Postoperative Neurological Complications of Cardiovascular Surgery

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The neurological complications associated to cardiovascular surgery are relatively frequent, and they generate a high increase of morbimortality. Therefore, the main function of the medical team in charge of evaluating and treating those patients who require a cardiac surgery is the proper assessment and prevention of such complications. At any rate, despite all the efforts made in the detection of the most vulnerable patients, postoperative neurological events will probably not decrease. This is so because the patients who are operated on are older, with more comorbidities, and with greater vascular deterioration in general and coronary deterioration in particular, thus generating more complex and lengthier surgeries.

The genesis of postsurgical neurological deficits is due to a functional or morphological suffering of the neurons, in surgery-related factors (embolisms or hypo-perfusion), on a sometimes already compromised basis of chronic atherosclerotic cerebral suffering. In this field, as well as in the perioperative one, some factors which strengthen cerebral suffering -such as hyperthermia, hyperglycemia, and the systemic inflammatory response- are also added.

According to the extension of the anatomic damage in relation to the noxa's magnitude and duration, the affectation will be focal, multifocal or diffuse and, in line with this, so will be the clinical characteristics of the neurological manifestations. They cover from cerebral infarct, lengthy coma, stupor, convulsions, and a great variety of neuropsychological alterations which are revealed by means of late awakenings and psychomotive excitement (encephalopathy), to subtle changes of the intellectual function, memory, and behavior (cognitive deterioration).

According to the guides of the American College of Cardiology / American Heart Association of coronary by pass surgery of the year 1999 [1], neurological complications are classified in deficit type 1, which includes the stroke, stupor and coma, and deficit type 2, when the intellectual function and memory are affected. However, there are intermediate manifestations which are difficult to be categorized.

In this written document, I will not refer to peripheral neuropathies of upper members, or to diaphragmatic pareses due to the affectation of the phrenic nerve.

Cerebrovascular Accident (stroke)

The cause of the perioperative stroke can be ischemic, due to macro or microembolism, hypoperfusion, or very rarely a hemorrhagic stroke. The embolism frequently arises during surgical manipulation from the aorta, the cardiac chambers, the carotids, or the extracorporeal circulation pump.

The reported incidence after a by pass surgery varies according to the series. In prospective studies it is of 3.1% [2] and 5.2% [3], whereas the lower incidence is in retrospective studies: 1.3% [4] and 2% [5]. In patients who have been operated of valvular pathology the incidence is similar or lower, but it is notoriously higher in combined procedures. [4] [6]

The age and characteristics of the population being studied, the specific situations of the procedures (with or without extracorporeal circulation, aorta surgery) and other series of factors influence in the number of neurological complications. [7]

The stroke may appear early from the moment the patient enters the intensive care room up to the first 2 postoperative days, or it may appear later that is to say after a certain period with a normal awakening and without any apparent focal neurological damage. Some works show that most of them happen early with an incidence of 62% of the total events. [7] [8]

In another study of retrospective character, which includes coronary and valvular patients as well as mixed procedures, the majority of the strokes were belated. [4]

This situation has a high intrahospital and far-away mortality. In Hogue's study, the mortality of precocious and belated strokes is of 41% and 13 % respectively. [4]

In a prospective study of 2108 patients, mortality reached 21%, in relation to 2% of the general operated population without any major neurological complications. [2]

At the same time, the stroke generates high disability, lengthy hospital stays, and high rehabilitation costs.

Encephalopathy

This situation is habitually secondary to a diffuse cerebral injury, and it is presumably originated by a multiple microembolic phenomenon or by hypoprofusion. It has several clinical manifestations, but it is generally diagnosed as a state with a global involvement of the cognitive functions, sometimes lengthy decrease of conscience state, hallucinations, and with increase or decrease of psychomotive activity. Its incidence is of 8.4% [9].

This situation has a high mortality rate (7.5%), but this is lower than that of the stroke, and it has a hospitalization average which doubles the habitual stay. [10]

Neurocognitive disorders

These disorders have a wide variety regarding their clinical expression, and the most evident ones generate an important concern in the family environment as well as deterioration in the patient's quality of life.

They are widely described in literature, their incidence varying a lot (up to 70%) according to the definitions, the sensitivity of the tests and the moment they are carried out. They improve with time and, according to the series, they decrease to 40% and 20% in a period of 6 weeks and 6 months respectively.

Some of them can be a minor manifestation of an encephalopathy, or they can be transitory dysfunctions due to edema, hyperglycemia, hyperthermia, or maybe to the effects of anesthetic drugs.

