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Neurological Complications in Aortic Valve Surgery and Rehabilitation Treatment Used

M. Paz Sanz-Ayan[1], Delia Diaz[1],
Antonio Martinez-Salio[2], Francisco Miguel Garzon[1],
Carmen Urbaneja[1], Jose Valdivia[1] and Alberto Forteza[3]
[1]*Department of Rehabilitation, University Hospital 12 de Octubre, Madrid*
[2]*Department of Neurology, University Hospital 12 de Octubre, Madrid*
[3]*Department of Cardiac Surgery, University Hospital 12 de Octubre, Madrid*
Spain

1. Introduction

Around the second decade of the twentieth century there was speculation about the possibility of cardiac surgery and its possible consequences in the central nervous system. To reduce these potential consequences as much as possible, research was carried out into three different approaches: systemic hypothermia, by placing the patient in a bath of ice-cold water, cross circulation between two people, and cardiopulmonary bypass (CPB) with a roller pump and an artificial oxygenator (Clau Terré, 2009). Shortly after using these procedures, it became clear there was an advantage provided by the CPB technique with an independent oxygenator and normal systemic flows that neither cross-circulation nor surface hypothermia could provide. It thus became possible to address increasingly complex congenital heart disease and ventricular septal defects, tetralogy of Fallot and other more complex examples. With the introduction of CPB, early neurological complications such as coma, cognitive impairment, strokes, etc. began to appear.

Fig. 1. Extracorporeal (CPB) blood pump

Neurological complications (NC) associated with postoperative aortic valve surgery are relatively frequent in spite of technical advances in surgery and CPB systems, and they give rise to an increase in morbidity and mortality, increased lengths of stays in hospital and rising costs after discharge from hospital. Therefore, the main purpose of the medical team responsible for assessing and treating patients who require cardiac surgery is to conduct a proper assessment and preventive measures for these complications and, once they have occurred, to minimise the physical, psychological, social and economic consequences for the patient and their family.

2. Changes in cerebral blood flow during CPB with extracorporeal pump

The brain weighs about 2% of total body weight. Cerebral blood flow accounts for 10 to 15% of cardiac output. Cerebral blood flow in normothermia is 50 millilitres (ml)/100 grams (g) of tissue per minute (min) and oxygen consumption is 3.5 ml/100 g tissue / min. Cerebral circulation is unusual in its self-regulating ability performed through the arteries of medium and large size. The ability for self-regulation acts at between 50 and 155 millimetres of mercury (mm Hg) for systolic blood pressure in normal conditions, but below 50 mm Hg brain irrigation is directly dependent on the amount of flow to this area. In cases of severe hypertensive disease or cerebral vascular disease, the lower limits can be much higher (Sotaniemi et al., 1986, Caplan et al., 1999).

At normothermia, there is permanent neurological damage when there is a cerebral perfusion defect or flow is less than 125 ml/min for more than 7 minutes. Vascular territories with little reserve, such as the border zones of cerebral arteries, the spinal cord and basal ganglia are the most sensitive and most affected by a situation of ischemia. The hippocampal cells and cerebellar Purkinje cells are also particularly sensitive to ischemia.

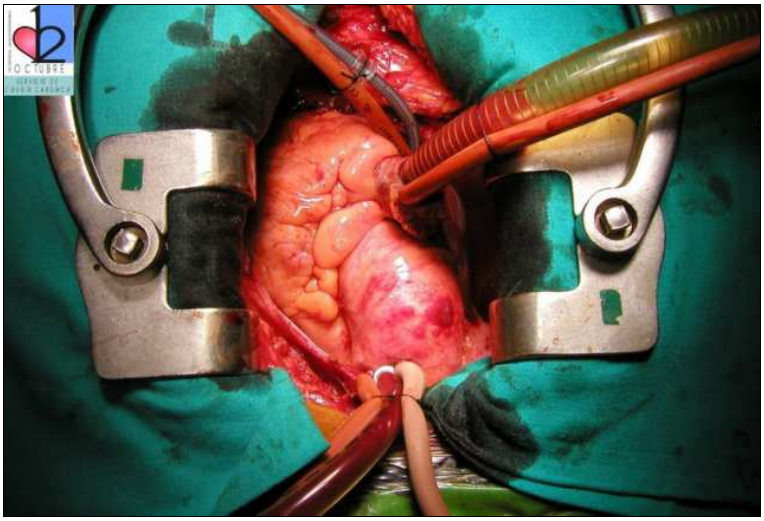

Fig. 2. Cannulation in ascending aorta and right atrium in preparation for using cardiopulmonary bypass. Similarly, the coronary sinus is cannulated to administer cardioplegic solution

The average cerebral blood flow in adult CPB is 25 ml/100g/min, which is approximately 6% of systemic flow. The ability for self-regulation with normotension persists, even in cases of hypothermia, ranging between 50 and 155 mm Hg. A decrease below 40 mm Hg may cause a significant decrease in cerebral oxygen delivery.

3. Etiological classification of neurological complications

The series that we can see in the bibliography show that there is a greater number of NCs in valve replacement surgery than in coronary artery bypass grafting, with an incidence of stroke or transient ischemic attack of 1.7% in patients undergoing coronary artery bypass grafting, 3.6% in those with a simple valve replacement, 3.3% in those undergoing both procedures and 6.7% in those who undergo a multiple valve replacement (Boeken et al., 2005)

The NCs in these patients may affect the brain, the spinal cord and peripheral nerves, and the most common of these are often strokes, anoxic-ischemic encephalopathy, epilepsy and brachial plexus injuries

Among the many threats to which the Nervous System is subjected during cardiovascular surgery, we can highlight the following: embolism, CPB, general anaesthetics, hypothermia, aortic clamping, and in some cases circulatory arrest. (Mills, 1995; Roach et al., 1996; Hallow et al, 1999).

