

Neuropsychological features of memory after cardiac surgery with cardiopulmonary bypass

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ABSTRACT

Introduction: Cardiovascular diseases are the leading cause of death in developed countries and one of the therapeutic strategies is surgery with the use of extracorporeal circulation, which can cause undesirable effects on the neurologic system.

Objective: To characterize neuropsychological functioning of the memory process in patients who have undergone surgery with extracorporeal circulation.

Method: An exploratory-descriptive study in 25 patients operated at Cardiocentro Ernesto Che Guevara in the period from January to March 2012 was performed. The assessment was based on the multivariate test memory, Digits subtest of Wechsler scale, review of the clinical history and a semistructured interview to the patient.

Results: There were limitations regarding the direct fixation of memory trace and retention process based on repetition, with specific manifestation in verbal and numerical retention. Regarding immediate memory, the quality of associations based on visual stimulation was evidenced and affectations presented in recalling, which is consistent with the difficulty in fixing and retention. The existence of alterations in declarative memory was also demonstrated.

Conclusions: Male patients, between 50 and 70 years of age, with a low educational level were predominant. Difficulties in the direct fixation of memory traces were found, as well as failures in immediate recalling of stimuli offered and even after making good associations, and impaired declarative memory. This indicates the existence of neuropsychological limitations in the functional systems associated with declarative and non-declarative, voluntary and involuntary memory, in patients undergoing cardiopulmonary bypass.

Key words: Memory, Cardiopulmonary bypass, Neuropsychology

Características neuropsicológicas de la memoria tras cirugía cardíaca con circulación extracorpórea

RESUMEN

Introducción: Las enfermedades cardiovasculares constituyen la primera causa de muerte en los países desarrollados y una de las estrategias terapéuticas es la quirúr-

gica, con el uso de circulación extracorpórea, la que puede producir efectos indeseables sobre el sistema neurológico.

Objetivo: Caracterizar el funcionamiento neuropsicológico del proceso de memoria en pacientes intervenidos quirúrgicamente con el uso de circulación extracorpórea.

Método: Se realizó un estudio exploratorio-descriptivo en 25 pacientes operados en el Cardiocentro "Ernesto Che Guevara", en el período comprendido de enero a marzo de 2012. En la exploración se utilizaron el test multivariado de memoria, el subtest Dígitos de la escala Wechsler, la revisión de la Historia Clínica y una entrevista semiestructurada al paciente.

Resultados: Se encontraron limitaciones en cuanto a la fijación directa de la huella mnémica y al proceso de retención con base en la repetición, con manifestación concreta en la retención verbal y numérica. En lo referente a la memoria mediata se evidenció la calidad de asociaciones sobre la base de la estimulación visual y las afectaciones se presentaron en la evocación, lo cual es consistente con la dificultad en la fijación y retención. Se constató además, la existencia de alteraciones en la memoria no declarativa.

Conclusiones: Predominaron los pacientes del sexo masculino, entre 50 y 70 años de edad, con un nivel escolar bajo. Se encontraron dificultades en la fijación directa de las huellas mnémicas, insuficiencias en la evocación mediata de los estímulos ofrecidos y aun después de haber realizado buenas asociaciones, y alteraciones en la memoria no declarativa. Esto indica la existencia de limitaciones neuropsicológicas en los sistemas funcionales vinculados con el recuerdo declarativo y no declarativo, voluntario e involuntario en los pacientes sometidos a circulación extracorpórea.

Palabras clave: Memoria, Circulación extracorpórea, Neuropsicología

INTRODUCTION

Cardiovascular diseases are the leading cause of death in developed and developing countries¹. Among them, ischemic heart diseases and severe valvular diseases are serious health problems that have a common therapeutic strategy: surgery.

Aortic and mitral are usually the most damaged valves. Among the main causes for the damage are rheumatic heart disease, infective endocarditis, and other less common, such as mitral valve prolapse. But in social systems with high levels of health, such as ours, where life expectancy exceeds 75-80 years, degenerative valve diseases represent a high percentage of these conditions².

Myocardial revascularization (surgical or interventional) is performed when there is severe atherosclerotic disease of the coronary arteries, which, in turn, can be catalyzed by a number of risk factors including smoking, diets high in saturated fat, obesity and a history of hypertension, diabetes mellitus, hypercholesterolemia, among others³.

Coronary and valvular surgeries require, in a high percentage of cases, the use of extracorporeal circulation (ECC), a procedure by which the patient's

blood is removed and, through a complex system, is filtered, oxygenated, accumulated carbon dioxide is eliminated, and blood is reinjected back into patient⁴.

