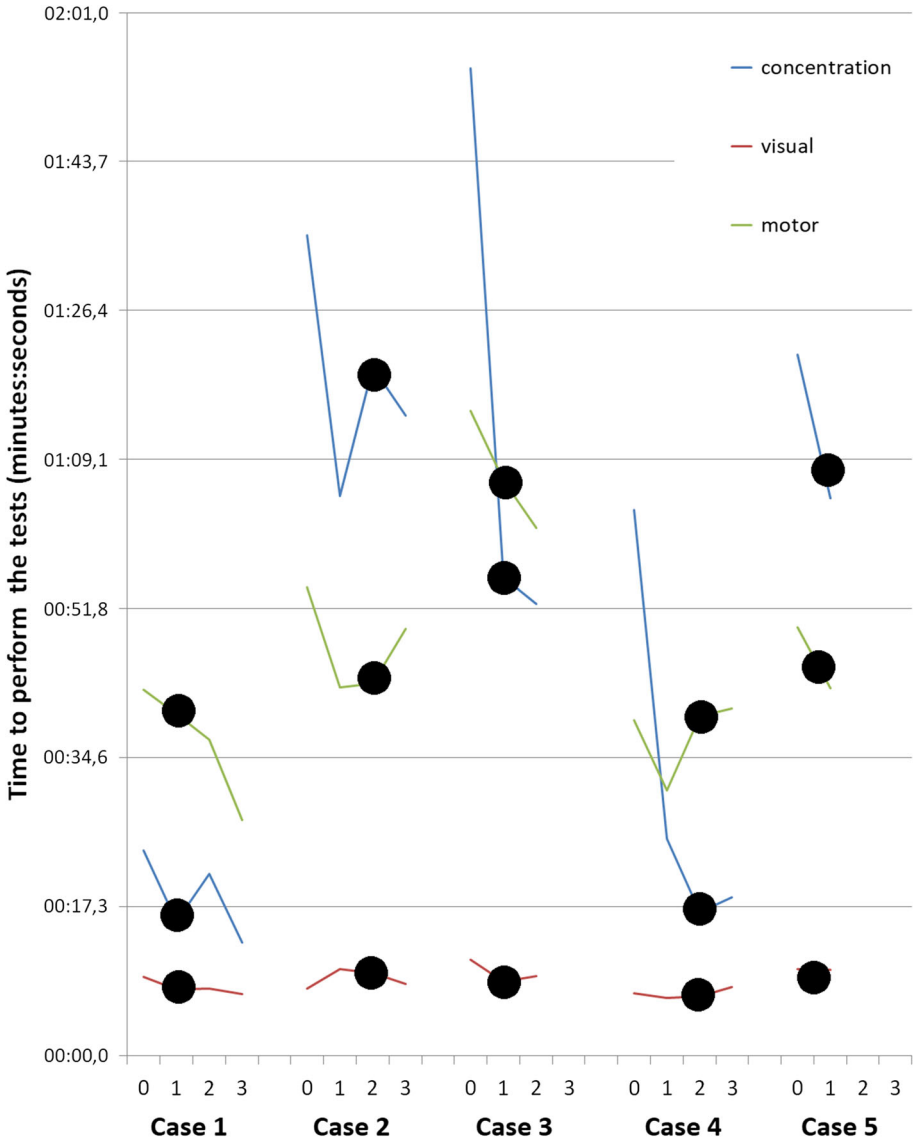

Fig. 2 Time to perform cognitive tasks in the cases that an intraoperative complication occurred (n = 5). Circles indicate the moment of the complication

Several previous studies focused on operative team performance and operating room (OR) environment. Interestingly, findings, such as the fact that noise in the OR may increase surgical-site infection rates [9] but music increases the speed and accuracy of surgeons [10], show that perioperative milieu affects directly surgical outcomes and patient care.

Evaluation of surgeons' cognition

We chose 3 different measures of cognition to record surgeons' mentation: visual [11], concentration [6], and motor tests [7]. We had to choose tests to be used during a real operation. We looked for adequacy in a sterile field, short duration, easy to be performed, free access, reproducibility, and evaluation of different cognitive skills that we considered relevant for surgical performance even though neither test has been specifically used before or validated with the purpose of assess surgeons' cognition in the intraoperative period. The trail making test has been used in a simulated scenario to evaluate sleep deprivation on surgical residents' performance [12]. Most validated tests measure surgeons' performance in simulated scenarios though the speed and accuracy of repetitive and standardized tasks [13].