According to the guidelines of the American College of Cardiology / American Heart Association as regards heart surgery for 1999, neurological complications are classified as type I deficiency, including focal lesions such as stroke and stupor or coma, and type II when intellectual functioning and memory are affected, and seizures. However, there are intermediate forms that are difficult to classify (Roach et al., 1996).

Strokes or **cerebrovascular accidents** are on the whole 80% ischemic and 20% hemorrhagic (use of anticoagulants). 50% of the ischemic ones are usually caused by atherothrombotic reasons, 25% are lacunar (associated with chronic arterial high blood pressure), 20% are cardioembolic, and the remaining 5% involve the ones we usually include in cardiac surgery: heart attacks in the border zone area between the anterior cerebral artery and the middle cerebral artery (called man-in-the-barrel syndrome due to its clinical consequences), and between the latter and the posterior cerebral artery. (Sanz et al., 2008)

In cardiac surgery, the incidence of stroke ranges from 0.7 to 3.8% when assessed retrospectively or between 4.8 to 5.2% if assessed prospectively (Bocerius, 2004). This is the main cause of morbidity in people undergoing cardiac surgery. Its frequency is 5% higher in patients with valvular disease, either due to an increased frequency of atrial fibrillation in these cases or because the valve surgery requires opening the heart chambers and increases the likelihood of air embolization, unlike in coronary surgery.

It may appear early on, occurring during surgery, and become apparent when the patient awakes, or later after normal awakening with no focal neurological damage apparent. Both the early and late kinds have a high hospital mortality of 41% and 13% respectively. (Hogue et al, 1999).

Strokes cause major disability and high rehabilitation costs because these patients most often require the use of different technical aids or orthotics for walking, wheelchairs, adaptation of their home due to architectural barriers, help from third parties and in some cases the everyday need for health care staff, requiring admission to specialised homes.

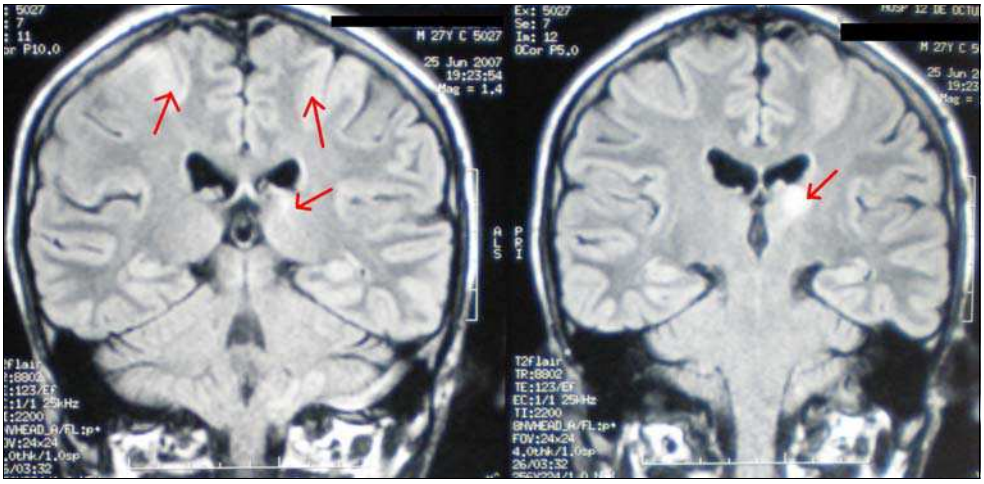

Fig. 3. Sagittal cross-section MRI image showing effects firstly on the cortex of both hemispheres of the brain in the superior fronto-parietal regions and bilaterally. Bilateral basal ganglia are also affected, especially in the left thalamus and both heads of the caudate nuclei. Infarction in the border zone. Man in a barrel syndrome

Fig. 4. Sagittal cross-sectional MRI image showing a hyperintense lesion in T2 (which was T1 hypointense) from D7 to L2, compatible with secondary spinal cord ischemia with aortic arch surgery. (Taken from Martin C et al, 2007)

Encephalopathy is usually secondary to a diffuse cerebral injury, and is believed to originate from multiple microembolic events or hypoperfusion (Jacobs et al, 1998). This clinical situation manifests itself in various ways, but it is diagnosed as a state of global

impairment of cognitive functions, a reduced level of consciousness that is sometimes prolonged, hallucinations, and increased or decreased psychomotor activity. Its incidence ranges from 3 to 12% and though it involves high mortality (7.5%) this is usually lower than that of a stroke, and has an average hospital stay double that of the usual stay. Encephalopathy in these patients may be metabolic (disorders in the internal environment), pharmacological (drug toxicity), hypoxic ischemic (hypotension) or due to multiple causes (the aforementioned ones plus sepsis, use of balloon counterpulsation).

Epilepsy usually occurs as a result of diffuse encephalopathy, a stroke, and in patients with previous epilepsy, and is usually related to the presence of metabolic disorders (generalized epilepsy) or a structured lesion (focal epilepsy). It occurs in 0.3 and 10% of cases and does not often lead to epilepsy.

