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Research

Cognitive Training to Reduce Memory Disturbance Associated With Postoperative Cognitive Impairment After Elective Noncardiac Surgery: An Experimental Study

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A B S T R A C T

Purpose: Assess the efficiency of a cognitive training program using an artificial intelligence application to optimize cognitive reserve and reduce memory disturbance in patients aged 55 to 75 after Class II-III elective noncardiac surgery.
Design: Experimental with random assignment.
Methods: The study was conducted on 80 patients undergoing surgery at the Teknon Medical Center Hospital in Barcelona, from April 2018 to June 2021. Both groups were evaluated with cognitive tests before surgery and 7 and 30 days after surgery. The experimental group was subjected to cognitive training for 10 days before surgery to improve their cognitive reserve.
Findings: Significant differences were found between the study groups 30 days after surgery in the three screening tests (Mini-Cog, T@M, and MFE). The intervention group presented with fewer cognitive and memory alterations. Age and pre-existing comorbidities were not correlated with an impact on memory impairment or cognitive function.
Conclusions: A cognitive training program based on artificial intelligence, prescribed and monitored by anesthesia nurses has a positive impact on increasing cognitive reserve and reducing memory disturbance in patients aged 55 to 75 undergoing Class II to III elective, noncardiac surgery. This intervention may serve as a prehabilitation strategy in patients with a risk of cognitive dysfunction evaluated by anesthesia nurses for the purpose of preserving their cognitive function and optimizing their recovery.

Postoperative cognitive dysfunction (POCD) is a postoperative complication that is usually mild but has an important impact on elderly patients. POCD was initially associated with cardiac surgery,[1,2] although it is known that this complication also exists in other surgical contexts. Very little is known about this dysfunction, which has often been underestimated. A systematic review by Van Sinderen, Schwarte, and Schober[1] has shown a lack of consensus in defining postoperative cognitive dysfunction. Even so, POCD is not the only postoperative cognitive dysfunction that can appear, hence it should not be confused with delirium or dementia.[2]

POCD is largely defined as mild or moderate cognitive impairment that is temporary (a priori), and is associated with anesthesia and surgery.[1] It is characterized by the fact that it affects various cognitive domains, such as memory, learning ability, perception, verbal ability, executive functions, and abstract thinking. Its detection and assessment depend on the comparative analysis of the cognitive function by means of neuropsychological tests between the pre and postoperative periods. The presentation of this complication may vary among patients, and may be subtle or cause major intellectual and operational disability, a loss of autonomy in

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everyday life, social isolation, and depression. Its effects may last for weeks or even years.[3,4] Some clinical studies agree on the need to establish a battery of tests covering various cognitive domains, together with scales that provide information about the patient's emotional state, associated mainly with anxiety and depression.[1,5]

The POCD rate described in noncardiac surgery is between 25% and 80%, depending on the type of surgery, the criteria used to define it, and the moment when screening tests are applied during the postoperative period. In general, it is estimated that the prevalence of POCD in patients over 60 undergoing noncardiac surgery is 15% to 25%, and that approximately 10% may develop this condition up to 3 months after surgery.[6] Moller's[7] ISPOCD1 study on a sample of 1,218 patients over the age of 60 undergoing noncardiac surgery, reported a POCD rate of 25.8% 1 week after surgery and 9.9% 3 months afterward. The study concluded that anesthesia and surgery caused long term POCD and that controlled hypotension and hypoxemia were not associated with the onset of POCD. Other studies, however, have concluded that there are no statistically significant differences based on the type of anesthesia used and the onset of POCD.[8–10]

Subsequently, Monk et al,[6] in a large-scale study on a sample of 1,064 patients over 18 undergoing noncardiac surgery, concluded that POCD may develop at any age, but the risk increases exponentially from the age of 60. Monk reported a POCD rate for elderly patients of 41.4% on discharge and 12.7% after 3 months, of 36.6%. POCD rates for young and middle-aged patients were 30.4% on discharge, and of 5.7% and 5.6% after 3 months for young and middle-aged patients respectively. The study also concluded that the lower the educational level, the greater the risk of suffering POCD, and that the people who continued to suffer from this dysfunction 3 months after surgery had a higher probability of suffering dementia and a higher mortality risk during the first year of the postoperative period.

The specific cause of this complication is unknown, and its pathophysiology is considered complex and multifactorial. The most widely accepted pathophysiological hypothesis is that of inflammatory alteration of the central nervous system or neuroinflammation,[11,12] due to surgical stress with the ensuing reduction in cognitive reserve.[4,13] Age is the most important risk factor for the onset of POCD, which has become an increasingly more relevant and concerning health problem, as the age of the world's population is steadily increasing.