Certain groups associate these early situations with cognitive deteriorations which have increased with time. However, it is discussed if this is in relation to surgery and anesthesia, or if it simply corresponds to a progressive deterioration related to the age of the patients with previously existing risk factors. [11]

A) Preoperative factors of neurological risk

Research work has determined several clinical risk factors which predict the development of the perioperative stroke and encephalopathy, and which have an additive effect (Table 1). Thus, McKhann establishes a risk model of 3 common variables for the stroke and encephalopathy which are the following: previous history of cerebrovascular accident, the existence of arterial hypertension, and age (younger than 65, between 65 and 75, and older than 75 years old); he adds the presence of carotid disease and diabetes as independent variables for the estimation of encephalopathy risk. [10]

Table 1

Variables which can predict neurological risk in some studies
(without discriminating stroke of neuropsychiatric manifestations)

Age (2 -4 -9 -11-29)
Previous neurological events (2- 4 -- 9 -11-13-29)
Atherosclerotic disease of ascendant aorta (2 -4)
Diabetes (4- 9-10 -11 -29)
Arterial hypertension (2 -9- 29)
Carotidal disease (9- 11 -29)
Peripheral vascular disease (11- 13 -29)
Auricular fibrillation (4-13- 29)
Re-operations (11 -29)
Renal insufficiency (31)
Female sex (30)
Severe deterioration of ventricular function (13-31)
Chronic lung disease (11)
Unstable angina (11)

Another score which is used is that developed by Newman in a multicentre study of diseased people who had been operated of coronary bypass. This one sums up several factors to which a score is assigned, and the total score is related to a nomogram with the risk of stroke. By way of example, a score of 100 has 5% of major neurological events. [12]

However, there are other studies of predicting factors which do not coincide in the strength of the variables, but the important thing is their search, as they express a systemic vascular involvement. This will allow to explain to the patient and his/her family the risks of neurological complications, and, in case the clinical situation necessarily requires surgery despite a high neurological risk, to plan strategies in order to reduce it.

The above mentioned variables arise from the patient's interrogation and clinical assessment. But at present, there are other methods of study which increase the sensitivity for risk estimation: the carotid doppler, the tomography and the nuclear magnetic resonance. The first one is indicated when studying asymptomatic carotid murmurs in patients with previous cerebrovascular accidents o with a high risk score (Table 2).

Table 2

Indications of presurgical carotid doppler (asymptomatic)

- Carotidal murmurs when being examined
- Previous cerebrovascular accident
- Trunk injuries
- Older than 65 years old, specially women with peripheral vascular disease and smoking habits

The new resonance techniques detect up to 50% of the ischemic injuries in presurgical studies of coronary by pass (silent infarcts), and this has forecasting implications as it indicates that the patient already has previous cerebral damage although he/she is asymptomatic. [13]

In a recent work about biomarkers as predictors of postoperative neurological complications, the S100B protein which is present in the cells of the glia, the reactive C protein as an expression of systemic inflammation, and the peptidic receptor N-methyl D-aspartate, as well as the generation of antibodies to fragments of this receptor (NR2Ab), were evaluated. Considering all these markers, the presence of NR2Ab in the blood at levels higher than 2 ng / ml before the surgery, increases 18 times the possibility of postoperative neurological events. [14]

It is still to be asked if this kind of studies will in the future be part of the routine preoperative assessment in spite of the costs.

B) Intraoperative factors of neurological risk

There are different intraoperative factors which influence in the incidence of neurological complications. In this way, the kind of surgery which has been carried out –coronary, valvular or combined, or those of higher complexity over ascendant aorta and crook – is a risk determiner. The same happens with the surgical tactics or techniques which are used: use or non use of extracorporeal circulation, clamp type, doing arterial bridges without the need of working on the aortic wall, etc.

In case the extracorporeal circulation is used, the selected techniques, their duration, and the achieved hemodynamic stability are crucial in the postsurgical neurological state. [4][15][16]

C) Postoperative factors

Belated cerebral accidents are unfortunate as many times they appear after an initial postoperative period without any inconvenient. The appearance of auricular fibrillation (30%), especially on the second and third day after the surgery, is a frequent cause of belated embolic stroke.

Also a predisposing factor is the syndrome of low cardiac minute volume which can generate cerebral hypoperfusion.

All the above mentioned is strengthened by the varying systemic inflammatory response, the anemia, or the inadequate metabolic and oxygenation management.

Diagnosis

The diagnosis is suspected when there is a belated postanesthetic awakening, or some clinical signals such as lack of movement in some of the extremities, conjugated deviation of the eyes, or lack of response to simple orders, etc. In these cases, a neurologist's assessment is required, and in the meantime, all the hemodynamic parameters, of oxygenation, must be optimized, and the possible metabolic alterations must be corrected.