Effects on the **spinal cord** are usually diagnosed by the appearance of paraparesis in connection with a spinal cord infarction related to hypotension in the border zone or clamping of the aorta. The effects appear most often in reconstructive aortic aneurysms, dissections or traumatic rupture, as well as in valve repairs and the use of intra-aortic balloon counterpulsation.

The most common injuries to the **Peripheral Nervous System** are **brachial plexus neuropathy**, **recurrent laryngeal nerve injury** and **phrenic nerve injury**, almost all related to compression neuropathy of a mechanical nature, due to fracture of the first rib by excessive intraoperative traction exerted on the sternum and chest wall.

- Brachial plexus trauma injury is related to trauma during jugular cannulation, plexus stretching and during the dissection of the internal mammary artery that requires extreme retraction of the chest wall. The incidence ranges between 2.6 and 13%. Most of the deficits are usually transient. (Benecke et al, 1988).
- Phrenic nerve injuries are usually related to local hypothermia for myocardial protection (Beran et al, 2008).
- Injuries to the radial or ulnar nerve are usually associated with puncturing or hematoma when cannulating arteries for intraoperative pressure monitoring.
- Recurrent laryngeal nerve injuries occur in surgery affecting the convexity of the aortic arch.
- The facial nerve is usually affected by hypothermia or direct mechanical injury.
- Peroneal nerve compression resulting from incorrect and prolonged support of the fibular head on a hard surface.

We must rule out other types of polyneuropathy such as ICU, produced by malnutrition or deficits such as phosphorus.

Extrapyramidal system damage: especially choreoathetosis, whose frequency ranges from 1-12% of patients with neurological complications. This is most often associated with hypothermia and total cardiac arrest. It appears between the 2nd and 6th days after surgery and usually decreases in intensity over time, although it may leave significant hypotonia.

Neuropsychological disorders: these are assessed by means of memory, intelligence, visual acuity and motor tests. Diffuse disorders can appear in up to 80% of cases in the immediate postoperative period and up to 20-40% still persist two months after surgery. They are more common at older ages. They appear as the patient's subjective sensation of loss of concentration, alertness, memory, learning etc. (Asenbaum et al, 1991; Bendszus et al, 2002).

Table 1 shows a summary of the most common complications in cardiac surgery in general.

SYNDROME	DIAGNOSTICS	MECHANISMS
Diffuse encephalopathy	Anoxo-ischemic encephalopathy Metabolic encephalopathy Encephalopathy for various reasons	- Hypotension - Drug toxicity - Disorders in the internal medium - Sepsis
Focal defect	Stroke Cerebral Haemorrhage	- Embolism - Hypotension (hemodynamic infarction) - Clotting factor consumption - Anticoagulants
Epilepsy	Diffuse encephalopathy STROKE Prior epilepsy	- Metabolic disorder (generalized epilepsy) - Structural lesion (focal epilepsy)
Paraparesis	·Spinal cord infarction	- Hypotension (border zone) - Aortic clamping
Peripheral neuropathy	Brachial plexus neuropathy Recurrent laryngeal lesion Injury of the phrenic nerve	- Compression neuropathy

Table 1. Major neurological complications in cardiac surgery

4. Prevention of neurological damage in aortic valve surgery

Identifying patients at high risk of neurological damage is as important as the techniques to prevent it.

Pre-operative prevention: achieving adequate metabolic control, especially in hypertensive and diabetic patients, optimizing treatment for each patient (antihypertensive, anti-anginal), hemodynamic stabilisation and prevention of the patient's previous arrhythmias, and attempting to reduce postoperative atrial fibrillation. It is also important to carry out a prophylaxis to minimise perioperative stress through suitable information for the patient on the surgery they are to undergo.

Intraoperative prevention: the possibility of embolisation is the main cause of postoperative stroke, especially as regards the ascending aorta's atheromatous plaques, so it is important to conduct a pre- and post-operative transesophageal echocardiography to diagnose these plaques. In this way one can locate and change the cannulation site, location and type of clamping. Another region from which the embolisations come is the left atrial appendage, above all the flap, and the risk of embolisation here may be reduced by ligature of the same. In valve surgery, delicate mobilization of the heart is particularly important as well as adequate purging of the cavities.

CPB may cause injury to the central nervous system in various ways: it is a cause of embolism and a stimulus for the activation of systemic inflammatory response. This is why

membrane oxygenators are used, as well as arterial line filters and smaller circuits coated with heparin. These circuits also attempt to maintain the functioning of platelets, preventing the formation of procoagulants, fibrinolysis, reducing bleeding and the need for transfusion.
Proper control of temperature is important (avoiding cerebral hyperthermia), metabolic control and correctly maintaining the acid-base status so as not to increase the possibility of neurological effects.
Cerebral hypoperfusion may reduce purging of microemboli, thereby encouraging neighbouring infarcts. This is why hemodynamic stability should be maintained throughout the surgery. Although autoregulation of cerebral blood flow during cardiopulmonary bypass occurs within a wide range of pressures, hypertensive and diabetic patients may require higher average pressures to maintain perfusion (90 mm Hg). Therefore, although the optimal level is not firmly established, one attempts to apply more pressure than usual to reduce neurological damage in high-risk patients.
Non-CPB surgery does not remove medical complications since the inflammatory response is also triggered, though to a lesser degree. This is associated with a relative reduction in the risk of stroke by 50%.
It is important to try to avoid haematomas on the central or peripheral vascular accesses and pressure zones in order to decrease potential injury to the peripheral nervous system.
Post-operative prevention: metabolic control should be continued as regards blood glucose and adequate oxygenation, and anticoagulation and antiagregation should be started immediately. Arrhythmias should be avoided as much as possible, especially atrial fibrillation, usually by using beta blockers.
One should continue avoiding zones of compression or of excessive pressure in order to decrease injury to the peripheral nervous system.
It is very important at this stage to control all that has been mentioned above since all of this may prolong the time in intensive care units, possibly leading to polyneuropathy in the critical patient with a pattern of axonal damage that would cause long-term consequences similar to those caused by the side effects of a stroke. It is therefore important to get the patient to sit up as soon as possible.