In Europe, it is estimated that the number of persons over 65 will increase from the current 19.1% to 23% by 2030, and to 28.1% by 2050. The UN Department of Economics and Social Affairs forecast that by 2050, one out of every four persons will reach the age of 65 or more.[14] This will have an important impact on the perioperative management of patients, as it is foreseen that this population will require surgery four times more often than other age groups, with the ensuing health, economic, and social repercussions.[4] Apart from risk factors such as old age and a low level of education,[6,7] other risk factors have also emerged that could contribute to the onset of POCD, such as: the complexity and duration of surgery, postoperative complications, the length and depth of anesthesia, episodes of hypoxemia and/or hypotension, sleep disorders, pain control, pre-existing comorbidities,[8,15,16] alcoholism, depression, and pre-existing dementia, or a combination of all the above.[4]

There is no pharmacological treatment for managing POCD, so prevention must be an indisputable priority.[11] In this regard, various studies are now considering cognitive training as a potential strategy for the prevention and treatment of POCD, as a modifiable or treatable factor. It is postulated that an increase in functional reserve could constitute a protective factor in preventing cognitive dysfunction.[17–23] Other reviews are already directing scientists to investigate interventions that improve cognitive reserve during the preoperative period.[24]

Cognitive training is based on brain plasticity and cognitive reserve and is a set of systematically ordered techniques and exercises targeted at maintaining or improving cognitive function by means of memory, perception, attention, language, executive function, visual function, and spatial exercises, among others. It usually involves working in dysfunctional cognitive areas or those that are starting to become dysfunctional, and also in those that are not affected, but whose performance can be improved. Of all the so-called nonpharmacological interventions, it is the one that receives the highest evidence-based support and is the one in which nurses can play a major role in its implementation, follow-up, and control.[25–29]

Given the lack of knowledge about ways to prevent or treat POCD, it is important for nurses to be able to identify the most vulnerable profiles and foresee their needs to increase clinical safety throughout the surgical process. The development and evaluation of nonpharmacological interventions may be useful for these patients. These measures have a low implementation cost and no side effects.[22] For this reason, a nonpharmacological, prevention approach during the perioperative period to reduce the risk of POCD may be a useful strategy for nurses when caring for these surgical patients.[17,18,23,25,28–32]

Perianesthesia nurses are the most suited for evaluating and caring for these patients, as their competencies include assessment of the patient before anesthesia, identification of potential risks to their safety, reporting of such risks and formulation of care plans based on their knowledge, scientific evidence, and the principles of nursing.[33] Within the scope of their competencies and care plans, perianesthesia nurses are involved in all surgical phases, which puts them in a privileged situation for the study of this disorder.

Along these lines, this study was conducted in response to the research question as to whether cognitive training is an efficient nursing technique to reduce the risk of memory disturbance, as a symptom of postoperative cognitive dysfunction in elderly adults undergoing Class II to III noncardiac surgery (classification based on the preoperative guide of the *NHS National Institute for Clinical Excellence* and equivalent to moderate-high levels of complexity, respectively).

Objective

The objective of this study was to assess the efficiency of a cognitive training program using an artificial intelligence application to optimize cognitive reserve and reduce memory disturbance in patients aged 55 to 75 after Class II to III elective noncardiac surgery.

Methods

Design

An experimental study with random assignment was used. Two groups were established: a control group (CG), which received the standard of care, and an experimental group (EG), which received the cognitive training 10 days before surgery. The study scope was the Anesthesiology Service of a third-level hospital located in the city of Barcelona, (Teknon Medical Center), a leading center in private national and international medicine, with a total of 247 beds and 19,000 surgeries per year. The study sample was made up of men and women aged between 55 and 75 with scheduled visits to the preanesthesia consultation clinic for Class II to III elective noncardiac surgery between April 2018 and June 2021. A nonprobability, convenience or consecutive sampling method was used. The type of surgery evaluated did not permit the use of data masking techniques. The sequence for assigning the participants to the study groups was random, using a randomized names chart.

Table 1
Selection Criteria for Participants

Inclusion criteria	Exclusion criteria	Withdrawal criteria
Men and women between the ages of 55 and 75	Patients with vascular or degenerative dementia	Voluntary withdrawal
ASA Classification*: I-II-III	Recent surgical intervention (< 6 months)	Cancellation of surgery
Elective, noncardiac surgery, grade II-III complexity.	Illiterate	Postoperative delirium
Preanesthetic visit at least 10 days before surgery.	Psychiatric illness	Serious perioperative complications or need for postoperative ICU
Spanish or Catalan speakers.	History of severe head injury	Reintervention 30 days after surgery.
Access to an electronic device with Internet connectivity.	Patients with a history of stroke	Not complying with the cognitive training program.
Grant and sign the consent inform.	Neurological disease	Untraceable
	Severe visual or auditory deficit	
	Presence of brain tumor	
	Unstable disease, severe or estimated survival < 3 months	

For all results tables, values are presented in the form of an average (interquartile range) for quantitative variables and the number of cases (%) for qualitative variables.
* ASA (American Society of Anesthesiologists): Anesthetic risk classification.

Accepting an alpha risk of .05 and a beta risk of less than .2 in a unilateral contrast, 34 patients were assigned to each group, to detect as statistically significant the difference between two proportions, which was expected to be 0.2 for group 1 and 0.5 for group 2. A loss to follow-up rate of 10% was estimated. The inclusion, exclusion and withdrawal criteria were defined and are shown in Table 1.

