

Neurological Complications Following Adult Open-Heart Operations and its Predisposing Factors

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Objective : Neurological injury is a devastating complication of cardiac surgery that results in a longer duration of hospitalization, increased costs and increased likelihood of death. Such injury can affect any level of the central nervous system, and its manifestations are broad, ranging from neurocognitive dysfunction to frank stroke.

Method : During the period June 2003 to December 2004, a total of 432 adult patients underwent various types of open heart surgical procedures. Most of these patients (315) subjected to coronary artery bypass grafting (73.1 %), (64) patients underwent mitral valve replacement (14.8%), (28) patients underwent aortic valve replacement (6.5%), (14) patients underwent double mitral and aortic valve replacement (3.3%), and the last (10) patients underwent excision of left atrial myxoma (2.3%).

Results : (18) Patients (4.1%), developed new neurological signs after surgery. The latter formed three groups: Group (I) consisted of 2 patients with severe neurological deficits, who never regained consciousness and died in spite of intensive support of vital systems. Group (II) consisted of 4 patients with postoperative clinical evidence of focal cerebral infraction (2 had hemiplegia and 2 showed alteration of memory), all of them had residual defects at discharge. Group (III) was composed of 12 patients with minor neurological deficits after surgery (hemiparesis, gait disturbance, mental changes) which had cleared up by discharge.

Conclusion : Such neurological complications after an otherwise successful cardiac surgery represent a devastating outcome for patients and their families, and the social and economic impacts are enormous. Several factors are identified including atheromatus embolism, carotid occlusive disease, air embolism, valve calcification, atrial fibrillation and severe perioperative hypotension.

Neuropsychiatric dysfunction from embolic and low-flow phenomena accompanying open-heart procedures has been well recognized. Such disorders significantly increase perioperative mortality and hospitalization time and can lead to a decrease in the patient's quality of life. (1)

Early studies of intracardiac operations emphasized the association of neurological complications with air or particulate emboli from calcified valves or thrombi within the heart chambers and from the cardiopulmonary bypass circuit. (2, 3)

Reported potential mechanisms of the effects of cardiopulmonary bypass are the microembolization and macroembolization of gas, particulate matter and inadequate cerebral perfusion pressure or flow. However, studies on the impact of conventional, uncomplicated cardiopulmonary bypass are rare and

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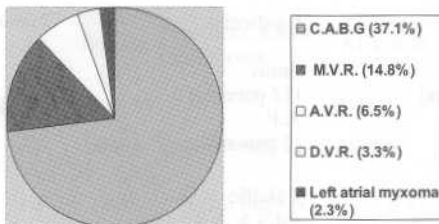
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usually are performed on small, selected groups of patients. Furthermore, the multifactorial nature of neurologic dysfunction after cardiopulmonary bypass makes the results of such investigation controversial. (4)

We undertook this prospective study to determine the incidence of neurological complications after adult open heart operations, and the associated preoperative and intraoperative risk factors, including the characteristics of cardiopulmonary bypass that might predispose the patients to such neurologic complications following surgery.

Patient & Methods

This is a prospective study of the patients for neurological complications that developed postcardiac surgery. All patients who underwent adult open heart surgery during the period June 2003 to December 2004 at Ain Shams University Hospitals were included in the study. These included mitral valve replacement, aortic valve replacement, double valve replacement, coronary artery bypass grafting and excision of atrial myxoma. (Fig. "1"). Patients who underwent close heart surgery, repair of aortic coarctation, dissecting or non-dissecting thoracic aneurysm were excluded from the study.



C.A.B.G. (coronary artery bypass grafting), M.V.R. (mitral valve replacement), A.V.R. (aortic valve replacement), D.V.R. (double valve replacement).

Figure (1): Types of open heart operation performed.

Data collected included: Age, sex, preoperative diagnosis including the New York Heart Association functional classification score (NYHA), Rhythm, ejection fraction and valve or coronary lesion. It also included presence or absence of diabetes and hypertension, cardiopulmonary bypass and aortic cross clamp times and pre and postoperative neurological deficits. Carotid duplex is done only in some selected cases (patients above 60 years and those with preoperative neurological event).

