Side differences in cerebrovascular accidents after cardiac surgery: A statistical analysis of neurologic symptoms and possible implications for anatomic mechanisms of aortic particle embolization

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Background: Aortic manipulation and particle embolization have been identified to cause cerebrovascular accidents in cardiac surgery. Recent data suggest that left-hemispheric cerebrovascular accident (right-sided symptoms) is more common, and this has been interpreted as being caused by aortic cannula stream jets. Our aim was to evaluate symptoms of cerebrovascular accident and side differences from a retrospective statistical analysis.

Methods: During a 2-year period, 2641 consecutive cardiac surgery cases were analyzed. Patients positive for cerebrovascular accident were extracted from a database designed to monitor clinical symptoms. A protocol was used to confirm symptom data with the correct diagnosis in patient records. Patients were subdivided into 3 groups: control, immediate cerebrovascular accident, and delayed cerebrovascular accident.

Results: Among pooled patients, immediate and delayed cerebrovascular accidents were 3.0% and 0.9%, respectively. The expected predisposing factors behind immediate cerebrovascular accidents were significant, although the type of operation affected this search. Aortic quality was a strong predictor ($P < .001$). The rate of delayed cerebrovascular accident was unaffected by surgery group. Left-sided symptoms of immediate cerebrovascular accident were approximately twice as frequent ($P = .016$) as on the contralateral side. This phenomenon was observed for pooled patients and for isolated coronary bypass procedures ($n = 1882$; $P = .025$).

Conclusions: Immediate cerebrovascular accident and aortic calcifications are linked. The predominance of left-sided symptoms may suggest that aortic manipulation and anatomic mechanisms in the aortic arch are more likely to cause cerebrovascular accidents than effects from cannula stream jets.

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Cerebrovascular accidents (CVAs) are a problem in cardiac surgery.¹ Several risk factors behind CVAs after cardiac surgery have been identified.¹⁻³ Of particular interest is atherosclerosis of the ascending aorta in relation to aortic manipulation.⁴⁻⁷ In addition to CVA are diffuse symptoms of brain damage that occur in the postoperative period. These are often discussed in relation to the use of extracorporeal circulation, such as from fat microembolism of retrieved pericardial suction blood,^{8,9} from immunologic mechanisms,¹⁰ or from being secondary to hypoperfusion and anesthetic management.¹¹ Recently we identified that aortic crossclamping on cadaver aortas generated not only macroscopic particles, but also significant amounts of

TABLE 1. Patient demographics subdivided into groups of CVA, in all patients versus CABG only

All patients (n = 2641)	Control group (A) (n = 2537)	P value (A-B)	Immediate CVA (B) (n = 79)	P value (B-C)	Delayed CVA (C) (n = 25)	P value (A-C)	P value (A-B-C)
General data							
Age (y)	65.4 ± 10.3	.046	69.5 ± 9.2	.242	67.3 ± 9.6	.352	.002
Males (%)	73	.850	72	.029	48	.008	.030
Weight (kg)	79.6 ± 14.2	.172	76.0 ± 13.5	.496	74.1 ± 10.3	.052	.014
Clinical preop data							
Cerebral history (%)	11.5	.004	22.8	.524	16.0	.388	.012
Peripheral vascular disease (%)	2.7	.006	9.4	.779	5.6	.259	.014
Pulmonary disease (%)	10.6	.050	17.7	.734	20.0	.122	.048
Serum creatinine (μmol/L)	93.0 ± 45.4		101.1 ± 32.7		106.2 ± 89.3		.125
Cardiac general data							
Left ventricular function (%)							
Good	70.4		64.9		60.0		.089
Reduced	23.6		22.1		36.0		
Bad	5.7		13.0		4.0		
NYHA (%)							
I	1.0	.001	2.5	.614	0.0	.951	.009
II	8.0		6.3		8.0		
IIIA	36.5		17.7		32.0		
IIIB	34.8		34.2		36.0		
IV	19.1		35.4		24.0		
Higgins score	2.5 ± 2.5	.063	4.5 ± 2.5	.064	2.4 ± 2.3	.916	.022
CABG only (n = 1882)	Control group (A) (n = 1836)	P value (A-B)	Immediate CVA (B) (n = 30)	P value (B-C)	Delayed CVA (C) (n = 16)	P value (A-C)	P value (A-B-C)
General data							
Age (y)	65.2 ± 9.2	.010	71.4 ± 5.5	.015	65.8 ± 10.0	.786	.001
Males (%)	77.5	.830	76.7	.072	50.0	.014	.048
Weight (kg)	80.8 ± 13.7	.072	74.4 ± 12.0	.593	72.6 ± 10.9	.026	.003
Clinical preop data							
Cerebral history (%)	11.0	.013	26.7	.597	18.8	.256	.025
Peripheral vascular disease (%)	2.5		8.3		0.0		.190
Pulmonary disease (%)	10.2		16.7		18.8		.216
Serum creatinine (μmol/L)	93.0 ± 47.7	.254	107.1 ± 39.8	.380	118.0 ± 113.1	.055	.038
Cardiac general data							
Left ventricular function (%)							
Good	70.2		66.7		43.8		.125
Reduced	24.9		30.0		56.3		
Bad	4.9		1.1		0.0		
NYHA (%)							
I	0.1		0.0		0.0		.525
II	5.7		6.7		6.3		
IIIA	38.1		26.7		25.0		
IIIB	35.5		40.0		37.5		
IV	20.6		26.7		31.3		
Higgins score	2.0 ± 2.0	.035	4.2 ± 2.9	.072	2.4 ± 2.3	.679	.027
Unstable angina (%)	27.7	.268	36.7	.21	56.3	.016	.031
Main stem occlusion (%)	26.4		33.3		43.8		.197

