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Research Article

Neurophysiology of learning in basic skills of laparoscopic surgery in undergraduate students

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ABSTRACT

Background: The development and progress in laparoscopic surgery requires greater emphasis on surgical skills, developing skills in undergraduate students allows them to be at the forefront in health demands.
Methods: An experimental and descriptive study of a group of 30 undergraduate students of the Faculty of Medicine. They attended 30 hours of theoretical and practical sessions distributed by 10 sessions, supported by basic simulators minimally invasive, being evaluated by checklist. Their brain activity was monitored with an electroencephalography before and after the development of skills.
Results: It was observed that the average necessary for the acquisition of skills is 5 sessions. The competition in which further progress was observed is video assistance. There is an increase in the activity of the prefrontal cortex on the electroencephalography.
Conclusions: A series of neurophysiologic processes involved in learning of laparoscopic surgery are described. Laparoscopic skills development lies in keeping them updated on the teaching-learning, where the use of simulators is growing.

Keywords: Neurophysiology, Learning, Laparoscopic surgery, Learning curves, Electroencephalogram, Simulators

INTRODUCTION

The capacity that humans present to acquire and store information is one of the most significant advantages it holds. Throughout history there have been attempts to define and explain the learning process and achieve understand the acquisition of various skills and knowledge. Currently, the definition of learning is perceived as "the changing of own potential, to see, think, feel and act through perceptual, intellectual, emotional and motor experiences "; in other words it is a change in the response or behavior resulting from the experience.[1,2] This neurophysiological process of learning is closely related to memory, as both involve brain regions such as the hippocampus, amygdala, middle lobe, prefrontal cortex and prefrontal association area.[3-5]

Physiologically, the memories are produced by variations in the sensitivity of synaptic transmission from one neuron to the next, however, is the repeated experience that strengthens the memory.[3] From the point of view of the educational psychology and behavior will distinguish two types of learning: explicit and implicit learning, the explicit learning refers to a conscious effort and controlled processing of information, this type of learning is for the novice, who tends to change the focus of continuous attention; while the implicit learning corresponds to relevant experts in motor skills, such as surgery, where the expert focuses attention only on surgical action and the expression of the acquired knowledge is automatic.[6,7]

Currently the development and advancement in minimally invasive surgery requires increasing demands on surgical skills, it is of great importance to develop skills in undergraduate students achieving at the forefront in the demands in health, with the completion of procedures that require complementarity with working memory.

This article seeks to explain the neurophysiological processes that are carried out when acquiring new skills focused on laparoscopic surgery, primarily undergraduates, because they are inexperienced in this surgical technique innovative and required.[8]

Objectives

1 Describe the neurophysiological process applied to learning basic skills in laparoscopic surgery in undergraduate students of the Faculty of Medicine of the Universidad Nacional Autónoma de Mexico.
2 Determine the average time needed for the acquisition of skills in laparoscopic surgery in undergraduate students of the Faculty of Medicine of the Universidad Nacional Autónoma de Mexico.

METHODS

It was carried out a cutting, observational, descriptive and evaluative study at the Faculty of Medicine of the "Universidad Nacional Autónoma de México" during the school year 2013-2014, in which participated 30 students of the subject of Surgery I of the Faculty of Medicine, UNAM. The study was analyzed using descriptive statistics.

The obtaining of the sample was determined by convenience, where interested students who met the inclusion criteria participated (Table 1).

Table 1: Inclusion criteria.

Sr. No.	Inclusion criteria
1.	To Be enrolled in the second year of the Bachelor of Surgeon at the National Autonomous University of Mexico.
2.	To Have a minimum average grade of 8.0
3.	To Be enrolled in the course of surgery for the first time.
4.	To Have approved the other subjects.
5.	Not taking additional courses compulsory subjects.
6.	Availability of time.