Results

During the study period, 432 patients underwent adult open heart surgery. (Table 1)

Of them, 315 patients (73.1%) underwent coronary artery bypass grafting. 47 patients were NYHA class (IV) and 268 patients were NYHA class (III). Their age range was 50 to 74 years (mean 54 ± 7). 278 patients were males while 37 patients were females. The rhythm was sinus in 312 patients and atrial fibrillation in 3 patients. The atherosclerosis was affecting the left main coronary artery in 106 patients, four vessels in 23 patients, three vessels in 151 patients and two vessels in 35 patients. The ejection fraction range was 42 to 56% (Mean 44 ± 6), 297 patients were diabetic, 309 patients were hypertensive and cerebrovascular disease was present preoperatively in 2 patients. The cross clamp time range was 25 to 85 minutes (Mean 38 ± 11) and the bypass time range was 35 to 105 minutes (Mean 46 ± 12).

64 patients (14.8%) underwent mitral valve replacement because of mitral stenosis which was calcific in 22 patients and non calcific in 12 patients, mitral regurge in 15 patients and prosthetic valve malfunction and thrombosis in 15 patients. NYHA class was (IV) in 26 patients and (III) in 38 patients. Their age range was 22 to 46 years (Mean 24 ± 5). 30 patients were males and 34 patients were females. Sinus rhythm was present in 46 patients while atrial fibrillation was present in 18 patients. The ejection fraction range was 40 to 54% (Mean 44 ± 7). None of the patients was diabetic or hypertensive and only one patient had preoperative neurological event. The cross clamp time range was 25 to 42 minutes (Mean 27 ± 5) and the cardiopulmonary bypass time range was 40 to 62 minutes (Mean 45 ± 5).

Aortic valve replacement was done in 28 patients (6.5%), 7 patients were NYHA class (IV), 17 patients were NYHA class (III), and 4 patients were NYHA class (II). Their age range was 18 to 36 years (Mean 23 ± 5). 16 patients were males and 12 patients were females, the sinus rhythm was present in 27 patients and only 1 patient had atrial fibrillation. Aortic stenosis was the diagnosis in 15 patients, 8 of them were calcific while 7 were non calcific. Aortic regurge was the diagnosis in 13 patients, their range of ejection fraction was 45 to 58% (Mean 48 ± 6), of cross clamp time was 25 to 36 minutes (Mean 26 ± 4) and of bypass time was 38 to 51 minutes (Mean 41 ± 2). None of them was diabetic or hypertensive and none of them had preoperative neurological event.

Double valve replacement was done in 14 patients (3.3%). 5 patients were NYHA class (IV) and 9 patients were NYHA class (III). 8 patients were males and 6 patients were females. The rhythm was sinus in 12 patients and atrial fibrillation in 2 patients. The diagnosis was calcific mitral and aortic stenosis in 6 patients, non calcific mitral and aortic stenosis in 2 patients, and mitral and aortic regurge in 6 patients. Their range of age was

23 to 48 years (Mean 24 ± 7), of ejection fraction was 44 to 56% (Mean 45 ± 4), of cross clamp time was 48 to 86 minutes (Mean 50 ± 9) and of bypass time was 62 to 107 minutes (Mean 65 ± 9). None of them was hypertensive or had preoperative neurological event. But only one patient was diabetic.

10 patients (2.3%) subjected to excision of left atrial myxoma. 2 patients were NYHA class (IV), 6 patients were

NYHA class (III) and 2 patients were NYHA class (II). 3 patients were males and 7 patients were females. The diagnosis was left atrial myxoma in all patients and all of them had sinus rhythm. Their range of age was 40 to 48 years (Mean 43 ± 4), of ejection fraction was 50 to 60% (Mean 52 ± 5), of cross clamp time was 17 to 32 minutes (Mean 20 ± 6) and of bypass time was 35 to 43 minutes (Mean 36 ± 2). One patient was diabetic, one patient was hypertensive and one patient had preoperative neurological event.