5. Rehabilitation treatment for neurological complications after aortic valve surgery

The **rehabilitative treatment** for NCs arising from aorta surgery ranges from prevention of possible complications to restoring the motor control of walking, improving limb functions and increasing the patient's participation in and return to daily life.
In patients with stroke and severe postoperative NCs, rehabilitation treatment in the **acute phase** is:

- Reducing **respiratory complications** such as atelectasis, retention of secretions, respiratory infections, pleural effusions or those generated by phrenic nerve palsy causing paresis or diaphragmatic paralysis. In any patient on whom a median sternotomy or thoracotomy is performed, active and passive chest physiotherapy protocols are carried out. These patients are protected with a sternal compression vest to avoid pain with the movements induced by Valsalva manoeuvres such as coughing.
  A technique of expectoration, chest expansion, postural drainage and chest vibrations could be added to techniques such as incentive spirometry and airflow acceleration techniques.

The typical respiratory pattern of patients undergoing median sternotomy is: low tidal volume, high respiratory rate, absence of sighing, restrictive pattern [reduced vital capacity, reduced inspiratory capacity and reduced functional residual capacity produced by both anesthesia (18%) and decubitus (30%)]. Apart from altering the exchange of gases, it is also beneficial in that there are cases where there is aspiration as this decreases mucociliary activity, decreases cough reflex, and produces a hyper-reactive and altered alveolar surfactant.

- **Swallowing, hydration and nutrition:** the incidence of dysphagia in strokes is 50% with a high risk of aspiration and pneumonia. Early sitting up is essential. If there are signs of impaired swallowing as tolerance to food increases, liquids should be thickened and if necessary nasogastric tubes should be put in place to avoid choking. In this event, patients should be referred to medical specialists in dysphagia rehabilitation.
- **Urinary incontinence** is common (30-50%) in the early days, due to lack of sphincter control, immobility, communication problems, prior prostate or gynaecological diseases, urinary tract infection and confusional states. The bladder catheter must be removed when possible, because this is usually resolved in the first few days. If it is not resolved, it is necessary to carry out a urodynamic study to determine the exact cause of the incontinence.
- 5% of stroke cases also present **deep vein thrombosis**, and **pulmonary embolism** is the leading cause of death between the 2nd and 4th week after the stroke. Early mobilisation and low molecular weight heparin are the two possibilities for prevention. Medium compression stockings are used for patients at high risk of developing this.
- **Contractures and spasticity:** Immobilization in shortened positions is the main mechanism of contracture with limited passive movement. Prevention is based on passive exercises involving the complete joint range of motion and prolonged muscle stretching. If spasticity appears, one may consider using braces to keep up the stretching and functional postures.

Fig. 5. Postural night splint

- **Early mobilisation:** Beginning activities early on such turning over in the bed or transfer to the seated position. Helping to gain control over the trunk in the sitting position as an essential step to the standing position. The patient should use their non-plegic limbs for basic hygiene and begin to resume everyday activities.
- **Shoulder pain:** With stroke, subluxation may appear in the first weeks as a result of the flaccid stage and it may also appear solely due to immobilization. The appearance of

this shoulder pain may delay the recovery process. Prevention is based posture and movement guidelines given by the patient's medical staff and family. Transcutaneous neuromuscular stimulation can prevent and treat pain but is not recommended as a standard guideline.

- **Perception, cognitive and communication deficits:** Orientation, contact and communication with people and the environment is to be helped. Speech therapy treatment is to begin as soon as possible when the patient's condition permits this.

In the **subacute phase** of postoperative neurological complications, work is done directly on the motor deficit and physical disability using different techniques involving: compensation, facilitation, task-oriented rehabilitation, technology applied to rehabilitation programmes geared towards tasks (e.g. walking on a treadmill with part of the body weight suspended), therapy by movement induced by the healthy side being restricted, muscle strengthening techniques and aerobic exercise. Intervention in the perceptual and cognitive area and emotional disturbances.

Technical aids such as braces, walking sticks, walking frames, botulinum toxin and occupational therapy are also used.

Fig. 6. Different technical aids and ortheses used for hemiplegics

There follows an analysis of the impact of different NCs in aortic valve surgery, including both early and late complications from 2008 to 2010 in the University Hospital 12 de Octubre (Madrid). The study includes single and multiple aortic valve replacements, aortic valve replacement plus coronary artery bypass grafting and aortic valve replacement plus tube graft due to root aneurysm (techniques: Bentall (Kirali et al, 2002), David (modified) (Forteza et al, 2010) and 2nd aortic valve replacement).

6. Objectives

1. To assess the clinical risk factors for NC developing.
2. To assess the different NCs and their impact/frequency.
3. To analyse the different rehabilitation techniques that have been used in the treatment of NCs.

7. Materials and methods

452 patients who underwent aortic valve surgery were retrospectively analyzed by being divided into the following groups: single and multiple aortic valve replacements, aortic

valve replacement plus coronary artery bypass grafting and aortic valve replacement plus tube graft due to root aneurysm between January 2008 and November 2010.