NYHA, New York Heart Association; CVA, cerebrovascular accident; CABG, coronary artery bypass grafting. Data are means ± SD unless otherwise indicated.

microscopic debris, and this may suggest an additional mechanism behind the diffuse brain symptoms.¹²

Major surgical and scientific efforts are focused on the issue of aortic calcification and technical methods to

avoid this problem,^{13,14} such as off-pump surgery,^{15,16} aortic ultrasound scanning,¹⁷ single clamp procedures,¹⁸ automated graft connectors,¹⁹ and intra-aortic filtering.²⁰ Ultrasound scanning has the advantage of visualizing not

TABLE 2. Intraoperative data in groups of CVA, all patients versus CABG only

All patient (n = 2641)	Control group (A) (n = 2537)	P value (A-B)	Immediate CVA (B) (n = 79)	P value (B-C)	Delayed CVA (C) (n = 25)	P value (A-C)	P value (A-B-C)
Surgical data							
Aortic wall quality/calcification (%)							
Normal	74.1	<.001	34.6	.078	61.1	.330	<.001
Moderately	19.4		29.1		27.8		
Severely	6.5		36.4		11.1		
Surgery time (min)	3.26 ± 1.22	<.001	4.32 ± 2.35	<.001	3.28 ± 1.12	.924	<.001
CPB data							
Cardioplegic direction (%), antegrade	84.4	.001	65.4	.110	88.0	.708	.001
Cardioplegic type (%), crystalloid	77.5	.002	59.7	.009	91.7	.104	.002
CPB time (min)	88.6 ± 54.6	<.001	137.4 ± 82.5	<.001	96.0 ± 37.1	.447	<.001
Aortic clamp time (min)	51.6 ± 36.5	<.001	80.1 ± 58.5	<.001	52.5 ± 28.7	.903	<.001
Lowest temperature (C°)	31.9 ± 7.5		30.8 ± 6.9		33.3 ± 3.0		.301
Anesthetic data							
Pacemaker requirement (%)	13.4		21.8		24.0		.224
Complicated weaning CPB (%)	8.0	<.001	24.4	.213	12.0	.347	<.001
Inotropic support (%)	33.0	<.001	61.5	.396	52.0	.049	<.001
IABP (%)	1.5		5.1		0.0		.078
Total volume load (mL)	3399 ± 2016	.002	4639 ± 3450	.021	3739 ± 2182	.384	<.001
Total bleeding (mL)	596 ± 819	<.001	1433 ± 2301	<.001	602 ± 625	.971	<.001
CABG only (n = 1882)	Control group (A) (n = 1836)	P value A-B	Immediate CVA (B) (n = 30)	P value B-C	Delayed CVA (C) (n = 1)	P value A-C	P value A-B-C
Surgical data							
Aortic wall quality/calcification (%)							
Normal	79.0	<.001	43.3	.449	62.5	.139	<.001
Moderately	16.5		30.0		25.0		
Severely	4.5		26.7		12.5		
Surgery time (min)	3.0 ± 0.9		3.2 ± 1.0		3.1 ± 0.8		.239
No. of anastomoses (n)	3.4 ± 1.1		3.3 ± 0.9		4.0 ± 1.4		.052
CPB data							
OPCAB (%)	6.0		0.0		0.0		.402
Cardioplegic direction, of CPB (%), antegrade	94.6		96.7		100.0		.918
Cardioplegic type (%), crystalloid	93.1		96.6		100.0		.706
CPB time (min)	69.7 ± 33.4		79.1 ± 28.7		82.7 ± 27.3		.096
Aortic clamp time (min)	36.2 ± 18.5		38.6 ± 14.3		41.7 ± 15.7		.383
Lowest temperature (C°)	31.9 ± 8.4		34.0 ± 0.7		34.0 ± 1.0		.254
Anesthetic data							
Pacemaker requirement (%)	8.1		13.3		25.0		.162
Complicated weaning CPB (%)	4.3		3.3		6.3		.728
Inotropic support (%)	20.6	.014	40.0	.799	43.8	.031	.005
IABP (%)	1.0		0.0		0.0		.798
Total volume load (mL)	3188 ± 1586		3395 ± 1697		3251 ± 1188		.768
Total bleeding (mL)	471 ± 432		535 ± 522		484 ± 182		.721