The study group attended ten theoretical sessions lasting a total twenty hours over two hours each session, and ten 60-minute practice sessions each, with a total duration of ten hours, which was revised in general the basics in laparoscopic surgery. The practical sessions were carried out by students and supervised by a professor in this field, including the recognition and use of equipment and instruments for laparoscopic surgery and an inexpensive simulator for minimally invasive surgery.

Throughout this study the performance and progress of undergraduate students in the acquisition of new techniques in laparoscopic surgery were evaluated during ten sessions through three different methods: one was through checklist (Table 2) at the end of each session, with which we could obtain 30 grades of each of the skills acquired; The second method was through learning curves generated from the averages obtained through the checklist (Table 2); and the third method was using electroencephalographic recordings, one before and another after the evaluation of each practice session.

Table 2: Checklist made for the evaluations conducted each session.

Sr. No.	Characteristics to be evaluated	Grade
1.	Identifies instruments for minimally invasive surgery	
2.	Identifies and activates a trocar	
3.	Makes video assistance	
4.	Identifies binding site CO_2 cable to Veress needle	
5.	Makes the connection of light source to the laparoscope	

The assessment and recording of electrical potentials generated by the brain were measured by electroencephalography, through electrodes on the scalp surface placed according to Ten Twenty international system.

After a period of six months students were evaluated again, only by checklist (Table 2) in order to observe the retention of learning acquired by students.

RESULTS

Throughout the study six skills in laparoscopic surgery were evaluated, in which it was included to recognize and identify the use of equipment and instruments for laparoscopic surgery, connecting the light source to the laparoscope, a proper installation of the Veress needle, identify a loaded trocar, explain the procedure for placement of a trocar and be able to execute a suitable video assistance.

Table 3 shows the average assessment of the group shown in each session and in each of the competitions, through these we can see the significant progress in acquiring skills that students played over the ten sessions, that progress can be observed more graphically in Figure 1, through a learning curve.

Table 3: Average evaluation of acquired skills in laparoscopic surgery.

Skills/Session	1	2	3	4	5	6	7	8	9	10
Average: Identification of instruments	0	6.1	8.2	9.2	10	10	10	10	10	10
Average: Placement of a trocar.	0	6	8.1	9.2	9.8	10	10	10	10	10
Average: Video assistance	0.5	7	9.1	9.8	10	10	10	10	10	10
Average: Recognize a loaded trocar.	0	6.9	7.9	9.4	9.8	10	10	10	10	10
Average: CO_2 cable connection	0	5.9	7.9	8.9	10	10	10	10	10	10
Average: Connection of light source to the laparoscope	0	5.9	7.8	9.5	9.8	10	10	10	10	10