Instrument and Data Collection

The independent variable was the imparting of the cognitive training program using the "Sincrolab" computer app. The dependent variables were the onset or non-onset of memory disturbance based on screening tests to measure the memory objectively and subjectively (perceived by the participant), and cognitive dysfunction in general. In addition, other variables included sociodemographic data (sex, age, anthropometric data) and clinical data (comorbidities and anesthesia risk, anesthetic depth, oxygen saturation, and the noninvasive mean arterial pressure).

Three instruments were used to collect information on cognitive dysfunction and memory:

1. The Memory Failures of Everyday Questionnaire (MFE).[34] Designed to assess subjective memory disturbance in an everyday context. Configured for 28 items related to everyday situations and activities, using a Likert scale with three options for each question. Scores considered altered: Mild cognitive impairment: > 10 points. A > 10 score indicates a mild amnesic deficit and > 18, a moderate amnesic deficit. Moderate cognitive impairment: > 18 points This questionnaire was completed during the preanesthesia visit to establish a baseline value and was repeated 30 days after surgery.
2. Mini-Cog©.[35] A brief version of a cognitive screening tool for elderly patients used to identify potential cognitive impairment. Includes the evaluation of the ability of an elderly person to remember three words and to draw a clock. A score of 0 to 2 indicates a potential cognitive impairment (the highest score is 5). This test is issued on a routine basis to preanesthetic patients by the anesthetist or anesthesia nurse.[36]
3. T@M: Memory Disturbance Test.[37] A 50-item screening test. Evaluates different memory subtypes (short-term memory, time-based prospective memory, remote semantic memory, spontaneous evocation memory, and evocation memory with cues). All the questions were oral and only one answer was possible. One point was awarded for each correct answer. The cut-off score to distinguish between amnesic cognitive impairment and subjective memory complaints in the patients was 37 points (highest score: 50 points).

Intervention Development

The intervention consisted of prescribing a cognitive training program to the EG using the Sincrolab computer app. This is a digital platform that, based on artificial intelligence and through directed play, tests the recovery and development of cognitive abilities. The software was developed for this purpose and was created by a group of Spanish neuropsychologists (https://sincrolab.es/para-profesionales/).

The software has been clinically validated and designed to adapt to the cognitive profile of each user and to their progression, modifying the level of the different games based on the participant's daily performance. Memory disturbance training is based on gaming, that is, on doing exercises in the form of games that both stimulate and work on different cognitive processes, such as attention, flexibility, operative memory, planning, logical and mathematical reasoning and calculus, processing speed, inhibitory control, eye-hand coordination, strategy and problem-solving, eye tracking, and the generation of alternative responses.

The app is available for mobile phones and tablets on both IOS and Android. There is also a desktop version targeted at the practitioners who have prescribed the training, so they can supervise each user's activity.

Meanwhile, a cognitive evaluation with the same neuropsychological tests as the EG was performed on the patients from the CG who received no cognitive training. The CG received the usual care aimed at making recommendations to encourage and maintain an active life before surgery, such as physical exercise depending on the patient's state of health, walking, reading, doing Sudokus, etc.

ASA I-II-III patients receiving Class II to III surgery derived from preanesthesia clinical visits were recruited. On their arrival, they were evaluated by the anesthesia nurse based on the selection criteria (Table 1). If they met the criteria, they were provided with all the information related to the study, verbally and in writing, and if they agreed to participate, the informed consent was processed. After randomization, the patients in the EG were issued verbal and written instructions on how to download the Sincrolab app to their mobile phone or tablet and they were provided with the access credentials and an email and telephone number to clear up any doubts. They were also informed about the purpose of the cognitive training program. The patients in both groups (control and intervention) were informed of the postoperative follow-up guidelines. At that point, all the variables related to the first visit were obtained, including the cognitive and memory tests.

The Anesthesia Service R&D Department developed an ad hoc computer app for the purpose of collecting all the data. The participants' sociodemographic data were recorded, in addition

to their associated comorbidities, the results of the cognitive tests, the clinical data related to the surgery and the established anesthetic risk.

In the case of the CG, the same cognitive and memory tests were performed, but no cognitive training was prescribed. In this case, the usual health care education was provided, aimed at encouraging reading and physical and social exercise before surgery. The members of the research team were able to monitor the training of each patient remotely by means of a web site targeted at the practitioners; in the event of failing to comply with the agreed frequency, the participant was contacted by telephone or by email and reminded of the importance of performing the intervention or to clear up any doubts they might have. In addition, the platform for practitioners generated a report on the training of each participant. The training frequency was three games for 15 minutes a day for 10 days before surgery. On the day of surgery, the patient was not identified as a study participant, to avoid potential conditioning factors that could interfere with intraoperative care. Later, a member of the research team performed a second cognitive assessment of the patient 1 week after surgery. The third cognitive assessment was performed 30 days (±7 days) after surgery. Monitoring was performed in person, but during the COVID-19 pandemic, both in-person and remote monitoring were used.