Table (1)

Clinical variables	C.A.B.G patients	M.V.R patients	A.V.R patients	D.V.R patients	Left atrial myxoma patients
Pre-operative					
Number	315 (73.1%)	64 (14.8%)	28 (6.5%)	14 (3.3%)	10 (2.3%)
NYHA class	IV (47 patients) III (268 patients)	IV (26 patients) III (38 patients)	IV (7 patients) III (17 patients) II (4 patients)	IV (5 patients) III (9 patients)	IV (2 patients) III (6 patients) II (2 patients)
Age	50-74 years (mean 54 ± 7)	22-46 years (mean 24 ± 5)	18-36 years (mean 23 ± 5)	23-48 years (mean 24 ± 7)	40-48 years (mean 43 ± 4)
Sex					
Male	278 patients	30 patients	16 patients	8 patients	3 patients
Female	37 patients	34 patients	12 patients	6 patients	7 patients
Rhythm	Sinus (312 patients) A.F. (3 patients)	Sinus (46 patients) A.F. (18 patients)	Sinus (27 patients) A.F. (1 patient)	Sinus (12 patients) A.F. (2 patients)	Sinus (10 patients)
Diagnosis	Left main disease (106 patients) 4 vessel disease (23 patients) 3 vessel disease (151 patients) 2 vessel disease (35 patients)	Calcific M.S (27 patients) Non calcific M.S (12 patients) M.R. (15 patients) Prosthetic valve malformation (15 patients)	Calcific A.S (8 patients) Non calcific A.S (7 patients) A.R. (13 patients)	Calcific M.S & A.S (6 patients) Non calcific M.S & A.S (2 patients) M.R. & A.R (6 patients)	Left atrial myxoma
Ejection Fraction	42-56% (mean 44 ± 6)	40-54 years (mean 44 ± 7)	45-58 years (mean 48 ± 6)	44-56 years (mean 45 ± 4)	50-60 years (mean 52 ± 5)
Diabetes	+ve (297 patients)	-ve	-ve	+ve (1 patient)	+ve (1 patient)
Hypertension	+ve (309 patients)	-ve	-ve	-ve	+ve (1 patient)
Previous cerebro-vascular disease	+ve (2 patients)	+ve (1 patient)	-ve	-ve	+ve (1 patient)
* Intra-operative					
Cross clamp time	25-85 min. (mean 38 ± 11)	25-42 min. (mean 27 ± 5)	25-36 min. (mean 26 ± 4)	48-86 min. (mean 50 ± 9)	17-32 min. (mean 20 ± 6)
Bypass time	35-105 min. (mean 46 ± 12)	40-62 min. (mean 45 ± 5)	38-51 min. (mean 41 ± 2)	62-107 min. (mean 65 ± 9)	35-43 min. (mean 36 ± 2)

C.A.B.G (Coronary artery bypass grafting), M.V.R (Mitral valve replacement), A.V.R. (Aortic valve replacement), D.V.R. (Double valve replacement), M.S. (Mitral stenosis), M.R (mitral regurge), A.S (Aortic stenosis), A.R (Aortic regurge), A.F (Atrial fibrillation).

Neurological Complications

18 patients (4.1%) suffered neurological sequelae. The average age of these patients was 60.7 years, 72% were hypertensive and about 78% were diabetic. The clinical profile of these patients is shown in (Table 2). 11 patients had coronary artery bypass grafting, 4 patients had mitral valve replacement, 2 of them were redo operations, 1 patient had aortic valve replacement, one patient had double valve replacement and one patient

had excision of left atrial myxoma. (Table 3)

Three categories of neurological events were identified. Group (I) consisted of 2 patients (0.46%) who never regained consciousness and died after intensive support of vital systems. Group (II) consisted of 4 patients (0.92%) with postoperative clinical evidence of focal cerebral infarction; all of them had residual defects at discharge. Group (III) consisted of 12 patients (2.72%) with minor neurological deficits after surgery which had cleared up by discharge.