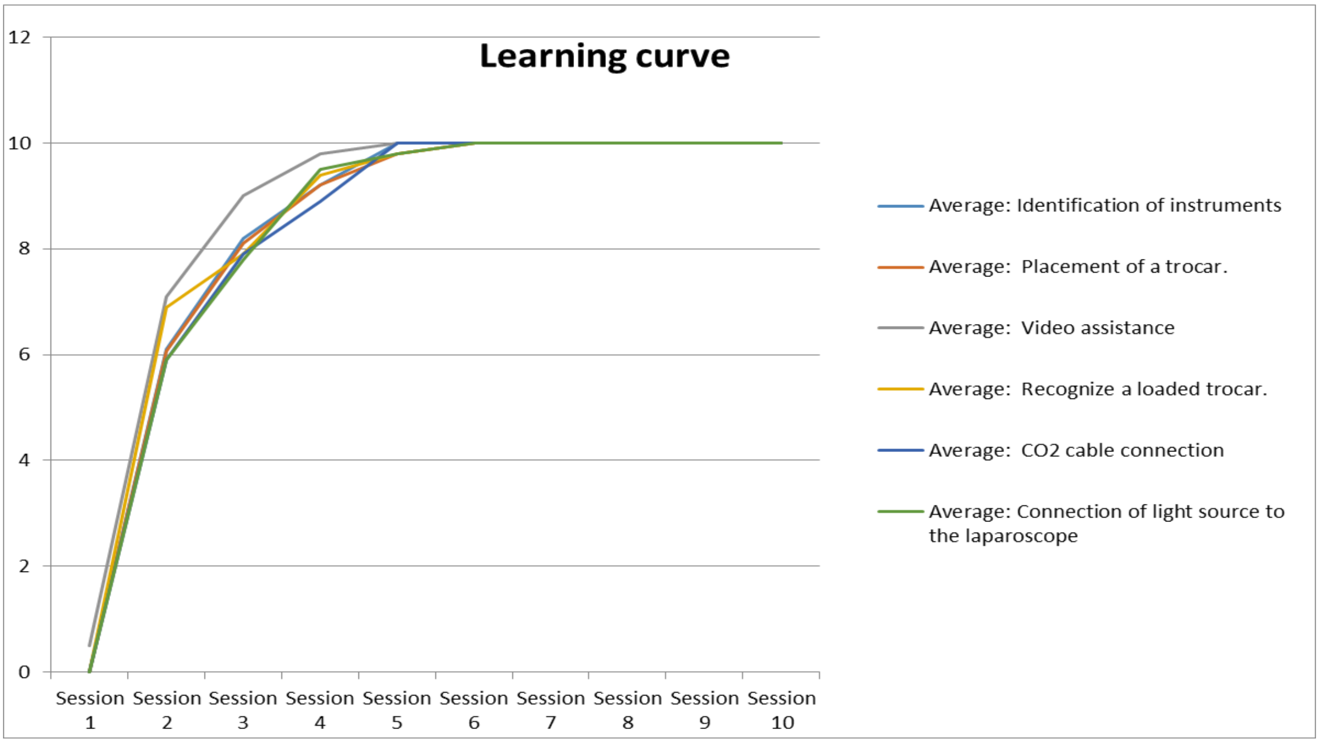

Figure 1: Learning curve in the acquisition of skills in laparoscopic surgery.

Table 4: Average evaluation skills acquired in subsequent laparoscopic surgery to 6 months.

Skills/Session	1	2	3	4	5	6	7	8	9	10	11 (6 months later)
Average: Identification of instruments	0	6.1	8.2	9.2	10	10	10	10	10	10	9.6
Average: Placement of a trocar.	0	6	8.1	9.2	9.8	10	10	10	10	10	8.7
Average: Video assistance	0.5	7	9.1	9.8	10	10	10	10	10	10	9.23
Average: Recognize a loaded trocar.	0	6.9	7.9	9.4	9.8	10	10	10	10	10	8.63
Average: CO2 cable connection	0	5.9	7.9	8.9	10	10	10	10	10	10	8.6
Average: Connection of light source to the laparoscope	0	5.9	7.8	9.5	9.8	10	10	10	10	10	8.43

Figure 1 shows considerable progress in the group after the third meeting, it shows an accelerated video assistance compared to other tasks to assess learning; while the cable connecting CO_2 to Veress needle was a more difficult to learn procedure for students.

Table 4 shows the averaged results obtained after evaluating students six months after the tenth session of the first assessment, this table shows that on average, students had a poor assessment compared to the last assessment.

In Figure 2 we can see a decrease in the learning curve from the tenth session, where the eleventh session represents the assessment made six months later.

In the electroencephalography performed before practical assessment, major changes were not appreciated; however, small changes were made after the assessment. In Figure 3 we can see a fragment of an EEG of a student, made subsequent to develop competition, where a normal EEG is seen slightly increased wakefulness in frontoparietal areas, represented by Fp1-F3, Fp1-F7, Fp2 -F4y Fp2-F8; this indicates that the prefrontal cortex (episodic memory and working memory) and supplementary motor areas (procedural memory) are enabled.