Analysis

For the descriptive analysis, the mean, standard deviation, maximum/minimum confidence values for the quantitative variables, and percentage and number of cases for the qualitative variables were calculated. The memory disturbance rate was calculated for each study group. The Kolmogorov-Smirnov test was used to verify whether the sample scores had a normal or an abnormal distribution. The Mann-Whitney U test was used for the age, height and weight variables. Fisher's exact test was used for the descriptive analysis of the two-level categorical variable (gender) and the χ^2 test if the variable had three or more levels. The Mann-Whitney U test was used for the correlation of variables not presenting a normal distribution. A significance level of 5% was considered ($P \leq .05$) in all the tests.

Ethical Considerations

The research team observed the Principles of Bioethics and guidelines for the protection of human subjects in research set out in the Declaration of Helsinki (1964-2013) and the Belmont Report (1978). The study obtained a favorable report from the Research Ethics Committee of Quirónsalud Hospital Group and permission to execute it from the management of Teknon Medical Center with protocol code: DCPO-2017-01. The participants were informed verbally and in writing about the use of the informed consent process pursuant to current legislation and ethical recommendations. Confidentiality of the data was guaranteed by means of a coding system for each participant. Both the informed consent and the other documentation generated by the study were kept by the Anesthesiology Service, following the circuits of documents classified as Class III by Organic Act 15/1999 of 13 December, on Personal Data Protection and only the researchers involved in the study had access to them. The members of the research team and the developers of the "Sincrolab" computer app declare that they have not had and do not currently have any conflict of interest in relation to the research. This study was filed in Clinical trials.gov with ID: NCT03620968. The study complies with the CONSORT guidelines.

Results

A total of 80 patients participated, 46 of them from the EG and 34 from the CG.

Description of the Socio-Demographic and Clinical Characteristics of the Sample

The average age of all participants was 68 years (SD: 6.41) and the average age by groups was 67 years (SD: 5.12) in the CG and 68 years (SD: 7) in the EG. 44 of all the included participants were men and 36 were women. The sociodemographic and clinical characteristics are shown in Table 2.

In relation to anesthetic risk, measured with the American Society of Anesthesiologists Physical Status Classification scale, 90% of the total sample presented an American Society of Anesthesiologists II anesthetic risk (low or moderate). Of the recorded comorbidities, the most common for all groups was high blood pressure (41.3% of the sample), and the second most common was diabetes mellitus (13.8%).

In the intraoperative phase, other clinical variables that could have an impact on the cognitive function of the patients were collected and analyzed, but in all cases, the BIS (bispectral index) monitor was maintained between values of 40 to 60, the oxygen saturation between 90% and 100%, and the noninvasive mean arterial pressure did not fall below 55 mmHg for more than 10 minutes.

Impact of the Intervention on Memory Failure and Cognitive Dysfunction

In relation to memory failure, no statistically significant differences were detected in the everyday memory failure (EMF) test during the preanesthetic period, but there were differences one month after surgery. 55% of the study group had no memory complaints during the preanesthetic period. However, after 30 days, the CG showed a higher rate (41.2%) of cognitive dysfunction with respect to the EG (32.6%), and a statistically significant difference of $P < .05$ was observed between both groups (Table 3).

Moreover, statistically significant differences were detected between the CG and the EG in regard to objective memory disturbance assessment, measured by the T@M test 1 month after surgery. 12% of the CG presented mild cognitive impairment after 30 days, while the EG presented only 7% ($P = .03$).

In relation to cognitive screening to detect dementia, the results of the Mini-Cog test showed no significant differences during the preanesthetic period, but statistically significant differences were observed 1 month after surgery between the CG and the EG ($P < .03$). The CG presented an increase of 38.2 in the detection of signs of dementia compared to the EG (17.4%). Table 3 shows the results of the Mini-Cog test, where the test score is shown and a categorical variable that indicates if the patient has dementia that would be positive in the event that the Mini-Cog score was below four.

Variables Correlated to Memory Failure and Cognitive Dysfunction

The data corresponding to the rate of memory disturbance and cognition by age groups and pre-existing comorbidities are shown below.

By Age Group

Of the total sample of 80 participants, 44 were under the age of 70 and the remaining 36 were aged between 70 and 75. No statistically significant differences were observed in relation to memory

Table 2
Sociodemographic and Clinical Data of the Sample

Sample	General (N = 80)	Control (CG) (N = 34)	Experimental (EG) (N = 46)	Sig.
Age	68.08 (6.41)	67.82 (5.12)	68.26 (7.00)	0.71
Height	165.90 (8.71)	163.59 (7.79)	167.61 (9.04)	0.04
Weight	77.08 (11.47)	74.88 (10.92)	78.70 (11.72)	0.13
BMI (body mass index)	28.01 (3.71)	28.01 (5.12)	28.01 (3.58)	0.83
Men	44 (55)	18 (52.9)	26 (56.5)	0.82
Women	36 (45)	16 (47.1)	20 (43.5)	
ASA Classification I	2 (2.5)	2 (5.9)	0 (0)	0.11
ASA Classification II	72 (90)	31 (91.2)	41 (89.1)	
ASA Classification III	6 (7.5)	1 (2.9)	5 (10.9)	
Comorbidities				
Diabetes	11 (13.8)	5 (14.7)	6 (13.0)	0.54
Hypertension	33 (41.3)	14 (41.2)	19 (41.3)	0.58

CG, control group; EG, experimental group; SIG, statistical significance result of *P* value.
In parentheses, the standard deviation is presented.

disturbance and the age groups studied at the different moments of application (preanesthesia, 1 week after surgery, and after 1 month of the postoperative period).