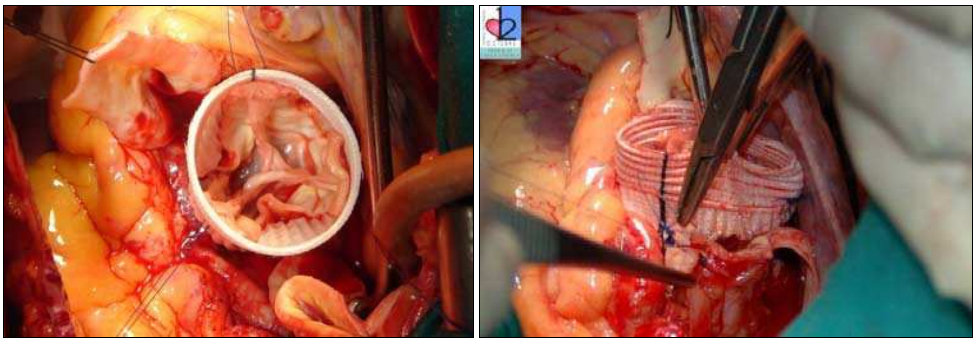

Fig. 7. Reimplantation using the inclusion (David) technique

An NC was defined as the occurrence of a cerebrovascular accident (STROKE) (ischemic or hemorrhagic), transient ischemic attack (TIA), spinal cord injury, peripheral neuropathy, seizure, stupor, coma, polyneuropathy of critically ill patient, dementia, acute delirium or encephalopathy.

A comparative analysis was carried out on the incidence of NCs according to a series of preoperative and postoperative clinical variables: arterial hypertension, diabetes mellitus, dyslipidemia, chronic obstructive pulmonary disease, heart failure, renal failure, prior STROKE, smoker, drinker, calcified valves, endocarditis, peripheral arterial disease, previous revascularization, aortic atherosclerosis, acute myocardial infarction within 3 months prior to surgery, left ventricle ejection fraction, aortic clamping time and CPB time, postoperative arrhythmia, number of transfusions required, whether resuscitation techniques were required, drugs the patients were taking, surgical priority (scheduled, priority and urgent) and type of surgery performed.

An attempt was made to determine which of these variables was more important statistically in relation to the others.

7.1 Definitions used

- **Prior STROKE:** a documented history of STROKE with side-effects such as impaired motor, speech or sight functions.
- **STROKE:** sudden onset of one or more neurological symptoms caused by ischemia or haemorrhage persisting longer than 24 hours or which leaves side-effects.
- **TIA:** loss of neurological function caused abruptly by ischemia persisting less than 24 hours and with no side-effects.
- **Spinal Cord Injury:** alteration of the spinal cord that can cause loss of sensation and mobility
- **Seizures:** sudden, short event duration in relation to excessive abnormal cortical neuronal activity. This is usually transient with convulsive movements and with or without loss of consciousness.
- **Stupor:** decreased activity of intellectual functions together with immobility and mutism.

- **Coma:** complete lack of consciousness with no evidence of voluntary motor reactivity, no response to verbal or visual stimuli.
- **Critical illness polyneuropathy:** generalised effects on the peripheral nervous system responsible for muscle weakness that occurs during the care and recovery of patients in intensive care units and which delays withdrawal of ventilator and leads to prolonged immobilization.
- **Acute confusional state:** altered mental state characterized by being acute and reversible.
- **Encephalopathy:** a set of brain disorders that cause deterioration in general, in terms of motor functions, seizures and psychiatric disorders
- **Arterial hypertension (AHT):** a previous history of hypertension that has been diagnosed or treated with medication, a diet or exercise by a doctor
- **Diabetes Mellitus (DM):** a previous history of DM that has been diagnosed or treated by a doctor with medication, a diet or exercise.
- **Dyslipidemia (DL):** a previous history of DL that has been diagnosed or treated by a doctor with medication, a diet or exercise.
- **Chronic obstructive pulmonary disease (COPD):** a prior history of COPD that has been diagnosed or treated with medication or chest physiotherapy.
- **Heart failure (CHF):** at least one of the following medical history cases must be present: paroxysmal nocturnal dyspnea, pulmonary rales, pulmonary congestion in the chest x-ray, dyspnea, or ventricular gallop.
- **Renal failure:** serum creatinine greater than 2 mg/dl.
- **Regular smoker:** any person who has smoked tobacco daily, regardless of the amount, for at least the last month. Our country, Spain, is currently among the highest per capita consumers of cigarettes (>2500 cigarettes/person/ year).
- **Drinker:** harmful alcohol consumption between 40-57gr/day depending on whether female or male or 35 to 50 units of a standard drink meaning 8-10 grams of absolute alcohol.
- **Endocarditis:** infectious inflammatory process located in the natural or prosthetic valves that were operated on.
- **Peripheral arterial disease (PAD):** This is considered to be present when the patient has intermittent claudication or underwent peripheral vascular surgery or non-traumatic amputation.
- **Ejection fraction of left ventricle (EF):** Normal>59%, Light 50-58%, 30-49% moderate, severe <30%.
- **Priority of the surgery: scheduled** (stable patients who undergo surgery on a scheduled basis), **priority** (the clinical picture does not allow for medical discharge even though one could wait a few days) and **urgent** (patients admitted to operating theatre with a cardiovascular emergency).
- **Kinesitherapy:** These are the different treatment techniques based on moving different parts of the body and they must be performed by a physiotherapist through medical prescription. Kinesitherapy can be passive, active-assisted, with resistance, or hydro-kinesitherapy.
- **Occupational Therapy:** This is the set of techniques and therapies used to prevent, restore and maintain the physical, mental and social state of individuals, helping in performing daily activities that are important for the patient's health and welfare.