Patient	Age (in years)	Sex	Diagnosis	Surgery	C.P.B	A.C.C	Neurological complication	Risk factors identified
Group (I)								
1	64	male	3 vessel disease	C.A.B.G	73	47	Persistent coma & seizures	Previous neurological event
2	72	male	Left main disease	C.A.B.G	85	56	Persistent coma & seizures	Atheromatus aorta
Group (II)								
3	48	female	Calcific M.S.	M.V.R	62	41	Left sided hemiplegia	Calcific mitral valve
4	62	female	3 vessel disease	C.A.B.G	68	42	Confusion & left sided hemiplegia	Previous neurological event
5	58	male	4 vessel disease	C.A.B.G	76	52	Right sided hemiplegia & aphasia	-ve
6	56	female	Prosthetic valve thrombosis	M.V.R.R	54	38	Left sided hemiplegia & seizures	Prosthetic valve thrombosis, A.F., re-operation
Group (III)								
7	48	male	Calcific A.S	A.V.R	55	39	Left sided hemiparesis & seizures	Calcific aortic valve
8	63	male	3 vessel disease	C.A.B.G	58	40	Fluctuating conscious level & irritability	Perioperative hypotension
9	47	female	Non calcific M.S & A.S	D.V.R	68	58	Left hemiparesis	A.F., left atrial thrombus
10	68	male	3 vessel disease	C.A.B.G	56	39	Irritability & confusion	Carotid artery disease
11	56	male	3 vessel disease	C.A.B.G	61	43	Right hemiparesis	Perioperative hypotension
12	46	female	Left atrial myxoma	Excision	43	26	Irritability & confusion	Myxoma
13	51	female	Prosthetic valve malformation	M.V.R.R	64	46	Left hemiparesis & confusion	Reoperation
14	67	male	3 vessel disease	C.A.B.G	65	48	Left hemiparesis & confusion	Atheromatus aorta
15	58	female	3 vessel disease	C.A.B.G	61	42	Irritability & confusion	A.F.
16	48	male	3 vessel disease	C.A.B.G	62	38	Irritability & confusion	-ve
17	44	female	Calcific M.S.	M.V.R	50	37	Right hemiparesis	Calcific mitral valve, A.F., Previous neurological event
18	58	male	3 vessel disease	C.A.B.G	61	40	Irritability & confusion	Perioperative hypotension

Table (2): Profiles of patients who developed neurological complications

logical dysfunction or stroke, defined as overt focal central nervous system deficit of acute onset and lasting more than 24 hours. The etiologies of these two distinct types of cerebral dysfunction are probably not identical. (8)

Macroembolization from the surgical field is thought to be the most common cause of stroke associated with cardiopulmonary bypass. (9, 10)

Other etiologies are gaseous or air emboli, severe hypotension and underperfusion, intrinsic cerebrovascular disease and thromboemboli from the left ventricle. (11)

The reported incidence of neurologic complications after open heart surgery varies from 0.8 to 3.2% in retrospective studies. (12, 13). And from 1.5 to 5.2% in prospective studies (14, 15). The frequency of severe postoperative neurologic disorders in the present study (4.1%) is in line with these previous findings.

Severe atheromatous involvement of the ascending aorta often accompanies coronary artery occlusive disease. This can present problems with cannulation, at times necessitating use of femoral artery for bypass and also with cross-clamping, often requiring repeated application of a partial-occlusion clamp. However, in most instances the operation can be done without the occurrence of cerebral dysfunction. (16)

In the present series, 1 patient who was unresponsive after the operation and another one with left sided hemiparesis and confusion had severe aortic disease with suspected atheromatous emboli. The first patient died while the second one demonstrated marked improvement in neurological function. Careful aortic clamping against low pressures, use of cross-clamps with soft Jaws (17), or use of a single cross-clamp period for construction of both proximal and distal anastomoses might be considered.

Alternatively, it may be necessary to use an internal mammary artery or gastroepiploic artery graft, to use the brachiocephalic vessels for the site of the proximal anastomosis (18), or to perform y-grafts with fewer proximal anastomoses.

One may occasionally have to resect a portion of the aorta and provide continuity from the graft to the aorta with an aortic patch of Dacron or Gore-Tex material. (19)

Neurological deficits after open heart surgery may be ascribed to inadequate cerebral perfusion. (16)

In this series, perioperative hypotension associated with low cardiac output state resulted in hypoxic cerebral damage with minor neurological deficit occurred in 3 patients which had cleared up by discharge.