EMF**:** Table 4 shows the EMF test results by age group. No statistically significant differences were detected between age groups and subjective memory disturbance at the time of preanesthesia and in the control performed one month after surgery.

During the preanesthetic period, 23 subjects under the age of 70 showed no alterations and 21 subjects showed mild or moderate alterations. In the same group, one month after surgery, 20 patients had no alteration and 24 had mild or moderate alterations.

With respect to the 70+ age group, almost 60% (58.3% in preanesthesia and 55.6% after 1 month of the postoperative period) showed no signs of alteration. And the number of cases with mild or moderate subjective memory disturbance was the same in both the preanesthetic period and after 1 month of the postoperative period (15 cases before surgery and 16 cases 30 days after surgery).

Mini-Cog: No differences were observed in the cognitive and dementia screening test and in the age groups. 25% of the sample

Table 3
Comparison of Results by Study Groups: Results of the MFE Memory Fault Questionnaire by Study Groups

	General (N = 80)	Control (CG) (N = 34)	Experimental (EG) (N = 46)	Sig.
MFE				
Preanesthetic assessment				
Punctuation	9.5 (6, 14)	9 (4, 13)	10 (7, 16.25)	0.34
Cognitive impairment				
No alteration (˂11)	44 (55)	19 (55.9)	25 (54.3)	0.16
Mild (11-18)	25 (31.3)	13 (38.2)	12 (26.1)	
Moderate (˃18)	11 (13.7)	2 (5.9)	9 (19.6)	
30 Days after surgery				
Punctuation	10.5 (6.25, 16)	12 (8, 17.25)	9.5 (4, 15)	0.05
Cognitive impairment				
No alteration (˂11)	40 (50)	14 (41.2)	26 (56.5)	0.37
MILD (11-18)	29 (26.3)	14 (41.2)	15 (32.6)	
Moderate (˃18)	11 (13.7)	6 (17.6)	5 (10.9)	
T@M				
Preanesthetic assessment				
Punctuation	44 (38.25, 47.75)	44 (39, 48)	44 (38, 47.25)	0.83
Mild impairment	14 (17.5)	5 (14.7)	9 (19.6)	0.39
A week after surgery				
Punctuation	43.5 (37, 47)	41 (36.75, 47)	44 (37, 48)	0.43
Mild impairment	23 (28.7)	10 (29.4)	13 (28.3)	0.55
A month after surgery				
Punctuation	43 (38, 48)	39 (35, 44.25)	47 (41, 49)	0.00
Mild impairment	19 (23.8)	12 (35.3)	7 (15.2)	0.03
Mini-Cog				
Preanesthetic assessment				
Punctuation	4 (3, 5)	5 (3.75, 5)	4 (3, 5)	0.36
Dementia	25 (31.3)	8 (23.5)	17 (37.0)	0.15
A week after surgery				
Punctuation	4 (3, 5)	4 (3, 5)	5 (3, 5)	0.44
Dementia	25 (31.5)	11 (32.4)	14 (30.4)	0.52
A month after surgery				
Punctuation	4 (3, 5)	4 (3, 5)	5 (4, 5)	0.02
Dementia	21 (26.3)	13 (38.2)	8 (17.4)	0.03

CG, control group; EG, experimental group; GIS, significance of *P* value.
The test score is shown and a categorical variable indicating the level of cognitive impairment with the following distribution: Moderate if the score is greater than 18, Mild: if the score is between 11 and 18, and nonalteration: if the score is less than 11. Results of the memory test T@M by study groups. The table shows the test score and a categorical variable indicating if the patient has a mild impairment, which would be positive if the test score is less than 37. Comparison of the results obtained from the Mini-Cog test between the experimental group and the control group. It shows the test score and a categorical variable indicating if the patient has dementia, which would be positive if the Mini-Cog score is less than four.