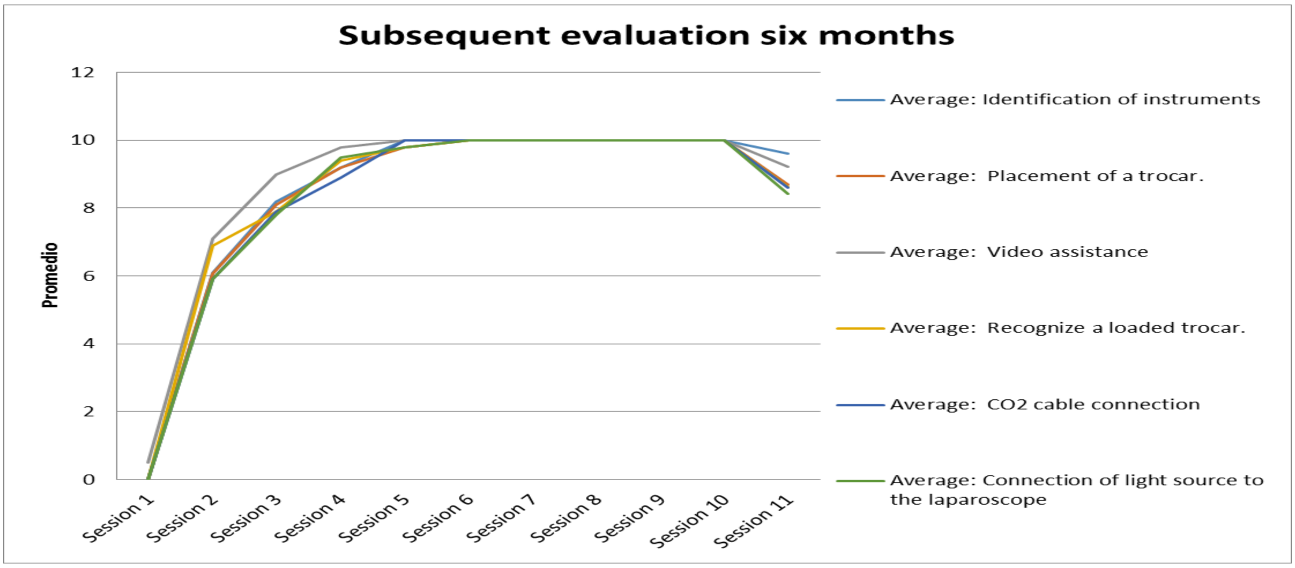

Figure 2: Subsequent evaluation six months.