Reoperation is associated with increased severity of the disease, increased impairment of myocardial func-

tion and sub-optimal general condition. The distorted anatomy and extensive adhesions increase the risk of improper deairing and re-exploration as a result of post-operative hemorrhage. These factors increase the risk of mortality and morbidity including neurological complications. (20)

In this series, 2 patients who subjected to mitral valve re-replacement developed neurological complications in the form of left sided hemiplegia with seizures in the first one and left sided hemiparesis with confusion in the second. The first one discharged with residual neurological deficit while the second one discharged neurologically free.

No consistent view exists regarding the relationship between neurological complications and cerebrovascular disease. Berner et al, showed that the rate of perioperative neurological complications increased with the severity of carotid artery stenoses and occlusions. (21)

Whereas, Schultz et al, showed no significant increase in perioperative stroke in symptom-free patients with carotid artery stenosis. (22)

In our study, carotid duplex was not done routinely preoperatively in coronary artery disease patients and done only in patients above 60 years and those with preoperative neurological symptoms. Only one patient from those who developed postoperative neurological complications had preoperative carotid disease but because he was in unstable angina and the patients had no neurological symptoms, so the decision was to proceed with coronary artery bypass graft. Because of the reported 1.5 to 6% incidence of concomitant coronary artery and carotid artery occlusive disease, it is advisable that patients with carotid artery bruits or neurological symptoms should be evaluated with carotid duplex or carotid angiography prior to coronary operations. (23)

Although atrial fibrillation is thought to be a benign arrhythmia, 4 of 18 patients who suffered from postoperative neurological complications had atrial fibrillation. All of them were anticoagulated preoperatively. One patient had in addition left atrial thrombus, one had prosthetic valve thrombosis and one had calcific mitral valve. So it is not clear whether atrial fibrillation alone is a risk factor for development of neurological complications or not.

Embolization is thought to be the most common cause of postoperative neurological complications. There are several potential sources of emboli during cardiac surgery. These include intra-cardiac thrombus, atherosclerotic plaques from ascending aorta, large and micro-particulate matter, microaggregate matter, air and or gaseous emboli. Intra cardiac thrombus may be atrial or ventricular in origin. Large particulate matters are

released during the excision of calcified aortic or mitral valve. Micro-particulates are formed from the plastic and other material from the disposable components of the pump oxygenator. Microaggregate matter formation develops from the residue of destroyed red and white blood cells, platelets, serum lipids fibrin, fibrinogen degradation products and denatured proteins. (24-26)

Air and gaseous microemboli occur in every operation which involves the use of the bypass machine and usually originate from the oxygenator, reservoir, pumps and/or cardiac chambers. (20)

In our study, embolization was incriminated to be the cause of postoperative neurological complications. The source of emboli was atheromatus aorta in 2 patients, calcific mitral and aortic valve in 3 patients, and left atrial thrombus in 1 patient, left atrial myxoma in 1 patient and prosthetic valve thrombosis in 1 patient.

Some studies (27, 28) have demonstrated that previous cerebrovascular disease is powerful predictor of postoperative stroke, whereas others (20, 30) have not found such an association.

In this series, 3 of 18 patients who developed postoperative neurologic complications had preoperative neurological event.

In our study, 2 of the patients who developed neurological complications had no evident risk factor to explain such complications. This may be attributed to microembolization from the cardiopulmonary bypass or to inadequate cerebral perfusion during bypass. So, one might infer that higher flow rates and pressures would be advisable in hypertensive patients and in those with uncorrectable minor carotid artery disease.

Conclusion

Such severe neurological complications after an otherwise successful cardiac surgery represent a devastating outcome for patients and their families and the social and economic impacts are enormous.

Several risk factors were identified, the main ones being calcification of the replaced mitral or aortic valves, left atrial thrombus, atrial fibrillation, carotid artery disease, atheromatus aorta, inadequate cerebral perfusion during cardiopulmonary bypass and perioperative hypotension associated with severe low cardiac output, tamponad or cardiac arrest. A detailed, structured neurological and neuropsychiatric assessment, both pre and post-operatively should be conducted on all patients who undergo open heart surgery. This will ensure that an accurate incidence of all types of neurological complications can be ascertained. A large scale prospective study is also needed to elucidate all risk factors for neurological complication

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