Table 4
Comparison of Results by Age Group: Results of the MFE Memory Test by Age Groups

	General (N = 80)	Under 70 years old (N = 44)	Greater or equal 70 years old (N = 36)	Sig.
MFE by age group				
Preanesthesia				
Punctuation	9.5 (6, 14)	9.5 (6.25, 13)	9.5 (6, 15.75)	0.862
Cognitive impairment				
No	44 (55)	23 (52.3)	21 (58.3)	0.825
Mild	25 (31.3)	15 (34.1)	10 (27.8)	
Moderate	11 (13.7)	6 (13.6)	5 (13.9)	
Assesment 1 month after surgery				
Punctuation	10.5 (6.25, 16)	11.5 (6.25, 16)	9 (6.25, 15)	0.760
Cognitive impairment				
No	40 (50)	20 (45.5)	20 (55.6)	0.349
Mild	29 (26.3)	19 (43.2)	10 (27.8)	
Moderate	11 (13.7)	5 (11.4)	6 (16.7)	
Mini-Cog by age group				
Preanesthesia				
Punctuation	4 (3, 5)	5 (3.25, 5)	4 (3, 5)	0.243
Dementia	25 (31.3)	11 (25)	14 (38.9)	0.182
A week after surgery				
Punctuation	4 (3, 5)	4.5 (3.25, 5)	4 (3, 5)	0.313
Dementia	25 (31.5)	11 (25)	14 (38.9)	0.182
Assesment 1 month after surgery				
Punctuation	4 (3, 5)	4 (4, 5)	4.5 (3, 5)	0.959
Dementia	21 (26.3)	9 (20.5)	12 (33.3)	0.193
T@M by age group				
Preanestesia				
Punctuation	44 (38.25, 47.75)	45 (40, 48)	42 (38, 47)	0.072
Mild impairment	14 (17.5)	6 (13.6)	8 (22.2)	0.315
A week after surgery				
Punctuation	43.5 (37, 47)	45 (40, 47.75)	40 (35, 46.5)	0.050
Mild impairment	23 (28.7)	10 (22.7)	13 (36.1)	0.188
Assesment 1 month after surgery				
Punctuation	43 (38, 48)	43.5 (38.25, 48)	43 (36.5, 48.75)	0.824
Mild impairment	19 (23.8)	10 (22.7)	9 (40.9)	0.812

The test score and a categorical variable indicating the level of cognitive impairment are displayed with the following distribution: Moderate if the score is greater than 18, Mild: if the score is between 11 and 18 and No: if the score is less than 11. Results for the Mini-Cog test by age groups. It shows the test score and a categorical variable indicating if the patient has dementia, which would be positive if the Mini-Cog score is less than four. Results of the memory test T@M by age group. The table shows the test score and a categorical variable indicating if the patient has mild impairment, which would be positive if the test score is less than 37.

Table 5
Comparison of Results According to Previous Comorbidities: Result of the MFE Test According to the Presence or Absence of Previous Comorbidities

	General (N = 80)	None (N = 42)	Comorbidity (N = 38)	Sig.
MFE & comorbidity				
Preanesthesia				
Punctuation	9.5 (6, 14)	9 (4.75, 13.25)	10.5 (7, 16.25)	0.157
Cognitive impairment				
No	44 (55)	25 (59.5)	19 (50)	0.477
Mild	25 (31.3)	13 (31)	12 (31.6)	
Moderate	11 (13.7)	4 (9.5)	7 (18.4)	
Assesment 1 month after surgery				
Punctuation	10.5 (6.25, 16)	9.5 (5.75, 15)	11 (6.75, 17)	0.460
Cognitive impairment				
No	40 (50)	22 (52.4)	18 (47.4)	0.514
Mild	29 (26.3)	16 (38.1)	13 (34.2)	
Moderate	11 (13.7)	4 (9.5)	7 (18.4)	
Mini-Cog & comorbidity				
Preanesthesia				
Punctuation	4 (3, 5)	5 (3, 5)	4 (3, 5)	0.485
Dementia	25 (31.3)	12 (28.6)	13 (34.2)	0.587
A week after surgery				
Punctuation	4 (3, 5)	4 (3, 5)	5 (3, 5)	0.603
Dementia	25 (31.5)	14 (33.3)	11 (28.9)	0.673
Assesment 1 month after surgery				
Punctuation	4 (3, 5)	4 (3.75, 5)	4 (3, 5)	0.738
Dementia	21 (26.3)	10 (23.8)	11 (28.9)	0.602
T@M & comorbidity				
Preanestesia				
Punctuation	44 (38.25, 47.75)	43 (38, 47)	44 (39, 48.25)	0.204
Mild impairment	14 (17.5)	9 (21.4)	5 (13.2)	0.331
A week after surgery				
Punctuation	43.5 (37, 47)	42.5 (36, 45.25)	44.5 (37, 48)	0.267
Mild impairment	23 (28.7)	13 (31)	10 (26.3)	0.647
Assesment 1 month after surgery				
Punctuation	43 (38, 48)	43 (36.5, 47.25)	43.5 (38, 49)	0.317
Mild impairment	19 (23.8)	11 (26.2)	8 (21.1)	0.590

The test score and a categorical variable indicating the level of cognitive impairment are shown with the following distribution: Moderate if the score is greater than 18, Mild: if the score is between 11 and 18 and no cognitive impairment if the score is less than 11. Mini-Cog test results depend on the presence or not of comorbidities. The table shows the test score and a categorical variable indicating if the patient has signs of dementia, which would be positive if the Mini-Cog score is less than 4. Results for the T@M test depend on the presence or not of previous comorbidities. The table shows the test score and a categorical variable indicating if the patient has mild impairment, which would be positive if the test score is less than 37.

of subjects under 70 showed possible signs of dementia both in the preanesthetic period and 1 week after surgery, and 20% after 30 days of the postoperative period. While the percentage for subjects aged between 70 and 75 years was 38% before surgery and after 7 days of the postoperative period and 12% after 30 days. Table 4 shows the Mini-Cog test results by age group.