Patients with these characteristics and using a respirator have risks when transferred for image studies and in most cases the therapeutics will not be modified. But carrying out such studies many times confirms the diagnosis, gives predicting information and, according to the technique being used, contributes other data of interest, such as suspecting the mechanism (embolic, by hypoperfusion, existence of hemorrhage) and time of appearance. It is possible to make use of the cerebral computed tomography (CT scan), which has a low diagnosis sensitivity in the first 24 hours, the conventional nuclear magnetic resonance and, lately, the diffusion magnetic resonance, which allows to distinguish smaller injuries (microembolisms) in a precocious way and, besides, to differentiate between an acute and chronic ischemia.

Treatment

The therapeutics of the stroke which is not related with cardiac surgery has notably varied over the last years due to the use of thrombolitics. This alternative is not possible in the cardiovascular postoperative period.

Likewise, there are no available drugs with tested clinical efficiency in patients over the zones of periinfarct ischemic penumbra. Thus, the treatment is only based on supporting measures:

- To keep blood pressure levels at normal high levels.
- Arterial saturation above 95%
- Treatment of hyperglycemia, fever, etc.

For all the above mentioned, the preventive treatment of neurological damage becomes very important.

1- Presurgical prevention

There is a high prevalence of carotid disease in coronary patients. Thus, around 20% of the patients have carotid stenoses higher than 50%, and 10% of them higher than 80%. At the same time, the risk of stroke in moderate injuries is of 10%, and in those of severe level or which have a bilateral disease, the possibility of stroke goes from 15% to 20%. For all this, when suspecting a carotid disease, the obstruction must be quantified by means of carotid echo-doppler or arteriography. According to the symptoms, the severity of the injuries, and if these are unilateral or bilateral, the carotid surgery will be previous to or simultaneous with the cardiac intervention. [17]

Considering the time between the first presurgical interview and the completion of the surgery, it is convenient to:

- Achieve an adequate metabolic control, especially in diabetic patients.
- Optimize the antihypertensive and antianginal treatment.
- Stabilize the hemodynamics, and to treat the low volume minute syndrome.
- Prevent arrhythmias due to electrolytic disorders, or to assess the use of drugs before the surgery so as to avoid postoperative auricular fibrillation.
- Carry out an adequate psychoprophylaxis to reduce the perioperative anxiety and stress to the minimum, explaining to the patient the procedure, how the postoperative period will be, the usual time of hospitalization, and the return to his/her habitual life. This action may have some influence in the extent of the inflammatory response, and it may avoid situations of psychiatric nature.

2- Intrasurgical prevention

Based on the multiple factors that take part in the genesis of postsurgical neurological complications, efforts must be made to prevent them at different levels.

The emboligenous source is the main cause of postsurgical stroke, and the greatest part arises from atheromatosic plaques of ascendant aorta [8]. The detection of these through the surgeon's manual palpation or their external visualization is very low. Carrying out transesophageal or epiaortic echocardiograms allows to diagnose the plaques easily, and finding thickenings larger than 3 mm, or the existence of protruding and mobile plaques, have allowed to avoid them modifying the strategy of the surgery. [18] In this way, the surgeon can change the place of cannulation, the place and kind of clamping, or even carry out arterial bridges without being necessary to touch the aorta.

The embolisms that come from the left auricle, which usually arise from the appendage, can benefit themselves with the ligation of this. The delicate mobilization of the heart and the adequate purging of the cavities, especially in valvular surgeries, are also of preventive importance.

The pump of extracorporeal circulation is not only a source of embolisms, but also a powerful stimulus for the activation of the systemic inflammatory response. Thus, the use of membrane oxygenators and filters in the arterial line [18], as well as the use of smaller circuits [19] covered with heparin [20], intend to decrease these factors.

But the inflammatory response is also triggered, though to a lesser extent, in cardiac surgeries without extracorporeal circulation. An activation of the complement and of neutrophils is produced, with a variable increase (probable genetic) of proinflammatory cytokines (interleukin 6 and 8) and endotoxins, which sensitize the cerebral vasculature, the neurons and microglia. For all this, an increase in the permeability of the hemato-encephalic barrier, the edema and other alterations of the neuronal functions are produced.