- **Bentall technique:** This is a surgical technique that replaces the aortic root and aortic valve with a valved conduit (dacron graft*, which has a mechanical aortic valve prosthesis). It requires reimplanting the coronary arteries in the graft.
- **Inclusion (David) technique:** This is also called "aortic valve reimplantation" and consists of replacing the entire aortic root and reimplanting the coronary arteries while preserving the patient's aortic valve. This technique avoids the complications of mechanical prostheses and the anticoagulant treatment they need.
- **Electrotherapy:** This is the application of various types of electric currents for therapeutic purposes.
- **ASIA: American Spinal Injury Association.** The ASIA classification provides basic definitions for terms used in the assessment of spinal cord injury (SCI) and describes the neurological examination: **A:** complete SCI with lack of sensory and motor functions that extends to the sacral segments S4-S5. **B**: incomplete, with preservation of sensory function below the neurological level of injury, extending to sacral segments S4-S5 with absence of motor function. **C:** incomplete, with preservation of motor function below the neurological level and more than half of the key muscles below the neurologic level having a muscle grade lower than 3. **D:** incomplete, with preservation of motor function below the neurological level and more than half of the key muscles below the neurologic level having muscle grade of 3 or more. **E:** normal.
- **Key muscle groups:** 10 muscle groups that are assessed as part of the spinal cord standardized test (5 on the upper limb and 5 on the lower limb)

8. Results

8.1 Descriptive analysis

Of the 452 patients, 261 (57.7%) were men and 191 (42.3%) women. The overall average age was 66 years. The types of surgery carried out were divided into: aortic valve replacement + coronary artery bypass grafting (n=71, 15.7%; biological 57.7% and mechanical 42.3%), aortic valve replacement (n=227; biological 50.2%, mechanical 44.5%), aortic valve replacement and another valve (n=72, 15,9%; biological 9.7%, mechanical 90.3%), aortic valve replacement with insertion of tube due to aortic root aneurysm (Bentall's technique) (n=58; 12.8%) (Modified inclusion (David) technique) (n=10, 2,2%), aortic valve replacement (n=12; 2.6% 16.6% biological, 83.4% mechanical), by endoscopy (n=2; 0.4% 100% mechanical). 4% had a history of previous coronary artery bypass grafting. 94.7% of the surgery was scheduled, 2.65% was priority and 2.65% was urgent.

Of the 452 patients, 62.8% (284 patients) had hypertension, 20.8% (94 patients) DM, 48.4% (219 patients) DL, 7.5% (34 patients) COPD, 58.2% (263 patients) CHF with NYCA dyspnea classifications: I - 5.4%, II – 41.6%, III - 45% and IV – 7.8%. CRI was present in 8.4% (38 patients). 37.6% were smokers and 4.4% drinkers. 29.6% had calcified valves, and of these 57.4% were Ao, 18% were mitral, 2.2% were tricuspid, 0.7% were pulmonary and 23.1% had more than one. 4.2% had PAD. 21.2% had a history of chronic atrial fibrillation and 1.5% had had AMI within 3 months prior to the valvular surgery.

The average aortic clamping time was 101 minutes and the CPB was 125.2 minutes. On average 2 packed red cell transfusions were performed per patient.

There were 22 cases of Ao valve replacement for endocarditis due to multiple causes, including Arthrographis Kalrae Fungi, Streptococcus viridans (2 cases), Streptococcus bovis, Streptococcus mitis, Coxiella burnetii (Q fever), Enterococcus faecalis (3 cases), lactococcus,

actinomyces odontolyticus, Granulicatella, pseudomonas aeruginosa, staphylococcus epidermidis, S. pneumoniae, 2 cases reported as Gram strains and two other cases as undetermined.

Drugs	Anti AHT	Sintrom	Diuretics	Hypolipemiant	Antiplatelet	OAD/Insulin
%	67	18.1	34.3	42.5	29.9	17.5

Table 2. Drugs used by patients with operation on the Ao valve

NC	STROKE	TIA	SCI	PN	Seizure	Stupor	Coma	CIP	ACS	Encephalopathy
%	1.5	0.67	0.4	0.2	1.3	1.3	0.4	1.1	6.6	5

Table 3. Percentages of NCs (neurological complications): TIA (transient ischemic attack), SCI Spinal Cord Injury, PN (peripheral neuropathy), CIP (critical illness polyneuropathy), ACS (confusional syndrome)

Table 3 shows the percentages of different NCs in Ao valve surgery. The rate of strokes was 1.5%, corresponding to 7 cases. Of these 7 cases, 2 came from the 71 patients who underwent valve replacement + CABG AO (2.8%), 3 were from the 227 patients that underwent single Ao valve replacement surgery (1.3%), one case was from the 72 patients who underwent multiple valve replacement (1.4%) and finally there was one case from the 12 patients who underwent a 2nd Ao valve replacement (8.3%). Table 4 shows the three most common NCs that have been seen in this study according to the different surgical techniques and the average times for CPB and Ao clamping measured in minutes.
Of the 23 cases of encephalopathy, 17.4% had a metabolic cause, in 56.5% the cause was hypoxic-ischemic and 26% had various causes. Of the strokes, 57.1% were right hemisphere and 42.9% were on the left. There was only one case in which the stroke was haemorrhagic. Of the ischemia (6 cases - 85.7%), 4 were of cardioembolic origin (66.6%), 2 border territory (33.3%) (Man in the Barrel Syndrome) and one was lacunar (16.6%).