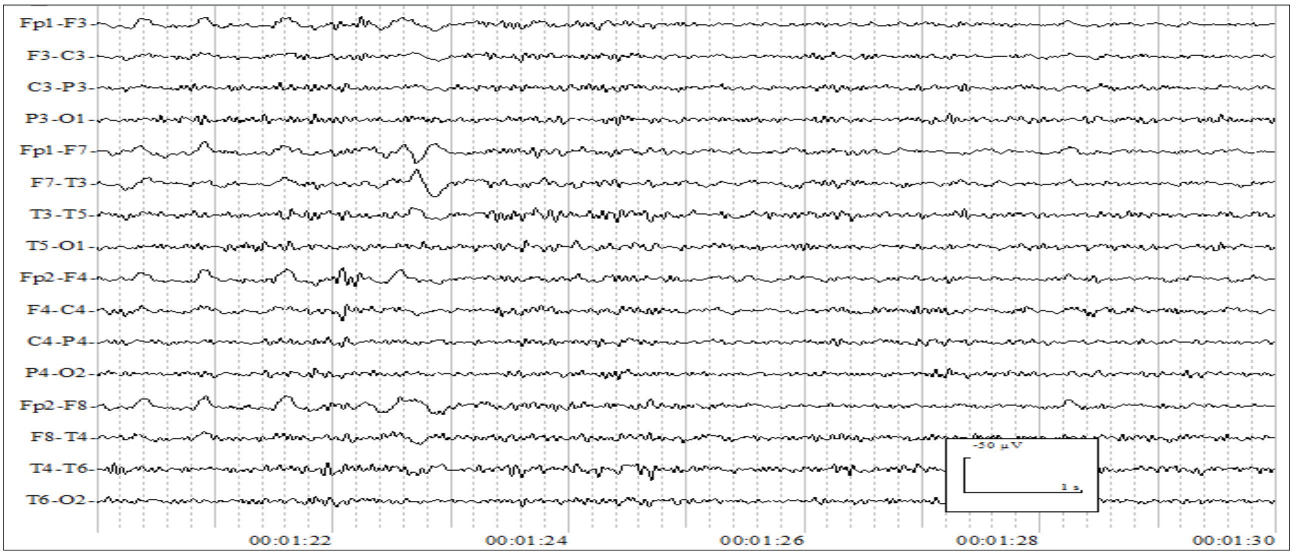

Figure 3: Electroencephalogram after surgical skill development.

DISCUSSION

Laparoscopic surgery compared with open surgery, is associated with faster recovery, shorter hospital stay and return to workplace faster.[9] His training as it involves two-dimensional and three-dimensional visualization, reduction in depth of the surgical field, and bimanual hand eye coordination to perform procedures, it requires space training.[10] Numerous studies fMRI activation imaging (fMRI) detected by changes in blood oxygenation, flow volume, activity on various brain anatomical structures in the acquisition of motor skills, is the case of: basal ganglia and cerebellum, somatosensory area (responsible for visual-motor coordination), inferior parietal lobe (space-time perception of the limbs), supplementary motor area or premotor (medial and lateral segments bimanual activities in manual side activities) and Brodmann area 4 (voluntary movement, including activation of Brodmann area 6 to allocate and execute a movement).[11-14]

Laparoscopic surgery, a task that requires more care, more visuospatial perception and motion planning capacity, is related to activation of the primary motor cortex, supplementary motor cortex area and somatosensorial area.[12,14]

The apprentice at an early stage of learning, as students of this study, presented greater activation of the anterior cingulate cortex and prefrontal cortex, responsible for attention and working memory.[14,15]

The long-term memory is classified as non-declarative (or implied) and declarative (or explicit) memory. The first one relates to the memory of skills and simple packaging (such as remembering how to tie the laces of the shoe) versus declarative memory, memory that can verbalize and is divided into semantic memory (fact) and episodic (event).[16]

In Table 5 are shown as different brain structures involved in learning laparoscopic surgery.

Table 5: Categories of memories and major regions of the brain involved.

Category memories	Main regions of the brain involved	Duration of memory storage	Examples
Episodic memory (explicit, declarative)	Medial temporal lobes, thalamus, fornix, prefrontal cortex.	Minute-Years	Remember the learned in lecture. Identifying practical assessment of laparoscopic instruments.
Semantic memory (explicit, declarative)	Inferior temporal lobes	Minute-Years	Recognize the name and function of each tool for minimally invasive surgery
Procedural memory (explicit and implicit, not declarative)	Basal ganglia, cerebellum, complementary motor areas	Minute-Years	Know how to place a trocar
Working memory	Words and numbers; prefrontal cortex, Broca's area, Wernicke's area. Space: prefrontal cortex, visual association areas	Seconds-minuts	Words and numbers: keep in mind what they learned in lectures. Space: Carefully follow the operation with video assistance

Observational learning, which provides students with information about the movement and the pitfalls to avoid, positive feedback, which makes learning self-conscious and self-controlled practice, as in the case of simulation, are factors that facilitate motor learning.[17]