Memory disturbance—T@M: Table 4 shows the test score and a categorical variable that indicates if the patient has mild disturbance, which was positive if the test score was below 37. Although there are no statistically significant differences between age groups, an increase in memory disturbance is observed in both groups with respect to the result of the preanesthetic visit. In the group of subjects under the age of 70, there was an increase of 9.1% in cases with possible signs of dementia or cognitive dysfunction both 7 days and 30 days after surgery. In the group of subjects aged between 70 and 75, 22.2% of the participants showed prior cognitive dysfunctions and these increased to 36.1% during the first week after surgery and to 40.9% 30 days after surgery.

By Comorbidities

38 subjects in the total sample had some kind of pre-existing comorbidity, whether high blood pressure, diabetes, or both, while the remaining 42 had none.

EMF: As shown in Table 5, during the preanesthesia assessment, 59.5% of subjects with no comorbidities had no subjective memory disturbance versus 40.5% who did, mostly of a mild nature (31%). Very similar data was shown by patients with comorbidities in this phase. 50% had no subjective memory disturbance, while the remaining 31.6% showed mild disturbance and 18.4% showed moderate disturbance.

When the test was taken again 30 days after surgery, it was observed that practically 50% of cases in the group with comorbidities and the group with none showed subjective memory disturbance (47% of mild and moderate cases in the group with no comorbidities and 52.6% of cases with comorbidities). The majority in both groups were mild.

Mini-Cog: No statistically significant differences were detected between the group with comorbidities and the group with no

comorbidities in relation to cognitive dysfunction during the entire follow-up period (pre and postoperative) (Table 5). Of the 38 cases of participants with comorbidities, 11 showed signs of dementia in both phases of postoperative follow-up (7-30 days). Of the 42 cases in the sample with no comorbidities, a slight increase was detected 1 week after surgery (14 cases, accounting for a rate of 33.3%) and a fall 30 days of the postoperative period in 10 cases (representing 23.8% of the sample).

Memory disturbance—T@M: As shown in Table 5, in both groups (with and without comorbidities), an increase was observed in cases of objective memory disturbance with respect to the presurgical phase during the first 7 days of the postoperative period, which fell slightly (in two cases per group) 30 days after surgery.

During the presurgical phase, the group with no comorbidities presented a rate of 21.4% of mild memory impairment, which increased to 31% 7 days after surgery and then fell again to 26.2% after 30 days. Similar data were observed in the group with comorbidities. During preoperative assessment, 13.2% showed mild memory impairment which increased to 26.3% during the short-term postoperative period and fell after 30 days to 21.1%.

Discussion

Cognitive dysfunction during the postoperative period continues to be a little-known complication that could lead to major deterioration of people's quality of living. This type of dysfunction is in most cases reversible, but in other cases, it may last for months.[2] This study evaluated cognitive training as a possible preoperative intervention carried out by anesthesia nurses, aimed at preserving and optimizing patients' cognitive reserve and reducing the risk of alterations caused by surgical trauma and anesthesia.

Study results show that cognitive training during the postoperative period significantly reduced cognitive dysfunction and memory disturbance rates 30 days after surgery. The cognitive dysfunction rate after 30 days in the CG was 38.2% while the trained group showed a dysfunction rate of 17.4%, measured by Mini-Cog. Similar results were observed 30 days after surgery in the T@M test, where 35.3% of the CG showed signs of possible mild cognitive dysfunction with respect to 15.2% of the intervention group. The comparison between the groups' scores for this test was significant.

The same improvement was observed in the subjective memory evaluation test. A comparison of the scores for this test 30 days after surgery was also significant. The CG had an average score of 12 points, indicating mild cognitive impairment, while the EG had an average score of 9.5 points. The test indicates mild cognitive impairment when presenting a score of between 11 and 18. These results match those reported by other studies.[1,2,38] In particular, the observed rate 1 week after surgery, of 29.4% for the T@M test and 32.4% for the Mini-Cog, matches those reported by Moller[7] in the ISPOCD1 study (25.8%).

In relation to the study intervention, other authors have also studied the benefits of cognitive training in reducing postoperative cognitive dysfunction.[18,19,21,23] However, it is difficult to compare results due to the heterogeneity of their designs and the type of training applied. In the reviewed works, considerable variety was observed in sample types, in the cognitive domains studied, and in the measuring instruments used.

