Original Article

Pulsatile Cardiopulmonary Bypass Failed to Prevent Neuropsychological Dysfunction

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To prevent neurological complications during cardiopulmonary bypass, cerebrovascular screenings by magnetic resonance angiography (MRA) and computed tomographic (CT) scan of the brain were performed preoperatively in patients who had ischemic heart disease and all patients aged 60 years or older. From 1996 to 1999, 173 adult patients (mean age 65.1±7.7 y) were evaluated. Forty-one patients were considered to be at high risk from the screening tests and pulsatile cardiopulmonary bypass was applied. The remaining 132 patients were placed in the control group. Postoperative cerebral infarction caused by embolism was encountered in three patients (3/173, 1.7%), two in the high-risk group (2/41, 4.8%) and one in the control group (1/132, 0.8%), but the difference between these incidences was not statistically significant. Cerebral infarctions caused by brain hypoperfusion did not occur in this series. A neuropsychological test (Hasegawa's dementia scale, HDS) was done pre- and postoperatively. No one was diagnosed with dementia preoperatively, whereas 7 patients were diagnosed with dementia postoperatively. Among these 7 patients, 6 patients were in the high-risk group (17.1%, 6/35) and one patient was in the control group (0.9%, 1/113). Under these circumstances, using cerebrovascular screening and pulsatile cardiopulmonary bypass, cerebral infarction due to hypoperfusion did not occur, but cerebral infarction due to embolism was encountered, and neuropsychological dysfunction was not prevented. (Ann Thorac Cardiovasc Surg 2001; 7: 89–93)

Key words: pulsatile cardiovascular bypass, neuropsychological dysfunction

Introduction

Although operative mortality in cardiovascular surgery using cardiopulmonary bypass is falling, neurological complications such as neuropsychological dysfunction[1,2] and cerebral infarction or hemorrhage still remain as a major problem associated with surgery. To prevent postoperative neurological complications including neuropsychological dysfunction, we screened carotid and vertebral and intracranial arteries preoperatively. When a stenotic or occlusive lesion was found, the patient was considered to be at high risk for cardiopulmonary bypass and pulsatile cardiopulmonary bypass was induced. The results in the high-risk group in comparison to the control group will be presented herein.

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Patients and Method

Subjects were 173 patients who had ischemic heart disease or were aged 60 years or older and underwent cardiopulmonary bypass during the three years and 11 month period between October 1996 and August 1999. Mean age of the patients was 65.1±7.7 years old. Of the 173 patients, 120 were male and 53 were female. Patients excluded from the analysis were those who were operated with selective cerebral perfusion or circulatory arrest with deep hypothermia, and those in whom pulsatile perfusion was applied for preservation of renal function.

Table 1. Profile of the high risk group and the control group

	High risk group	Control group	
Number of patients	41	132	
Age	67.8 ± 7.2	64.2 ± 7.7	p<0.01
Male : female	29 : 12	91 : 42	
Diagnosis			
Ischemic heart disease	32 (83%)	94 (71%)	
Valvular heart disease	7 (17%)	36 (27%)	
Others	0	2 (2%)	
Other conditions			
Diabetes mellitus	21 (51%)	43 (32%)	p<0.05
Hypertension	31 (76%)	61 (45%)	p<0.01

For cerebrovascular screening, magnetic resonance angiography (MRA) of the carotid, vertebral and intracranial arteries and computed tomographic scan (CT) of the brain were performed preoperatively. Diagnostic criteria of the high-risk group were stenotic (≥75%) or obstructive lesions in the carotid, vertebral or intracranial arteries, or cerebral infarction demonstrated on CT without atrial fibrillation and mitral valvular disease. Pulsatile cardiopulmonary bypass was undertaken in the high-risk group in order to prevent hypotension during cardiopulmonary bypass, under the condition where perfusion pressure was maintained over 80 mmHg. In the control group, a lower limit of perfusion pressure was not designated. In all patients circulating blood was cooled down to 30°C during cardiopulmonary bypass. The femoral artery was selected as the arterial cannulation site when the ascending aorta was severely sclerotic or when the saphenous vein was prepared as bypass material or in case of reoperation (n=117). In other cases, the arterial cannula was inserted in the ascending aorta (n=55). When neither the ascending aorta nor the femoral artery could be used as the cannulation site, the subclavian artery was selected (n=1). Pulsatile flow was produced by the pattern of roller pump rotation (CAPS: Stöckert, Munich, Germany). Neuropsychological examination was performed by using Hasegawa's dementia scale (HDS) pre- and postoperatively. Informed consent was obtained from each patient.

Statistical analysis was done by the Mann-Whitney U test, Student t test, chi-square test, and Fisher's exact test. A difference of $p<0.05$ was considered to be significant.

Results

In 33 cases (19.0%), stenotic (≥75%) or occlusive lesions of the carotid, vertebral or intracranial arteries were found by MRA. Cerebral infarction was found by CT in 8 patients with no mitral valvular disease or atrial fibrillation. Therefore, 41 patients comprised as the high-risk group. Pulsatile cardiopulmonary bypass was performed in all of 41 patients in the high-risk group, whereas constant flow bypass was performed in 132 patients in the control group.