ECC fully or partially replaces the functions of the heart and lungs, and may be essential in a number of patients and clinical situations^{4,5}, however, regardless of its positive elements, it is capable of producing undesirable effects on organs and systems including the neurological system⁵. Neurological complications in the immediate postoperative period are an important cause of morbidity and mortality, increased expenses on health resources, and lead to functional limitations in patients who survive⁶. That is why the neuropsychological study of these patients is essential, since it is a very common procedure in patients treated at the Cardiocentro of Santa Clara, and is a subject not yet investigated in our province.

The objectives of this research were to characterize neuropsychological functioning of the memory process in patients undergoing surgery for valvular or coronary disease with the use of ECC; to describe their age, gender, educational level, diagnosis and cardiovascular risk factors; direct fixing of memory trace, retention in memory, immediate memory, and to determine

whether there were damages on the declarative or involuntary memory.

METHOD

Type of study

A conducted exploratory-descriptive study was conducted, as we aimed to define the characteristics of a given phenomenon that is still new in the field of scientific research in our province.

Research paradigm

An essentially quantitative methodology was used, since the techniques used require statistical processing of the results, even when a qualitative analysis of certain instruments is offered. This methodological choice uses data collection to test hypotheses based on numerical measurement and statistical analysis.

The research was carried out on the basis of a cardiovascular surgical procedure, which can cause damage at a neuropsychological level, and has not been studied in this regard (effects on the memory) in our province, nor have we found any similar study published in our country. That is why our research focuses on the description of the possible damage it can cause to the memory process.

Sample Selection

An intentional sampling was performed and the sample consisted of 25 patients from the Progressive Care Unit of Cardiocentro Ernesto Che Guevara of Santa Clara, Cuba. These patients suffered from valvular or coronary disease that caused the surgical procedure with CPB.

Inclusion Criteria

- To have undergone surgery due to valvular or coronary heart disease, or both, with the use of CPB.
- To be hospitalized in the Progressive Care unit of Cardiocentro Ernesto Che Guevara at the time of the research.
- To be in proper health condition to participate in the research.
- To agree to participate in the research.

Exclusion criteria correspond to the non-fulfillment

of the inclusion criteria.

Information Collection

For primary data collection the memory multivariate test of Luis Felipe Herrera⁷, Digits subtest of Wechsler scale for adults, review of documents (Personal Health Record) plus a semi-structured interview to each patient were used.

Multivariate Memory Test

This technique, created by Herrera et al.⁷, is based, from the theoretical point of view, on some of the assumptions of Vygotsky, Luria and Klix, on the active nature of human memory. It has two variants, one for adults and one for children. In this case, the variant for adults that includes three series was used. The first one allows the exploration of immediate recall of simple, familiar words, the second, the analysis of immediate memory and includes 15 stimuli words and 20 cards with representations of animate and inanimate objects, and the third, includes graphic reproduction of the representations offered in the cards of the previous series and responding to 5 questions that allow to find out about involuntary memory from the contents of the cards used in the second series (**Table 1**).

Table 1. Categories of memory quality, according to the results of the multivariate test.

Categorías	Calificación en puntos
Very good memory (VGM)	70 – 55
Good Memory (G)	54 – 39
Memory difficulties (D)	38 – 23
Marked difficulties in the memory (B)	22 or less

Captions. VGM: Very good, G: good, D: difficulties and B: Bad

Digits subtest of the Wechsler scale for adults⁸⁻¹⁰

The scale has a series of verbal and other manipulative tests. The subtests used in this research, belongs to the verbal scales. Digits has two series: one in direct order and another in reverse order, which

have in turn two trials respectively, and depending on the possibilities of the subject to have a good performance on the first, it is decided whether or not to pass to the second. The first series asks the subject to memorize several numbers and ends just in the last correctly reproduced serie. The second has the same procedure, but in this case digits are repeated starting with the last one the interviewer said. Both end after failing in the two trials of either series. The aim is to analyze the quality of memory trace fixation.

The score is equal to the number of digits in the longest series repeated without error: direct order = 9 points and reverse = 8 points. So the total test score can be equal to 17 points (sum of both results).

This test aims primarily at demonstrating the status of the short-term sensory memory, together with the mechanisms of recalling and memory trace fixation in a short period of time.

Document review (medical record)

It was done in order to access the patient's history that caused his/her surgical procedure. Hence, relevant information about the life history of each subject, risk factors for their disease and symptomatology associated with their clinical condition, in-hospital procedures and, most importantly, their evolution from diagnosis to the time of research, were analyzed.