CPB, Cardiopulmonary bypass; OPCAB, off-pump coronary artery bypass; IABP, intra-aortic balloon pump; CVA, cerebrovascular accident; CABG, coronary artery bypass grafting. Cardioplegic direction subgroups; antegrade/retrograde/antegrade + retrograde/none or arrest. Cardioplegic type subgroups: crystalloid/cold blood/warm blood. Data are mean ± SD unless otherwise indicated.

only hard calcifications, but also soft plaques not identified by palpation. The aortic clamp has been suggested to contribute to mechanical trauma as evaluated both clinically and experimentally.^{6,12} However, an opposing mechanism suggests that unfavorable stream jets at the

tip of the aortic cannula dislodge particles from the vascular wall.²¹⁻²³ This speculative assumption was based on findings that left-hemispheric lesions, ie, right-sided symptoms, are more often involved in immediate CVA than right-hemispheric lesions, assuming a particle

TABLE 3. Postoperative data in groups of CVA, all patients versus CABG only

All patients (n = 2641)	Control group (A) (n = 2537)	P value (A-B)	Immediate CVA (B) (n = 79)	P value (B-C)	Delayed CVA (C) (n = 25)	P value (A-C)	P value (A-B-C)
Intensive care data							
Atrial fibrillation (%)	3.0	<.001	12.7	.061	0.0	.729	.001
Mediastinal drain output 24 h (mL)	826 ± 439	.222	928 ± 507	<.001	611 ± 190	.010	.007
Time on ventilator (h)	21.0 ± 87.9	<.001	99.6 ± 158.4	<.001	12.1 ± 30.0	.602	<.001
Time in intensive care (h)	38.2 ± 83.7	<.001	134.0 ± 158.5	<.001	48.7 ± 61.0	.521	<.001
Ward data							
Atrial fibrillation (%)	20.1		27.8		24.0		.230
Hospital mortality (%)	1.9	.001	8.9	.563	12.0	.005	<.001
LOS (d)	8.6 ± 5.4	.002	11.8 ± 8.3	<.001	8.0 ± 2.8	.589	<.001
One-year mortality (%)	4.6	<.001	19.0	.844	20.0	.003	<.001
CABG only (n = 1882)	Control group (A) (n = 1836)	P value A-B	Immediate CVA (B) (n = 30)	P value (B-C)	Delayed CVA (C) (n = 16)	P value (A-C)	P value (A-B-C)
Intensive care data							
Atrial fibrillation (%)	1.4		6.7		0.0		.090
Mediastinal drain output 24 h (mL)	826 ± 403		852 ± 342		586 ± 198		.055
Time on ventilator (h)	10.8 ± 40.5	<.001	59.7 ± 130.3	<.001	14.1 ± 36.9	.770	<.001
Time in intensive care (h)	25.8 ± 40.7	<.001	71.5 ± 121.9	.018	45.6 ± 62.4	.072	<.001
Ward data							
Atrial fibrillation (%)	17.5		30.0		31.3		.075
Hospital mortality (%)	0.7	.081	3.3	.096	18.8	<.001	<.001
LOS (d)	7.8 ± 3.3	.016	9.8 ± 8.2	.003	7.2 ± 2.0	.503	.003
One-year mortality (%)	2.7	.001	16.7	.482	25.0	<.001	<.001

LOS, Length of stay; CVA, cerebrovascular accident; CABG, coronary artery bypass grafting. Data are mean ± SD unless otherwise indicated.

route through the left common carotid artery rather than the brachiocephalic trunk.²² The question about the anatomic focus of CVA in cardiac surgery has been addressed previously and with contradicting results that suggested either a right hemispheric or a posterior location,^{24,25} although these studies were based on limited patient numbers and low statistical power.