The process by which the short term memory becomes stable long-term memory is called consolidation, where gene expression, new protein synthesis and growth of synaptic connections involved, through repeated application of serotonin, which activates subunit PKA catalytic, who recruits another kinase second messenger; mitogen protein kinase (MAPK) kinase that is associated with cell growth, so a single application of serotonin Aplysia sensory neurons, causes a short term sensitization, but five applications enabled produce long-term sensitization, several days, however, both are kinase, PKA and MAPK are translocated to the nucleus of the sensory neuron and the active catalytic subunit here a genetic switch, the CREB-1 (binding protein camp response element), this transcription factor when phosphorylated, it binds to a promoter element called CRE (camp response element), through the MAPK, PKA catalytic subunit also acts indirectly by relieving the inhibitory actions of CREB-2, a repressor of the transcription suppression and inhibitory action CREB-2, CREB-1 activation induces expression of two genes as ubiquitin hydrolase enzyme that activates the proteasome to activate PKA persistently, and transcription factor C / EBP, one of the gene cascade components necessary for growth of new synaptic unions.[18]

Scientists have discovered that memory consolidation is a function of the medial temporal lobe, particularly the hippocampus and amígdala.[16,19] It is well known that stress increases the secretion of the "stress hormone" cortisol mainly where hippocampus and amygdala are rich in receptors of this hormone; This is why Fox says that while strong emotions increase memory encoding within the amygdala, stress can alter memory consolidation by the hippocampus and cognitive functions and working memory performed by the prefrontal cortex, i.e. stress can promote the storage of strong memories from the emotional point of view, but hinder the recovery of those memories and memory work.[19]

Learning is stored as persistent representation from one stage transitional working memory has a limited capacity and time range to a more durable and stable, with capacity for memory accesses versus future as a dynamic process in which information represented is subject to our personal experiences, the context of the learning environment, subsequent developments, service levels, stress and other factors.[20-23]

The nature of synaptic changes within the memory storage has been studied using the phenomenon of long-term potentiation (LTP) in the hippocampus, where the long-term memory and most axons use glutamate as a neurotransmitter; The enhancement phenomenon is induced by activation of the NMDA receptors for glutamate, however during the membrane potential at rest, the pore NMDA is blocked by an ion Mg2 + and prevents the entry of Ca2 +, even in the presence of glutamate, glutamate to activate its receptors NMDA, the membrane must also be partially depolarized, causing Mg2 + leave the pore, and has glutamate binding to its receptors AMPA, or in response to a different neurotransmitter.[24] Under these conditions, glutamate causes the Ca2 + and Mg2 + to diffuse through the NMDA channel into the cell, the Ca2 + entering through NMDA receptor binds to calmodulin, a regulatory protein, this complex Ca2 + calmodulin, activates an enzyme call CaMKII (dependent protein kinase calmodulin) makes AMPA receptors to glutamate move to the plasma membrane of the postsynaptic neuron, i.e. increased Ca2 + concentration causes changes in the longer term in the postsynaptic neuron persistent necessary for synaptic plasticity resulting in the formation of long-term memories that stimulate gene transcription and production of mRNA.[18,24]

It is believed that the cortex stores short-term memories where verbal lateralize information to the left hemisphere, and visuospatial information to right hemisphere.[16]

Was recently recognized the concept of deliberate practice (PD), a learning method mainly used in clinical skills for surgical procedures and diagnostic imaging, focusing on learning skills for clinical reasoning and problem solving, achieving better performance. It is accompanied by the guidance of a teacher who helps define what needs to be improved, providing continuous feedback and creating a self-directed learning based on repetition and effort, creating a physical brain change, as it ensures learning cannot occure without growth of over dendritas.[25]

Another type of learning involves the acquisition of motor skills or the ability to coordinate movements, involves two elements: the first one is the rule that describes how you must do the movements and the second is the real muscle movement becomes better defined and easier with practice and complementary information.[26]

Throughout this study the performance of undergraduate students in the acquisition of new techniques in laparoscopic surgery through checklists (Table 1, Figure 1) was evaluated, in which you can see a continuous improvement over sessions, showed that in all the skills the maximum score is reached at the sixth session, resulting in the need of 5 theoretical and practical sessions to achieve the performance of the required surgical skill, however, after assessing novices 6 months after the last session, a decayed assessment was obtained (Table 2); indicating that the lack of practice weakens the lessons learned, which could be avoided if the practice was strengthened; despite this, the grades obtained in the last assessment are similar to those obtained in Session 3 and 4, which proves that the performance of the freshmen in laparoscopic techniques has better results in time, improved accuracy and fewer errors after the previous basic training, as many systematic studies have mentioned.[27] So there is a need to understand and explain the neurophysiological processes that take place during the acquisition, enhancement, retention, retrieval and use of effective learning in the field of practical medicine.[24]