Type of surgery	n	Stroke	ACS	Encephalopathy	T. CPB	T. Clamp
Replacement + CBPG	71	2(2.8)	8(11.3)	5(7)	128.5	105.7
1 Ao valve replacement	227	3(1.3)	12(5.3)	6(2.6)	96.5	75.4
Multiple vv replacement	72	1(1,4)	4(5.5)	5(6,9)	151.2	126.8
Ao root repl. (Bentall)	58	0	5(8.6)	5(8.6)	148.2	118.2
Ao root repl. (David)	10	0	0	0	133.6	129.2
2nd Ao valve repl.	12	1(8,3)	3(25)	2(16.6)	166.2	127.3
Endoscopic valve repl.	2	0	0	0	-	-

Table 4. Most common NC percentages according to the different techniques used. Ao (aorta), vv (valve), repl (replacement), n: total number of patients, ACS (acute confusional syndrome). T. CPB (cardiopulmonary bypass time measured in minutes), T. Clamp (aortic clamping time measured in minutes). CBPG (coronary artery bypass grafting)

There are only 2 cases described of spinal cord injury. One was a side effect of Ao valve replacement surgery and the other came after surgery for aortic arch replacement using the Bentall technique. The two cases were side effects to a spinal cord ischemia. One was a ASIA

A, D6 D7 Spinal Cord Injury Syndrome and the other was an ASIA C, D7-D8 spinal cord injury syndrome. Both patients were taken to a hospital specializing in spinal cord injury (National Hospital for Paraplegics in Toledo).
Overall mortality was 1.7% and in no way associated with cases of stroke, or with patients who suffered acute confusional state. There were, however, two deaths of patients with hypoxi-ischemic encephalopathy and multiple causes.
The average time of hospitalization was 18.7 days. Table 5 specifies the different durations of hospital stay depending on the surgery performed and the most common NCs suffered.

Type of surgery	Hospital stay without NCs	Stroke	Hospital stay	ACS	Hospital stay	Encephalopathy	Hospital stay
Replacement + CBPG	16	2	39	8	23	5	63.5
1 Ao valve replacement	12	3	23.3	12	21	6	58.2
Multiple v replacement.	18	1	68	4	17.7	5	60.5
Ao root repl. (Bentall)	16	0	16	5	24.8	5	33.1
Ao root repl. (David)	14.5	0	14.5	0	14.5	0	14.5
2nd AO v replacement	14	1	41	3	30	2	26.5
Endoscopic v. repl.	9	0	9	0	9	0	9

Table 5. Average hospitalization time measured in days in the most common NCs.
ACS = Acute confusional state

The most common risk factors associated with NCs are shown in Table 6.
As regards rehabilitation for these patients, 97.3% underwent pulmonary rehabilitation before and after surgery, aiming to prevent respiratory complications. 43.8% of patients had some type of neurological complication and needed kinesitherapy techniques. 3.5% required occupational therapy. 1.75% of patients with NCs underwent electrotherapy techniques. During this period, no patient required any type of orthosis and only one of them needed to use a walker at home.

RFs	AHT	DM	DL	COPD	CHF	CRI	Prior stroke
STROKE	85.7%	14.2%	42.8%	28.6%	85.7%	14.2%	42.8%
ACS	53.1%	34.3%	31.2%	6.2%	46.9%	15.6%	12.5%
Encephal.	73.9%	21.7%	39.1%	-	65.2%	21.7%	17.4%
	Smokers	**Drinkers**	**PAD**	**AT**	**AF**	**AMI**	-
STROKE	42.8%	14.2%	14.2%	14.2%	28.6%	-	-
ACS	28.1%	6.25%	6.25%	-	21.9%	3.1%	-
Encephal.	43.5%	4.3%	-	4.3%	34.8%	-	-

Table 6. Risk factors for NC in Ao valve surgery in %. RFs (risk factors), AHT (arterial hypertension), DM (Diabetes Mellitus), DL (dyslipidemia), COPD (chronic obstructive pulmonary disease), CHF (heart failure), CRF (chronic renal failure), PAD (peripheral arterial disease), AT (atheromatous plaques in Ao), AF (a history of chronic atrial fibrillation), AMI (history of acute myocardial infarction in the last three months)