In view of the contradiction regarding possible CVA mechanisms, our aim was to investigate neurologic symptoms after cardiac surgery. The study was focused on possible side differences from the clinical pattern of CVA and how this phenomenon varied between immediate and delayed CVA.

Methods

Study Design and Patient Cohort

From January 1999 to May 2001, a group of 2641 consecutive patients operated on at the Cardiothoracic Department of the Heart Center of Umeå University Hospital was included in the study. The Umeå University ethics committee approved the study (Dnr 01-075).

The studied population had an average age of 65.6 ± 10.3 years and contained 72.6% men. The average weight was 79.4 ± 14.2 kg. Demographic data are shown in Table 1, with subdivision into controls and the 2 groups of CVA.

Surgical Techniques

In brief, on-pump coronary artery bypass grafting (CABG) was performed with standard aortic crossclamping; distal anastomoses were performed, followed by partial clamp for proximal connections. Off-pump coronary artery bypass (OPCAB) was performed in a subgroup of CABG (n = 111). In the great majority of cases, aortic quality was assessed by palpation only; otherwise, it was assessed by aortic scanning. A curved-tip/end-hole aortic cannula was used for all routine cases. Open cardiac procedures comprised routine venting via the apex, pulmonary vein, or pulmonary artery. Carbon dioxide flushing of the wound was not used during the study period. A membrane oxygenator was used in all procedures with cardiopulmonary bypass (CPB). Pericardial suction blood was recycled in all patients.

Database Recordings and Protocol

The database had a prospective design to monitor clinical symptoms in all operated patients. Preoperative data were followed by daily entry of information from the operating room, the intensive care unit, and the ward. Inputs were from surgeons, anesthetists, perfusionists, nurses, and physiotherapists. The same parameter could therefore have duplicate inputs in the database, and this possibly increased the precision of the more important findings. A synthesis of these multiple-input parameters was performed in the data processing. Records of all patients in the database with reported CVA were collected for review in a retrospective fashion. A protocol was designed to

TABLE 4. CVA rates versus groups of surgery

	All patients (n = 2641)	CABG isolated (n = 1882)	P value	AVR isolated (n = 196)	P value	CABG/AVR isolated (n = 200)	P value
Immediate CVA (%)	2.99	1.59	.003*	3.57	.046†	7.50	<.001†
Immediate CVA (n)	79	30		7		15	
Delayed CVA (%)	0.95	0.85	.736*	1.53	.341†	1.00	.828†
Delayed CVA (n)	25	16		3		2	

CVA, Cerebrovascular accident; CABG, coronary artery bypass grafting; AVR, aortic valve replacement.

*Difference versus all patients pooled.

†Difference versus corresponding data of isolated CABG procedure.

TABLE 5. Symptom pattern of CVAs

	Immediate CVA				Delayed CVA			
	All patients (n = 2641)	P value	CABG isolated (n = 1882)	P value	All patients (n = 2641)	P value	CABG isolated (n = 1882)	P value
No. of cases (n)	79		30		25		16	
General								
Reduced consciousness (%)	30.4		16.7		32.0		37.5	
Coordinating disorders (%)	21.5		20.0		20.0		18.8	
Focal CVA total (%)	65.8		76.7		68.0		62.5	
Focal symptoms								
Speech symptoms (%)	25.3		36.7		36.0		31.3	
Visual symptoms (%)	7.6		6.7		20.0		18.8	
Facial neurology (%)	2.5		6.7		12.0		6.3	
Right-sided symptoms								
Arm (%)	13.9		13.3		12.0		12.5	
Leg (%)	19.0		13.3		12.0		12.5	
Total (%)	21.5		16.7		12.0		12.5	
Left-sided symptoms								
Arm (%)	35.4	.003	43.3	.020	24.0	.464	18.8	.999
Leg (%)	30.4	.139	33.3	.125	20.0	.702	12.5	.999
Total (%)	40.5	.016	46.7	.025	24.0	.464	18.8	.999

Significance denotes difference versus contralateral side, within group. CVA, Cerebrovascular accident; CABG, coronary artery bypass grafting.

follow up the events in a systematic order, to verify symptom data with clinical diagnosis, and to subdivide patients into immediate and delayed CVA. The parameters “cerebral history,” “peripheral vascular disease,” and “pulmonary disease” referred to anamnestic information by the patient or from patient records for any previous ischemic cerebral event, regardless of type; peripheral vascular disease with or without operation; and any form of verified restrictive or obstructive disease or positive laboratory recordings, respectively.