Profile of patients in the high-risk group and the control group are shown in Table 1. Patients in the high-risk group were significantly ($p<0.01$) older than those in the control group (67.8±7.2 versus 64.2±7.7). There were no significant differences in the proportion of males to females as well as ischemic heart disease and other condition between the two groups. Preoperative incidence of diabetes mellitus and hypertension in the high-risk group (51% and 76% respectively) was significantly higher than in the control group (32% and 45% respectively).

Intra- and postoperative conditions are shown in Table 2. Femoral cannulation for cardiopulmonary bypass was significantly ($p<0.05$) more frequently used in the high-risk group (80%) than in the control group (63%). There was no significant difference in cardiopulmonary bypass time between the two groups. The patients in the high-risk group stayed in the intensive care unit (ICU) significantly longer (2.7 days) than those in the control group (2 days).

In hospital mortality as well as neurological complications are shown in Table 3. One patient from the control group died in the hospital (mortality rate 0.6%). The cause of death was renal and respiratory failure. Cerebral infarction diagnosed by CT of the brain occurred in 2 patients in the high-risk group (4.9%) and one patient in the control group (0.8%), but the difference between the two incidence rates was not statistically significant. Findings on CT on three patients were as follows: multiple infarction in a patient in the high-risk group, left-sided infarction in another patient in the high-risk group whose right internal carotid artery was occluded, and right-sided cerebral infarction of the midcerebral artery in a patient in the control group. The mechanism of infarction was diagnosed as embolism rather than hypoperfusion in all three patients. The two patients in the high-risk group who suffered a cerebral infarction never regained independent daily activity. The patient in the control group recovered fully and returned to a normal social life.

Table 2. Intraoperative and postoperative parameters

	High risk group	Control group	
Arterial cannulation site			
Ascending aorta	7 (17%)	48 (36%)	
Femoral artery	33 (80%)	84 (63%)	$p<0.05$
Subclavian artery	1 (2%)	0	
Duration of cardiopulmonary bypass (min)	102.7 ± 30.1	95.3 ± 27.4	
Duration of ICU stay (day)	2.7 ± 3.3	1.9 ± 3.3	$p<0.05$

Table 3. In-hospital mortality and neurological complication

	High risk group (n=41)	Control group (n=132)	Total (n=173)	
In-hospital mortality	0	1 (0.8%)	1 (0.6%)	n.s.
Cerebral infarction	2 (4.9%)	1 (0.8%)	3 (1.7%)	n.s.
Convulsion	1 (2.4%)	0	1 (0.6%)	n.s.

Table 4. Pre- and postoperative neuropsychological function evaluated by HDS

	High risk group	Control group	
Preoperative HDS score	27.2 ± 2.0 (n=41)	28.1 ± 1.5 (n=132)	$p<0.05$
Postoperative HDS score	25.1 ± 4.0 (n=35)	27.3 ± 2.1 (n=113)	$p<0.05$
ΔHDS	–2.1 ± 3.8 (n=35)	–0.9 ± 1.9 (n=113)	n.s.
ΔHDS 3	14/35 (40%)	19/113 (16.8%)	$p<0.01$
Postoperative dementia	6/35 (17.1%)	1/113 (0.9%)	$p<0.001$

HDS: Hasegawa's dementia scale, ΔHDS: change of HDS score (preoperative score to postoperative score).

One patient in the high-risk group developed seizures, but neither focal sign nor abnormal finding on CT was found.

A neuropsychological test using HDS was done in all patients preoperatively and 148 patients postoperatively. Preoperative average score for all patients was 27.9±1.6 points. There was a correlation between HDS score and patient age. Average score of patients younger than sixty was 28.8±1.2, whereas that of patients in their sixties was 27.9±1.5, and patients 70 or older was 27.3 ±1.8. Average score for the high-risk group was 27.2±2.0, and it was significantly ($p<0.05$) lower than that of the control group (28.1±1.5). Postoperative change in score (ΔHDS) was –2.1±3.8 relative to preoperative score in the high-risk group and –0.9±1.9 in the control group, although the difference between the two groups was not significant. Patients whose score decreased more than 3 points (1SD of the control group) accounted for 40% of the high-risk group, whereas it accounted for only 16.7% in the control group, and this difference was significant ($p<0.01$). The number of patients diagnosed with dementia postoperatively was 6 (17.1%) in the high-risk group and one (0.9%) in the control group, and this difference was statistically significant ($p<0.001$) (Table 4). Multiple regression analysis in the relation between several factors and ΔHDS showed that staying in ICU longer (≥3 days) and being in the high-risk group were effective factors for estimating ΔHDS (table 5). However four of the 7 patients diagnosed with dementia stayed in ICU just one day, and their postoperative courses were uneventful.