The concentration task used in this study is the serial sevens test that is now part of the Mini–Mental State Examination. It may be used not as a timed test but based on errors, which is more suitable to the evaluation of mental age in children though [14]. It is able to measure concentration, attention, memory, and mental function [14]. The discrimination of the number of forms with the

same color was used to test visual cognition. It evaluates attention, but mainly visuospatial ability. Motor skills were tested by trail making that also measures visual attention, visual search, and motor speed skills [7, 15]. It is part of the US Army General Classification Test. All tests may be influenced by education level and intelligence, but we believe that surgeons have similar levels of these characteristics.

Intraoperative breaks have been shown to be beneficial to surgeons and not detrimental to patients [16, 17], not offending ethical standards.

Effect of operative time on surgeons' cognition

Long operative time may influence surgeons' performance due to muscular and mental fatigue. Surgeons are faced with excessive strain and faulty ergonomics during operations that frequently leads to symptoms [18]. Long operations increase physical demand with a direct correlation between operative time and fatigue [19, 20]. Muscular fatigue as detected by electroneuromyography has been detected after only 45 min of operation [21]. Mental fatigue has been also recorded in surgeons performing operations. Concentration is decreased along time [17], and mental demand increased [20]. Despite all this evidence that long operation time increases surgeons' physical and mental workload, our results did not show a decrease in cognition. Conversely, surgeons learned how to perform the tasks better. In fact, physicians and medical students may retain their ability to learn even under unfavorable conditions [22]. Interestingly, only the visual test was stable during time in our experiment, and it may demonstrate that visuospatial focus may be in high levels during an operation since it is an essential aptitude for surgeons, especially with minimally invasive surgery when eyes and hands are not directly connected via instruments. We would expect this behavior for the motor test since it should be more prone to muscular fatigue effects.

Effect of intraoperative complications on surgeons' cognition

The effect of intraoperative accidents or complications on surgeons' cognition has been studied in crisis management simulated scenarios [23]. There are no previous studies on real operations to the best of our knowledge. Our results show that cognition is not impaired by adverse course of the operation. Interestingly, visual cognition was improved showing again the value that surgeons apply to this skill. The small number of cases with complications and the fact that most complications occurred soon after the beginning of the operations unfortunately precluded a more detailed mathematical analysis of the time curves before and after the complication occurred.

Study limitations and strengths

Our study has some limitations.

First, this is a pilot study since the number of surgeons was not based on a formal sample size calculation. It was a convenience sample based on the number of long-duration procedures and surgeons available in the setting. We also limited each surgeon to participate only once since we anticipated that they would improve performance based on learning. This fact generated a small number of complications and precluded sub-analysis of data, including for example gender, age, and specialty that certainly may have some effect on results. Also, underpowering prevents meaningful comparison of the complicated and non-complicated operations.

Second, the experiment was not performed in a controlled environment provided by simulators, but rather in real cases. This may be advantageous to show reactions in real cases scenario but precluded a standardization of the operations. The same operation can have different difficulty and stress levels depending on the patient, on the comorbidities, and the disease. In addition, other stressors that could influence results were not recorded.

The study differs from previous studies by evaluating the cognition of a wide group of surgeons from different specialties, ages, and genders in real situations and includes the effects of intraoperative complications. The study of a larger number of procedures to allow sub-analysis of data and the comparison of emergency versus elective operations are next steps to further understand the topic. In addition, the evaluation of a single standardized procedure, such as cholecystectomy, would bring a different and more controlled view of the effects of complications on surgeons' cognition.

Conclusions

Our results showed that neither time nor unexpected intraoperative complications decreased surgeons' cognition. Surgeons showed great levels of resilience during adverse situations. Resilience may be defined as the extent to which individuals positively cope with work stress or adversity by adapting effectively, bouncing back from it, and maintaining or enhancing their well-being [24]. Interestingly, resilience was the theme of 3 presidential addresses from 3 different surgical societies [25–27]. In all the 3 addresses, resilience was claimed as a desirable characteristic to excel in surgery.

Authors' contribution JB contributed to protocol/project development; data collection or management; data analysis; and manuscript writing/editing. FAMH involved in protocol/project development; data collection or management; data analysis; and manuscript writing/editing. FS and MGP performed manuscript writing/editing.

Compliance with ethical standards

Conflict of interest There are no conflicts of interest to report.

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