Semi-structured interview

It aimed at exploring the recall memory of patients through access to previous experiences. Indicators concerning personal data, situations about their illness, vital events occurred five years ago and recently, and exploration of elements related to declarative memory.

RESULTS

Sample characterization

A total of 25 patients was studied, 15 of them (60 %) were men. Ages ranged between 50 and 70 years, although a 32 -year-old patient was included. The predominant completed school level was middle school (28 %), followed by high school (24 %) and middle technician (20 %). The university level was represented by 20 % of the sample and the rest had completed primary school or just the fourth grade.

Table 2 shows that multivessel disease (48 %) predominated, followed by valvular regurgitation (36 %). Non-tabulated data showed that the most common risk factors were hypertension (60 %) and diabetes mellitus (16 %), and with respect to addictions, coffee intake (64 %), smoking (36 %) and alcohol (24 %).

Table 2. Diagnosis of cardiovascular disease.

Diagnosis	Nº	%
Infective endocarditis	1	4,0
Multivessel disease	12	48,0
Aortic stenosis	2	8,0
Valvular insufficiency	9	36,0
Valve prolapse	1	4,0
Total	25	100,0

Memory Test

In the corresponding serial analysis (not tabulated), it was found that the first series, which allows exploration of fixation through repetition, showed a trend of 5 words recalled from a total of 10. It was followed by responses of 4 words. These results, at least that of 5 points, is within the standard, but concomitant with the limit. Responses of 4 points or less are already out of the normality margins. In the series 2 (allows analysis of mediate memory and quality of associations) prevailed responses from 14 to 15 points (20 % of the sample equally) for a maximum of 15 points. This memory function was not severely affected, even when there were scores of 7 and 8, but they were in the minority of cases. In the third series (it measures graphic reproduction and mediate recall on the basis of the use of images), the scores were heterogeneous and ranged from 8 points to 22. The trend (represented by 20%) was 16 points responses, followed by those of 10. This was a series that, together with the first and the exploration of non-declarative memory, showed more difficulties during the assessment.

As for the latter (non-declarative memory, **Table 3**) 2 and 3 points responses were predominant (32 %, 8 patients each), and there were 2 (8 %) who recalled only one element of the total 5. This indicates that

non-declarative memory is severely affected, since in case of recalling properly, the patient required a comprehensive effort to meet the demand.

Table 3. Involuntary memory (non-declarative).

Response (points)	Nº	%
1	2	8,0
2	8	32,0
3	8	32,0
4	7	28,0
Total	25	100,0

Digits subtest of Wechsler scale for adults allow assessing the quality of memory trace fixation and retention of numerical series after repetition. In the series of direct order, patients recalled mostly up to the series 4 out of 9 total (36 % of the sample). Responses of series 5 and 6 followed, with a frequency equal to each other of 24 %. In the reverse order there were more difficulties because only up to the third series (40 %) was recalled, for a total of 8 points to reach. The second and fourth series followed with 28 % representation in each case.

The total score was heterogeneous (**Table 4**), and the effect on the the memory trace fixation was more

Table 4. Total score.

Response (points)	Nº	%
4	1	4,0
5	1	4,0
6	4	16,0
7	5	20,0
8	7	28,0
9	5	20,0
10	1	4,0
11	1	4,0
Total	25	100,0

directly observed, since 8 points responses (28 %) prevailed from a total of 17 to reach. Responses of 7 and 9 points followed, in order of frequency, represented by 20 % of the sample in each case.

The test generally showed the existence of memory difficulties in 16 patients (64 %) compared to 9 (36 %) with a good memory, as shown in **Table 5**.

Table 5. Integrated assessment of memory.

Assessment	Nº	%
Memory difficulties	16	64,0
Good memory	9	36,0
Total	25	100,0

Semi-structured interview

The interview showed results related to patients' experiences since they were diagnosed until the present. They generally express a desire to continue living, but are anxious and with somewhat negative expectations about the possibility of complications after surgery. Furthermore, some concern about their hospital stay after surgery and the typical anxiety for hospital discharge was noted.

Among vital events that occurred five years ago they mention disease diagnosis, the beginning of in-hospital procedures, changes in their projects and lifestyles (and also in their close family), in addition to referring to previous surgery in some cases. Among recent events they vaguely remember being in the intensive and intermediate care units, depending on the level of consciousness that the patient has had at that time.

