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ORIGINAL ARTICLE

Mechanisms of early and delayed stroke after systematic off-pump coronary artery bypass

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Background/Purpose: Stroke is one of the most devastating complications after cardiac surgery. Off-pump coronary artery bypass (OPCAB) has been reported to offer a lower risk of stroke. However, limited information was available on timing and mechanisms of stroke after OPCAB. We sought to assess the incidence, timing, and mechanisms of stroke after OPCAB.
Methods: A retrospective review of 1010 patients undergoing systematic OPCAB between 2001 and 2012. Stroke was defined as any focal or global neurologic deficits lasting for more than 24 hours. Stroke was classified as early stroke when it occurred less than 24 hours postoperatively, and delayed stroke when it occurred more than 24 hours postoperatively. Stroke mechanisms were classified as embolic or hypoperfusion.
Results: In a total of 10 patients (1.0%) 11 episodes of stroke developed after OPCAB. Early stroke occurred in five (0.5%) patients and delayed stroke occurred in six (0.6%) patients. Of five early strokes, the mechanisms were embolic in two (40%) and hypoperfusion in three (60%). Of six delayed strokes, the mechanisms were embolic in five (83%) and unknown in one. Of six delayed strokes, all the patients had diabetes mellitus and acute cardiac events prior to surgery, and five patients had postoperative atrial fibrillation.
Conclusion: The incidence of stroke after systematic OPCAB was low. Early and delayed strokes were equally distributed. Stroke mechanisms were predominantly embolic. Early and delayed stroke differed in their mechanisms. Early and delayed stroke should be considered as two separate entities and different preventive strategies should be applied in future intervention.

Conflicts of interest: All authors declare no conflicts of interest.

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Introduction

Perioperative stroke is one of the most devastating complications after cardiac surgery, and it can lead to severe debilitation and excess mortality.[1–4] Perioperative strokes are predominantly ischemic, and the timing of stroke after cardiac surgery shows a bimodal distribution, with early and delayed strokes.[4–13] However, previous research efforts have focused primarily on identifying perioperative risk factors,[5,7,9–12] and not much work has focused on understanding their mechanisms.[4,6,13] Without this information, we are unable to understand how best to prevent perioperative stroke. Thus, an understanding of the mechanisms of early and delayed strokes and whether they differ has important implications for potential preventive strategies in future investigations.

Coronary artery bypass grafting (CABG) is one of the most common types of cardiac surgery performed in adult patients. It has traditionally been performed with the use of cardiopulmonary bypass. Cardiopulmonary bypass has been suggested to be related to the development of perioperative stroke.[1–13] The technique of operating on a beating heart or off-pump coronary artery bypass (OPCAB) was developed to decrease postoperative complications.[14,15] OPCAB has been reported to offer a lower risk of stroke.[3,9–13,16] However, limited information was available on the timing and mechanisms of perioperative stroke in the setting of OPCAB.[9–12] The purpose of this study was to assess the incidence, timing of onset, and mechanisms of perioperative stroke after systematic OPCAB.

Materials and methods

Patients

In this retrospective study, we included all consecutive patients undergoing systematic OPCAB between December 2001 and January 2012 at the National Taiwan University Hospital (Taipei, Taiwan). No patient was excluded from OPCAB because of the pattern of coronary artery disease, presence of cardiogenic shock, or emergency surgery.

All data were collected by retrospective chart review. Intention-to-treat data were obtained in the current study. OPCAB cases that were converted to on-pump procedures remained in this study. The local institutional medical ethics committee approved the study and waived the need for informed consent.

A total of 1010 consecutive patients underwent systematic OPCAB. There were 809 males and 201 females, with the median age of 67 years (range, 26—91 years). Mode of surgical intervention was elective in 737 patients, urgent in 176 patients, and emergency in 97 patients. The hospital mortality rate was 0.4 % in elective cases, 8% in urgent cases, and 33% in emergency cases. The major causes of in-hospital death were severe cardiogenic shock in 28 patients, severe sepsis in 18 patients, ischemic stroke in two patients, and aortic rupture in one patient.

Surgery

Beginning in December 2001, we started a systematic approach to treat all patients with coronary artery disease with OPCAB. Surgery was performed through a median sternotomy. The heparin dose is two-thirds of the standard dose for cardiopulmonary bypass. The target activated clotting time is more than 350 seconds. This is partially reversed with one-half of the calculated protamine dose after the completion of coronary anastomosis. Cardiopulmonary bypass was on standby without priming the pump. Distal anastomoses were performed using a suction-type coronary stabilizer and intracoronary shunt. Pericardial traction suture and apical suction device were not used for assistance. The usual order of bypass was anterior wall, posterior wall, and lateral wall. Surgery was converted to on-pump beating heart coronary artery bypass if hemodynamic compromise was present during the procedure.[17]

Definition

Stroke definitions were according to the routine guidelines,[1–13] and included any focal or global neurologic deficits lasting for more than 24 hours. A neurologist was consulted when a stroke was suspected and imaging study was arranged. Noncontrast brain computed tomography was the initial study of choice. If the patient's hemodynamic status was stable, brain magnetic resonance imaging will be arranged when the result of the initial study was negative. The imaging diagnosis of stroke was confirmed by a radiologist. Stroke was classified as early stroke when a permanent new focal neurologic deficit occurred immediately after awakening from the surgery. Delayed stroke was defined as the neurologic deficit occurring after the awaking from surgery without a neurologic deficit.[4–13] Stroke appearing after discharge was not considered in this study.

Mechanism

The mechanism of stroke was classified by clinical presentation and imaging findings.[4,6,13] There are two types of strokes: ischemic and hemorrhagic. There are three major mechanisms of ischemic stroke: thrombotic, embolic, and hypoperfusion. Hemorrhagic and thrombotic strokes are extremely rare after isolated CABG.[4,6,13] Although some cases might have mixed mechanisms, we classified the most possible mechanism of perioperative stroke into either embolic or hypoperfusion strokes.

Embolic stroke was characteristic of multiple infarcts in multiple territories and predominantly occurred in the distribution of the middle cerebral artery.[6] There are two predominant causes of embolic strokes: cardiogenic and noncardiogenic. Cardiogenic embolism may originate either from the atrium, in cases of atrial fibrillation, or from the ventricle, in cases of recent myocardial infarction or left ventricular aneurysm. Noncardiogenic embolism may originate from atherosclerotic plaque from carotid arteries, the aortic arch, or the ascending aorta.

Hypoperfusion strokes may arise from a combination of extracranial or intracranial cerebral artery stenosis and systemic hypotension.[6,13] Typically, hypoperfusion stroke in patients with carotid or cerebral artery stenosis leads to watershed or large cerebral infarcts (Fig. 1). Hypoperfusion stroke in patients with stenosis of the small penetrating