Classification of CVA

The patients were subdivided into 3 groups: control, immediate CVA, and delayed CVA. Immediate CVA was defined as positive neurologic symptoms apparent at extubation after surgery. Delayed CVA was defined as having a free interval after extubation. Duration of neurologic symptoms was monitored to subdivide into transient ischemic attack lasting less than 24 hours versus CVA longer than 24 hours. The definitions were according to routine guidelines.²⁶ Because of few observations of transient ischemic attack (3 each in the immediate and delayed groups), these were pooled together with CVA in the

data presentation. Patients with borderline symptoms and uncertain diagnosis were grouped as control subjects. For obvious CVA, an experienced surgeon or anesthetist confirmed the diagnosis. In less obvious cases, computed tomographic scans were performed (76% of all cases) or a consultant neurologist confirmed the diagnosis (47% of cases). In 65% of immediate and 74% of delayed events, the computed tomographic scan confirmed the CVA.

Statistical Analysis

Mean values $\pm$ SD and frequencies are given throughout. Typically, the statistical analysis compared 3 groups: control, immediate CVA, and delayed CVA. For parametric data, 1-way analysis of variance was conducted with Duncan post hoc analysis. Non-parametric and nominal data were analyzed by means of 3-column contingency tables and by a log-linear model and maximum likelihood χ^2 output. Post hoc analysis was conducted by excluding 1 group to restrain the statistical model. If there were few observations, Fisher exact tests were used. Statistica (StatSoft, Tulsa, Okla), version 6.1, was used throughout.

Results

Parameters Predicting CVA and Outcome Data

Expected and predictive parameters are summarized for preoperative and intraoperative data in Tables 1 and 2, respectively. Postoperative data are found in Table 3. Of major importance was the strong link between aortic calcifications and immediate CVA. Female sex was associated with delayed CVA. Diabetes, hypertension, renal dysfunction, smoking habits, and preoperative atrial fibrillation did not show significance with CVA. The statistical results changed when isolated CABG procedures ($n = 1882$) were extracted from the pooled group of all patients (Tables 1-3). Of the intraoperative parameters, only aortic wall quality and the need for inotropic support remained significant.

CVA Pattern Versus Surgery

The overall rates for immediate and delayed CVA were approximately 3.0% and 0.9%, respectively (Table 4). The immediate CVA rate varied substantially between different subgroups of surgery.

Among isolated CABG procedures, the rate of OPCAB was 6.0%. However, none of the OPCAB cases ($n = 111$) had any recorded forms of CVA. The exposure to CPB thus yielded a numeric difference ($P = .086$) compared with the overall occurrence of CVA (immediate and delayed groups combined).

Patterns of CVA

CVA patterns are presented in Table 5. Left-sided symptoms (arm and leg) were almost twice as frequent as contralateral symptoms in the immediate CVA group. This was seen among pooled patients ($P = .016$) and among isolated CABG ($P = .025$). A similar numeric pattern was seen for delayed CVA, although this was not significant. The side difference was numerically similar for aortic valve replacement (AVR) and CABG/AVR combinations, although the numbers of CVAs for these groups were insufficient to yield significance.

Discussion

The avoidance of CVA is of the outmost importance for the future development of cardiac surgery, both for patient outcome and for the surgical profession. Of particular interest are CVA mechanisms relating to the calcified ascending aorta.

There is strong evidence that embolic particles are dislodged because of aortic manipulation⁶ and that aortic quality correlates significantly with immediate CVA.^{7,27} However, in contrast to this theory is the proposed mechanism that unfavorable stream jets induced by the aortic cannula dislodge embolic material.²² The latter assumption was based on findings that left-hemispheric CVAs dominate

over the contralateral side.²² The side difference was interpreted in terms of the anatomic location of the tip of the cannula in the vicinity of the left common carotid artery.²²

We found, in contrast,²² and despite the use of standard curved-tip/end-hole aortic cannula, a preponderance of left-sided symptoms with immediate CVA, ie, the right hemisphere. The CVA phenomenon was significant for pooled groups of surgery, as well as for isolated CABG, the latter of which dominated the statistical material. Similar numeric differences were, however, observed for AVR and CABG/AVR combinations, but this did not reach significance because of fewer observations. For comparison, side differences in CVA were not seen after surgery on the ascending aorta (data not shown).