DISCUSSION

The distribution by sex and age groups, as well as preoperative diagnosis corresponds with published data for cardiovascular diseases^{1-3,11}, but did not show statistical significance for this study; however, the educational level reached is indeed an important factor because it speaks about the stimulation to which the higher nervous activity of these patients has been subjected.

The ECC produces neuropsychological affectations in the memory process, manifested in limitations in fixation and recalling of voluntary and involuntary, de-

clarative and non-declarative memory traces^{4,5}. This procedure may have triggered affectations of varying severity in the neuropsychological functioning of the subject, mainly in the cognitive area. The damages caused to the thinking process have been studied previously in this sense⁴.

After ECC, cognitive damages are considered to occur at the level of all processes. In this case we refer to memory as neurocognitive function that allows to record, encode, consolidate, retain, retrieve, and recall the previously stored information. It is about the ability to retain the information learned^{4,12}. The memory as a process is divided into two main functions: short and long-term memory. Within these classifications several subcategories have been discussed, each with their roles properly explicit. In the present research and in Neuropsychology as a scientific discipline, attention is paid to the consideration made of declarative or voluntary memory and non-declarative or involuntary memory¹²⁻¹⁴. In this sense, declarative memory is merely experiences, facts or events acquired through learning which can be consciously retrieved by the subject. In turn, non-declarative memory is one which can not be accessed in a conscious way. Its information access and storing run unconsciously, so the subject does not know he/she has that information until a specific stimulus demand its recalling¹²⁻¹⁴. According to Portellano¹², this memory is the most important system of information acquisition in all species, since it allows adaptation to the environment through the automaticities that form at the base.

In any process of neuropsychological test of mnemonic function four key elements should be included¹⁴⁻¹⁸:

- Research of the direct fixation of memory traces: this should investigate the direct fixation of visual, auditory and tactile traces. A normal person easily retains and reproduces series of 5-6 elements (words, numbers, shapes).
- Research of the retention process: It is based on the use of words repetition to the patient.
- The study of mediate or declarative memory: here 12-15 sets of verbal stimuli can be used, as well as sheets that support recalling.
- Research of involuntary or non-declarative memory: great value is given to inquire about involuntary processes, since voluntary processes have been investigated more. Clinical evidence show

that more a patient's psyche disintegrates and his/her personality deteriorates, the more his/her involuntary processes will be severely affected.

The analysis of medical records provided general data of patients, duration of disease, risk factors and common complications of the disease. The essential features of these chronic diseases, lead to the degeneration of functions and can endanger the patient's life. That is why, despite knowing the possible complications, patients are turning to surgery with ECC as a guarantee and hope to extend life and improve its quality.

In the semi-structured interview a series of questions were asked regarding environmental elements which patients do not tend to be aware of, but they live daily with them. These include equipment in the wards, linen colors, specific characteristics of the next patient's belongings, among others. All this was done in order to further explore the declarative memory, and similarly, justified responses were obtained saying they have not noticed something, that they have seen something but do not remember the color or shape, or simply they do not remember those details although they are part of their everyday life.

Undoubtedly, ECC alters the mnemonic process which together with the known disorders of the anesthetic-surgical environment, produces neuropsychological disorders in the memory process manifested by limitations in the fixation and recalling of voluntary and involuntary, declarative and nondeclarative memory traces^{6,19}. These postoperative deficiencies may be associated with limitations in the arrival of blood flow to secondary and tertiary areas of the cerebral cortex, with consequent regional edema, and raise new questions in the field of rehabilitation and research in this area, where cardiovascular disorders and mnemonic neuropsychological functioning meet.

The alterations found indicate disorders in the most complex functional systems of the analytic-synthetic activity of the cortex, which are based in the frontal and temporofrontal structures of both cerebral hemispheres.

CONCLUSIONS

Male patients, between 50 and 70 years of age, with a low educational level were predominant. Typical elements in the memory of the patients studied express-

ing difficulties in direct fixation of memory traces as the basis of the retention process of verbal and numerical stimuli were found, as well as insufficiencies in the mediate recall of the stimuli offered and even after having made good associations, which is indicative that semantic categorical systems are affected.

There were also changes in declarative and involuntary memory, hence mental blocks after specific demands occurred. All these disorders found indicate the existence of neuropsychological limitations in the functional systems, linked with declarative and non-declarative, voluntary and involuntary memory in patients undergoing cardiac surgery with ECC.

RECOMMENDATIONS

To continue this line of research and find out more about the effect of ECC in patients undergoing this type of surgery. It is advisable to carry out research to deepen in the neuropsychological impairment that can occur in these cases which not only affects the memory process. It is important to consider the characteristics of memory found in the process of rehabilitation of these patients, where the neuropsychological factor is determinant.