Discussion

Embolism and hypoperfusion are the major causes of neurological complications after cardiopulmonary bypass. Mizuhara[3] reported that in a CT study more than half of the cases with neurological complications showed watershed infarction[4,5] due to hypoperfusion. Frequently we experience hypotension below 50 mmHg during cardiopulmonary bypass, but usually hypotension of such level is not harmful to the brain.[6] On the other hand, when severe stenosis or obstruction of major feeding arteries of the brain exists, brain hypoperfusion may occur during hypotension.[7,8] We thought that cerebrovascular screening was necessary to prevent brain hypoperfusion during cardiopulmonary bypass, as a consequence preoperative MRA and CT examinations were incorporated.

Table 5. Multiple regression analysis in the relation between each factor and change of HDS score

	t value	p value
ICU stay 3 days	–2.35	0.020
High risk group	–2.32	0.022
Diabetes mellitus	–1.26	0.210
Age 65 years	0.42	0.673
Cardiopulmonary bypass 120min	0.41	0.680
Preoperative HDS score 26	0.82	0.408
Hypertension	1.24	0.214

t value = (value of partial regression coefficient)/(standard error of partial regression coefficient).
Factors are considered as effective when (t value)2 >2.

MRA can display arteries from the neck to the head less invasively without contrast medium, and it is reported that sensitivity is high and specificity is sufficient for a screening test.[9] Brain CT cannot display a vascular lesion directly, but it is useful for the evaluation of high-risk patients. For symptomatic patients with a carotid lesion, endoartherectomy is needed prior to or simultaneously with heart surgery.[8] When a carotid, vertebral or intracranial lesion is found in an asymptomatic patient, it is recommended to maintain high perfusion pressure during cardiopulmonary bypass[8,10] to maintain sufficient flow through stenotic arteries or collateral circulation. How high perfusion pressure should be maintained is not clear. Some apply 50 mmHg,[8] and others 70 mmHg,[10] or 80 mmHg.[11] Whether pulsatility itself has a beneficial effect on the brain or not is still unclear,[12-14] but higher perfusion pressure is easily gained by a pulsatile pump without aggravating peripheral circulation by administering catecholamine or using excessive high flow perfusion. Therefore, we maintained perfusion pressure above 80 mmHg using a pulsatile pump.

Our strategy of screening and using a pulsatile pump seems to have some effect to prevent neurological complications, because we have not experienced neurological complications due to hypoperfusion since adopting this method. But cerebral infarctions due to embolism still occurred and neuropsychological dysfunction was for the most part not prevented by this strategy.

Neuropsychological dysfunction is now considered to be a serious postoperative complication. It is said that neuropsychological dysfunction occurs more frequently after cardiovascular surgery using cardiopulmonary bypass than after other major surgeries,[15] and that postoperative neuropsychological dysfunction lasts longer than expected.[1,2]

There are many tests for neuropsychological function, but for postoperative testing, tests that require less time are preferable to those that require more time. HDS[16,17] is a standard Japanese instrument designed to screen dementia, and it resembles Folstein's mini-mental state test (MMS).[18] The full score of HDS is 30, and scores of 20 or less strongly indicate dementia.

In this series, the significant factors affecting ΔHDS were staying in ICU longer (≥3 days) and being in the high-risk group. From the fact that 4 of 7 patients diagnosed with dementia stayed in ICU only a day and their postoperative courses were uneventful, neuropsychological damage in these patients seemed to be due to some organic change in the brain rather than a circumferential factor like staying in ICU longer.

It is speculated that neuropsychological dysfunction is not the result of a single factor.[11] Recently the relation between microembolism[19] and neuropsychological dysfunction has been frequently reported.[20-23] It has also been reported that PH-stat acid-base control during cardiopulmonary bypass increased neuropsychological dysfunction, although cerebral blood flow was increased by vascular dilatation due to the addition of CO_2.[25-27]

It is understandable that pulsatile perfusion failed to prevent neuropsychological dysfunction if the major cause is attributed to microembolism. Moreover, it is possible to speculate that pulsatile perfusion induces the risk of microembolism.

The benefit of pulsatile perfusion, we think, is the capability to produce high perfusion pressure easily for high-risk patients who need relatively high perfusion pressure to prevent cerebral hypoperfusion. Although we have not experienced neurological complications due to hypoperfusion, the effectiveness of pulsatile perfusion could not be proved by statistical evidence here. On the other hand, an undesirable effect, the possibility that it may induce micro- or macroembolism,[28] caught our attention.

We will continue to screen cerebrovascular lesions before cardiopulmonary bypass, but we will apply pulsatile perfusion more carefully and less frequently, taking into account the site of the arterial cannulation and perfusion pressure in each individual case based on the findings of the cerebrovascular lesion and atherosclerotic change in the aortic wall.

Conclusion

Under the circumstances using cerebrovascular screening and pulsatile cardiopulmonary bypass, cerebral infarction due to hypoperfusion did not occur, however cerebral infarction due to embolism were major complication and neuropsychological dysfunction was not prevented from our present strategy.

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