Unfortunately, the system of teaching skills and psychomotor skills of surgery, has been predominantly empirical and has lacked systematic and estructure.[28]

On the other hand, James C. Rosser found a significant correlation between the previous practice with video games and laparoscopic skills, which even suggests the curriculum included training on surgery simulators.[29] Currently simulators added exposure to structured study programs, it has been shown to improve performance skills in laparoscopic surgery.[31-33] Intrinsic reward system plays an important role in reinforcing behavior learned.[34]

Another way to assess students went through a learning curve (Figure 1), which are currently used in medicine as models that value in a unit time the success rate in performing a task, where they found a significant from the third session, showing dominance in the skills that requested increase, also it illustrates how students about the fifth and sixth procedure are awarded the highest score achievable, that is, for students to gain the skills assessed in laparoscopic surgery 5 sessions were necessary, equivalent to fifteen hours of teaching, which were distributed in ten practical hours and five hours of theory. In learning curves we often find a plateau effect, reflecting a decrease in the time to integrate learning even doing practically imperceptible or null, including a limit number for such repeated operations, in other words reached a certain point time to repeat the operations isn´t improved, some of the causes behind this plateau can be plain or poor motivation, inadequate use of learning methods, the difficulty of the subject, interference with other subjects, satisfaction level achieved, etc. The last one being the one most suited to our approach. In students the starting point of the curve in surgery indicates the level of baseline surgical skill, and the end point shows a level of experience made. However, in Figure 2 a decay shown in the learning curve, even after reaching the effect "plateau"; the most likely explanation for this phenomenon is that the interruption of the practice in the acquisition of minimally invasive techniques did not allow optimal memory consolidation, however if sessions were retake the plateau effect would be achieved in the highest rating, through facilitating the transmission routes, which would be responsible for finalizing the process of memory consolidation previously initiated.

Another alternative to understand the neurophysiological processes of learning acquisition in minimally invasive techniques was through pre- and post-practice evaluation electroencephalograms, obtaining greater activity in the EEG done after the test as shown in Figure 3, which can be seen as an increase in the activity of parietal and frontal lobes, which allowed us to identify the areas involved in the learning process, which can stimulate further through knowledge to optimize learning and skill acquisition in less time, with available resources, that is improving the performance and effectiveness of teachers and students, and encouraging continuous practice.

CONCLUSIONS

This paper describes a number of processes by which medical training may facilitate learning method, considering the number of factors that can prevent or improve significantly affect the process.

Currently medical training demands full time, which they may limit as repeated manual processes, multitasking, active participation, among others and promotes aspects that hinder its development as is the stress and fatigue.

It is of great importance the progressive and constant learning, through a joint or organization that depends on the individual, and how to react to various stimuli and external agents. You must know that certain components can work together, such as student motivation and awareness about the practice through appropriate simulation models, which encourages medical students to learn more about the laparoscopic technique confidence and encourages them generating improved performance in developing and learning tasks.

While the aim of developing skills in minimally invasive surgery undergraduates does not lie in train experts in advanced laparoscopic procedures, it is inherent in the current medical claims, and keep them updated with the latest techniques in the teaching and learning where the use of simulators is growing. Not outside the usual medical training either in hospital rotations, medical internship or community service, attend minimally invasive surgeries, where the right place to learn basic skills necessary instruments and equipment is not a real patient before surgery, but an operating room classroom with suited simulators; Simulation has recently gained acceptance in the past decade, thanks to the evidence of their effectiveness in training.

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