REFERENCES

1. Cordero Sandoval QM, Ramírez Gómez JI, Moreno-Martínez FL, González Alfonso O. Valor predictivo de algunos modelos de estratificación de riesgo en pacientes con infarto agudo de miocardio con elevación del ST. *CorSalud* [Internet]. 2013 [citado 2013 Ene 3];5(1):57-71. Disponible en: <http://bvs.sld.cu/revistas/cors/pdf/2013/v5n1a13/es/estratificacion.pdf>
2. García Cuesta D, Vázquez Roque FJ, Coll Muñoz Y, Rivero Valerón D. Relación de variables preoperatorias en pacientes con cirugía de reemplazo valvular aórtico y su evolución posquirúrgica precoz. *CorSalud* [Internet]. 2011 [citado 2013 Ene 3];3(1):26-33. Disponible en: <http://bvs.sld.cu/revistas/cors/pdf/2011/v3n1a11/variables.pdf>
3. Pell JP. Anuario 2012: Puntuaciones de riesgo cardiovascular. Las revistas de las sociedades nacionales presentan una selección de las investigaciones que han impulsado avances recientes en cardiología clínica. *CorSalud* [Internet]. 2013 [citado 2013 Ene 3];5(1):6-16. Disponible en: <http://bvs.sld.cu/revistas/cors/pdf/2013/v5n1a13/es/almanac-riesgo.pdf>
4. Abeledo AA. Comparación del funcionamiento neuropsicológico del pensamiento en pacientes sometidos a cirugía cardíaca con y sin circulación extracorpórea [Tesis]. Santa Clara: Universidad Central "Marta Abreu" de las Villas; 2011.
5. Lamas Ávila AD, del Cueto Espinosa H. Alteraciones neurológicas en la cirugía cardíaca durante el quinquenio 2001-2005. *MEDISAN* [Internet]. 2006 [citado 2013 Ene 5];10(3): [aprox. 4 p.]. Disponible en: http://www.bvs.sld.cu/revistas/san/vol10_03_06/san04306.htm
6. Silva E, Mazziotti J, Reisin R. Complicaciones neurológicas perioperatorias en el geronte. *Rev Arg Anest.* 2008;66(6):587-94.
7. Herrera Jiménez LF, Guerra Morales V, Casas Cardoso G, Fernández Ceballos M. Características neuropsicológicas de niños deficientes auditivos leves de siete a diez años de edad. *Rev Cub Psicol.* 2002;19(2):178-82.
8. Piacente T. Tests de rendimiento máximo de dominio general. Los tests de inteligencia. Las escalas Wechsler. 2012. [Internet]. Disponible en: http://www.psico.unlp.edu.ar/externas/evaluacion-psicologica/material2012/mat_didac_sistem/8-escalas_wechsler.pdf
9. Wechsler D. WAIS III. Test de Inteligencia para adultos. Manual de Administración y Puntuación. Buenos Aires: Paidós, 2002.
10. Wechsler D. WAIS III. Escala de Inteligencia Wechsler para adultos III. Manual Técnico. Madrid: TEA Ediciones, 1999.
11. Cotran RS, Kumar V, Collins T, eds. Patología estructural y funcional. 6ta Ed. Madrid: McGraw-Hill-Interamericana, 2000.
12. Portellano JA. Introducción a la neuropsicología. Madrid: Editorial McGraw-Hill, 2005.
13. Vega M. Introducción a la Psicología Cognitiva. La Habana: Félix Varela, 2005.
14. Técnicas de Estudio: La Memoria. Técnicas para desarrollar la memoria. [Sitio en Internet]. [citado 2012 Dic 28]. Disponible en: <http://www.psicopedagogia.com/tecnicas-de-estudio/memoria>
15. Alfonso D, Molerio O. Particularidades neuropsicológicas de los procesos cognitivos en escolares de 9-12 años con retraso mental leve [Tesis]. Santa

- Clara: Universidad Central "Marta Abreu" de las Villas; 1993.
16. Tirapu J, Ríos, L, Maestú F. Manual de Neuropsicología. Barcelona: Viguera Editores, 2008.
17. González D. Actividad nerviosa superior. La Habana: Félix Varela, 1977.
18. Luria AR. El cerebro en acción. La Habana: Pueblo y Educación, 1982.
19. Delgado P. Disfunción cognitiva posoperatoria en el anciano. Rev Arg Anest. 2008;66(6):595-605.