The change in the previously mentioned circuits also intends to preserve the plaquetary functioning, avoiding the activation of procoagulants and fibrinolysis, and decreasing bleeding and the need of transfusions, which are also proinflammatory stimuli. The use of filters which capture leukocytes and the use of some drugs such as the aprotinin seem to take part in the reduction of the inflammatory response. [18] [21] [22]

In a recent review based on evidence, it was highlighted the convenience of updating a series of changes in the methods of perfusion which are favorable to reduce neurological damage. The adequate management of temperature, the correct maintenance of the acid-base state, and the optimum metabolic control so as not to strengthen the neurological affectation were considered fundamental. [18]

- Care of the acid-base state, specifically related to the PH maintenance and the CO2 regulation, using the alpha-stat management which preserves an adequate relationship cerebral-sanguine flow / metabolism under conditions of hypothermia.
- Strict temperature monitoring throughout the surgery in order to avoid cerebral hyperthermia.
The hyperthermia generates a greater neuropsychological dysfunction, and it increases morbimortality in the stroke. [23] Although the temperature control is used at nasopharyngeal level, there are studies which show that it undervalues cerebral temperature, and some of them also suggest the thermal valuation of the arterial flow.

There is no agreement whether during the surgery the perfusion with hypothermia or normothermia is better as regards the postsurgical neurological result, but it is fundamental that the re-warming is progressive, whereas a cerebral temperature higher than 37º must be avoided.

- To avoid reinfusion of the blood aspirated from the mediastinal or pericardic surface, as it is a source of fat embolism, it activates the coagulation-fibrinolysis, and the inflammatory response.
- To keep glycaemia within normal levels during the perioperative period, even in non-diabetic patients, at levels lower than 150 mg/dl. An inadequate control not only increases the neurological damage, but also favors infections and mortality in general.

[24][25]

It is not simple to keep glycaemia at normal levels during the surgery, since there are multiple factors which contribute to hyperglycaemia: resistance to insulin during perfusion, the effect of endogenous catecholamines mediated by surgical stress, important use of glucose in the serum, the cardioplegic solution or in the pump priming, etc. Schemes with aggressive doses of intravenous insulin are required to level glycaemia.

-To reduce hemodilution decreasing the priming volume. To avoid that hematocrits are lower than 20%, as there are studies which evidence a greater risk of stroke in these situations. [26]

Although all the previous measures are beneficial, coronary interventions have been carried out since the late 80's without using the extracorporeal circulation when there are technical possibilities. In a recent meta-analysis, this surgery without cardio-pulmonary bypass is associated to a relative reduction of 50% of the stroke risk. [9] [14].

The mechanism of cerebral hypoperfusion as a cause for neurological damage must be suspected when in tomographyc or resonance studies there are infarcts in bordering territories, between the anterior and the middle cerebral artery, or between this one and the posterior one. Likewise, some people refer that low pressure can decrease the cleansing of microembols, and so favor bordering infarcts [27]. The hemodynamic stability must be maintained throughout the surgery so as to ensure perfusion. Although the autoregulation of the cerebral flow during the extracorporeal circulation is produced within a wide range of pressures, greater middle pressures can be required in hypertensive and diabetic patients to maintain the perfusion (90 mm Hg). Therefore, although the optimum level is not firmly established, pressures greater than the habitual ones are attempted so as to decrease neurological damage in high risk patients. [11] [28]

3- Postsurgical Prevention

As it has already been said, a considerable number of cerebral accidents occur belatedly after the first 48 hours. Therefore, it is important to continue with the metabolic control of glycaemia, and to maintain an adequate oxygenation. It is necessary to start with anti-aggregation quickly, and with anti-coagulation in patients of high thrombotic risk.

Likewise, it is desirable to avoid arrhythmias, especially the auricular fibrillation, precociously beginning with beta blockers mainly in patients who already received them before the surgery.

A common phenomenon to be seen in patients who start to mobilize, is the symptomatic pronounced arterial hypotension in the third or fourth day of the postoperative period. In general, they are severe hypertensive patients who during the first 48 hours required high doses of vasodilators and diuretics. In these cases, it is convenient to carry out a stricter control of the blood pressure, and to be progressive in the dosification.

Conclusion

Major neurological complications occur approximately in 5% of cardiac surgeries, and they are feared due to their high mortality (20%), the fact that they require a lengthy hospitalization, and that they imply a high disability (40%). Apart from the traditional risk factors to predict neurological damage, the carotid echo- doppler is part of the assessment in a large number of patients. We must wait for studies so as to determine if the high sensitivity of the magnetic resonance or new biomarkers add prognostic information.

We can prevent the complications thinking about them. I consider it is convenient that the medical doctors who work in cardiovascular recovery know the patient in detail before the surgery. In this way, they can contribute data to the surgeon and the rest of the team so as to generate strategy changes in order to avoid neurological damage.

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