Borchers' systematic review, which includes 274 studies (with a minimum patient follow-up of 1 month), highlighted the heterogeneity of the method used to study POCD. This study identified at least 259 different cognitive tests.[5] Borchers et al also highlight that in long-term follow-up studies, cognitive function was affected up to the third and sixth month after surgery, and later recovered. They also reported a higher rate between the first and third month after surgery (29%), and a lower rate between the third and sixth months (14.1%)[5]. However, this systematic review included cardiac surgery cohorts, which could give rise to an increase in rate data, as the neurobehavioral consequences arising after surgery are well established. This type of surgery may independently contribute to cognitive dysfunction due to the greater risk of the formation of microemboli involved in surgery using extracorporeal circulation. These results match the data we reported in this study on rates, as a higher rate of memory disturbance and general cognitive performance was detected 30 days after surgery as compared to the first week of the postoperative period.

On the other hand, studies by O'Gara and Brian and Song and Yanping,[18,23] despite not offering conclusive results, support the feasibility and efficacy of cognitive training for increasing cognitive performance in elderly patients undergoing cardiac and lung transplant surgery. Song[23] described a significant improvement in certain specific cognitive domains, such as verbal memory, in habitual attention, rather than an improvement in all the possible domains. This would be in line with our decision to focus on one domain to improve its functionality. Song[23] also highlights that the significant differences between the intervention and CG appeared 12 weeks after surgery and not during the immediate postoperative period.

Our results, along with those of Song et al,[23] suggest an improvement in the cognitive training effect in the long term, but Saleh et al[22] concluded that this intervention also enabled a more effective response to postoperative damage caused in the short term (during the first week); in any event, follow-up thereof did not continue beyond this time, and so it is not known whether its benefit would be maintained or subsequently increased. Contrary to these results, Vlisides et al[19] concluded that there was insufficient evidence to suggest that home-based cognitive prehabilitation had a positive impact on postoperative cognitive function and indicated that this could worsen preoperative anxiety, and that the intervention must be carried out over a prolonged period of time. These differences could also be explained by methodological inequalities and the fact that in their study, recruitment and commencement of training took place 7 days before surgery. In our study, the participants trained for 10 days before surgery, during which time constant communication was maintained with the research group to deal with all kinds of issues and ensure adherence to treatment.

As for other interesting results arising from this study, it should be noted that no significant differences were observed in relation to the onset of memory disturbance based on participants' age and pre-existing comorbidities. As shown by Monk,[6] this would seem to indicate that cognitive dysfunction appears in patients of all ages and may also be attributed to the fact that our sample comes from a similar age group (55-75 years). For this reason, it would be advisable to extend the age range in future studies to study whether there are significant differences.

Lastly, the lack of statistical significance with respect to the correlation between pre-existing comorbidities (in our case, high blood pressure and diabetes), and the onset of postoperative cognitive alterations shows that more studies are needed to investigate this assumption.

Limitations

The results of this study should be interpreted in consideration of limitations, such as heterogeneity in defining and evaluating postoperative cognitive dysfunction and the diversity of types of training for the prevention thereof described in the literature, which makes it difficult to compare the results of this study with other studies or clinical settings. Another limitation is the degree of adherence to the training program. To reduce this, the researcher monitored the participants' training by means of the professional Sincrolab platform, and constant communication was maintained with them by telephone or email to stress the importance of

performing the intervention and increasing compliance with it. The fact that it was necessary to monitor the participants for up to 1 month after surgery was a limitation, insofar as it could be a source of losses, hence the decision to adapt the schedule to suit the patients, holding sessions at the same time as the follow-up visits with their surgeon and, during the pandemic, to open up the possibility of performing the follow-up online.

Conclusions

The reduction of risks associated with or derived from surgery is an issue that involves the entire surgical and anesthesia team. The introduction of interventions that have proven to be effective in reducing complications such as POCD is a clinical safety measure and must be assigned the same priority as the correct identification of the patient or the checklist before surgery WHO (World Health Organization) checklist; for example, certain interventions that are already subject to protocol and widely used in surgical procedures. The monitoring of a cognitive training program based on prescribed artificial intelligence and monitored by anesthesia nurses has a positive impact on increasing cognitive reserve and reducing memory disturbance in patients aged 55 to 75 undergoing Class II to III elective noncardiac surgery.

This cognitive training may be considered a prehabilitating strategy for patients evaluated for risk in nurse-patient consultations, with the objective of preserving their cognitive function and optimizing their postoperative recovery. Anesthesia nurses play an important role in evaluating preoperative patients, offering them a personalized care plan that favors their clinical safety and optimizes their recovery. Future studies should analyze the impact of cognitive training on the quality of life of the participants, along with the continuous assessment of the intervention after surgery, that is, to ascertain its effect once the surgical trauma has occurred.

Relevance to Clinical Practice

Preoperative cognitive training based on play, applied through special platforms designed for this purpose and managed by anesthesia nurses has proven to be an effective intervention for increasing the cognitive reserve of patients, with the aim of reducing the rate of memory disturbance. For this reason, this intervention is recommended in preoperative patients with an increased risk of cognitive dysfunction and mainly in elderly patients.

Declaration of Competing Interest

None to report.

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