9. Discussion

NCs are still a common cause of morbidity and mortality in postoperative patients who have undergone aortic valve surgery. Although much has been achieved, there are still many issues to resolve. The research is complex because of the many variables to be considered.
Recent neuropsychological studies have shown that over 50% of patients undergoing cardiac surgery suffer brain injury, as evidenced by a CT scan or MRI (Mc Khan et al., 1997; Hallow et al, 1999).
As regards the sex of the patients, the percentages are fairly balanced (57.7% men and 42.3% women), which is a difference compared to other studies where the male sex clearly prevails over females (Hallow et al, 1999).
Our study evaluates the type of technique used in aortic valve surgery, focusing on the paradigm that with strokes as a neurological complication fewer complications have arisen than in other studies (Zabala, 2005). These averages in Ao valve replacement surgery + coronary artery bypass grafting were 2.8% compared to 3.3%, and in patients undergoing single Ao valve replacement they came to 1.3% compared to 3.3%. In the patients who underwent multiple valve replacement the percentage was 1.4% as opposed to 6.7%, and finally out of the patients that underwent a 2nd Ao valve replacement the percentage was 8.3%. (Table 4.)
The NCs evident in postoperative aortic surgery are in keeping with the big series: 0.4% for coma, 6.6% for ACS, 1.5% for STROKE and 5% for encephalopathy (Murkin, 1993, Harrison, 1995; Filsoufi et al, 2008), although there are others in which the incidence is higher (Bucerius et al, 2004).
Identifying predictors for NCs is important for understanding the pathogenesis of these complications as well as for developing preventive strategies (Mornals K et al, 1998; Tjang YS et al, 2007). According to the results of our study, the most influential risk factors in the development of intraoperative and postoperative NCs in aortic valve surgery are: arterial hypertension, heart failure, smoking, having a previous stroke, dyslipidemia and atrial fibrillation in this order, with lesser importance attached to COPD, diabetes mellitus, CRF, being a heavy drinker and peripheral arterial disease. The CPB and aortic clamping time is seen to be longer in cases where there is a NC but with no clearly significant relationship.
As regards strokes, we found that 85.7% were ischemic, as in other studies (Zabala, 2005), but the percentages into which the ischemic strokes are usually divided are not what we found in this study. 4 were of cardioembolic origin (66.6%), 2 border territory (33.3%) (Man in the Barrel Syndrome) and one lacunar (16.6%), whereas in the recorded literature 50% are usually due to atherothrombotic causes, 25% are lacunar (related to a chronic hypertension), 20% cardioembolic, and there remain 5% in which we most often include border zone infarctions in cardiac surgery.
The aortic valve surgery that proportionately produces the most NCs is 2nd aortic valve replacement followed by Ao valve replacement + coronary artery bypass grafting, aortic root replacement (Bentall) (17.2%), multiple valve replacement and finally single Ao valve replacement. Table 4.
As for the 22 cases of endocarditis, 50% occurred in single aortic valve replacement, followed by 27.2% in multiple replacement surgery, and 9% in both second valve replacement and aortic arch replacement. Of these 22 cases, 2 of them had a stroke, one an acute confusional syndrome and 3 suffered encephalopathy. 11 of them were operated on a valve and 11 on a prosthetic valve. The bacteria that produced it and the complications are

similar to other work associated with the incidence of endocarditis (Arauz-Gongora et al, 1998).
The average times for aortic clamping and CPB were 101 and 125.2 minutes respectively. This is somewhat higher in some of the surgeries with more NCs such as in 2nd valve replacement, followed by multiple valve replacement and aortic arch replacement (Bentall). Table 4.
Overall mortality was 1.7% and in no way associated with cases of stroke, or with patients who suffered acute confusional state. There were, however, two deaths of patients with hypoxi-ischemic encephalopathy and multiple causes. These results are similar to other publications. However, in our work the appearance of a neurological complication did not significantly increase mortality (Redmond et al, 1996). There are groups with no mortality although the number of patients is lower (n=118) (Mutarelli EG et al, 1993).
The length of hospital stay increases dramatically when there are NCs, as evidenced in other works. Table 5.
The data provided in connection with rehabilitation techniques carried out fall far short because many patients were referred to another hospital area in Madrid or another province of Spain and continued the rehabilitation in places near their original home.
This study is limited mainly in that it is a retrospective study and this prevents us from knowing the exact time of the onset of the NC and therefore we cannot draw valid conclusions regarding the type of NC, the rehabilitation treatment carried out and the prognosis.

10. Conclusions

According to the results of our study, cardiovascular aortic valve surgery has similar incidence of postoperative NC when compared with bypass surgery or combined surgeries. The risk factors in order of importance were: a history of arterial hypertension, heart failure, dyslipidemia, having a previous stroke and being a smoker.
NCs after aortic valve surgery have been associated with increased morbidity and mortality, with increased hospitalization time and rehabilitation costs, and they thus contribute to decreased quality of life. The incidence of NCs has remained unchanged in recent years, despite increasing age and comorbidity. The improvement in technical advances has contributed to keeping these percentages up.
Although most complications can be associated with cardiopulmonary bypass, other factors are also involved. Identifying high-risk patients may reduce the incidence of complications in high risk groups, but this seems to be a poor prevention strategy.
In an increasingly aging population and with a growing number of diseases, prevention strategies should focus on three aspects: firstly, technical improvements in cardiac surgery and cerebral protection, secondly, identifying reliable techniques to assess neuropsychological dysfunction after cardiac surgery, and finally carrying out technical training in rehabilitation to avoid or minimize the side effects as a result of NCs arising from aortic surgery.

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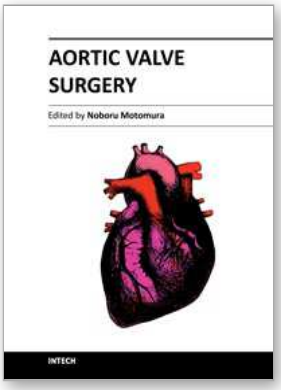

Aortic Valve Surgery

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The aortic valve is located at the center of the heart. It is the core of cardiac anatomy and aortic valve surgery has led the field of cardiac surgery. This book describes all aspects of aortic valve surgery and it will help clarify daily questions regarding the clinical practice in aortic valve surgery, as well as induce inspiration and new insights into this field.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
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Unit 405, Office Block, Hotel Equatorial Shanghai
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中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821