As expected, immediate CVA had a strong link to observed aortic calcifications. It is tempting to speculate that the previous and combined observations point toward embolic mechanisms due to manipulation of the ascending aorta. In theory, particles are tangentially expelled into the brachiocephalic trunk rather than being dislodged by cannula stream jets into the perpendicularly branched left common carotid artery.²²

In consonance with our data, a small study by Sotaniemi²⁴ demonstrated that the right hemisphere was involved in 71% of cases of brain damage after cardiac surgery. The question about possible side differences for delayed CVA has not, to our knowledge, been addressed previously. It is interesting to note that we found a similar percentage difference of right-to-left symptoms in delayed CVA as for immediate CVA, although this did not reach significance because of insufficient numbers. It can be speculated that blood clots formed in the cavities of the heart are predominantly expelled tangentially into the brachiocephalic trunk rather than into the left common carotid artery, similar to the embolic route of immediate CVA.

In this study, immediate and delayed CVA occurred in approximately 3.0% and 0.9% of patients, respectively. Delayed CVA seemed unaffected by the type of surgery, whereas immediate CVA varied markedly between surgery subgroups. For isolated CABG, the percentage was only approximately half of that for pooled patients. Thus, although CABG accounted for 71% of the procedures, most CVAs (56%) occurred in the more complex forms of surgery. The observed CVA rates are similar to what has been previously reported,²⁸ although both higher²⁹ and lower³ rates have been described. AVR produced a significantly higher incidence of immediate CVA than did isolated CABG, a pattern that again confirms previous findings.²⁹ Combination procedures of CABG/AVR were associated with unexpectedly high rates of immediate CVA, at 7.5%, but these results are nearly identical to those reported by Bucerius and associates.²⁹ The finding that CVA rates add

up for combined procedures is in consonance with previous suggestions.³ The use of CPB and the possible benefit of OPCAB over on-pump procedures did not yield significance in this study. Even so, all CVAs occurred among patients exposed to CPB, whereas the control group contained all OPCAB procedures.

Mechanisms behind CVA after cardiac surgery seem complex. This issue has been extensively studied in the past.^{27,29} In general, mechanisms can be subdivided into those relating to patient demographics and those caused by the operation. Immediate and delayed CVA were here found to represent different diseases in view of both demographic and surgical data. Our data confirm many previous reports. In brief, age, history of CVA, vascular disease, pulmonary disease, left ventricular function, New York Heart Association class, and high Higgins scores were associated with immediate CVA. Among procedure-related mechanisms, aortic wall calcifications; time of operation, CPB, and clamp; and cardioplegia type and administration all correlated with immediate CVA. However, many of these mechanisms disappeared when isolated CABG procedures were extracted for analysis. Only aortic quality and the need for inotropic support remained significantly associated with immediate CVA.

The sex difference suggesting more frequent delayed but not immediate CVA among women was interesting. Hogue and colleagues³ found a nearly 6.9-fold increased risk for immediate CVA among women, a finding that was not confirmed in our study. CVA is a critical complication of cardiac surgery that affects the patient outcome and requirement for resources, such as for intensive care. As expected, hospital and 1-year mortality were significantly higher in both the immediate and delayed CVA groups versus controls. One-year mortality was approximately twice the rate for hospital death. A CVA resulted in approximately a fourfold to fivefold increase in death rate whether the CVA was immediate or delayed.

The study is limited from its retrospective design that included all types of major operations during a defined period of time. The design resulted in a heterogeneous patient cohort subdivided into subgroups of procedures, among which isolated CABG dominated. Further, science based on data registries is less precise and is limited to selected parameters.

In conclusion, immediate and delayed CVA represented 2 different groups of disease that related to multiple and somewhat different risk factors. Immediate CVA was more frequent than the delayed form, and more complex operations increased the risk dramatically. Left-sided symptoms were twice as frequent as on the contralateral side, and it can be speculated that this finding points toward aortic manipulation and anatomic mechanisms in the aortic arch.

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