The effect of single aortic cross-clamp technique versus multiple clamp technique on postoperative stroke in octogenarians undergoing coronary artery bypass grafting

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Abstract

Aim: In this study, we aimed to investigate the effect of the single aortic cross-clamp technique (SCT) (aortic cross-clamp only) versus the multiple-clamp technique (MCT) (aortic cross-clamp + side-biting clamp) on postoperative stroke in octogenarians undergoing coronary artery bypass grafting (CABG).

Methods: A total of 171 patients aged 80 years and older who underwent isolated CABG were retrospectively analysed. The patients were divided into two groups according to the technique used during surgery: group 1 ($n = 88$) received the SCT, and group 2 ($n = 83$) received the MCT. Postoperative stroke was evaluated.

Results: Of the patients, 127 were men and 44 were women. The mean age was 83.05 ± 8.81 years in group 1 and 82.14 ± 8.92 years in group 2. There was no statistically significant difference in the rate of postoperative stroke between the two techniques ($p > 0.05$).

Conclusion: Postoperative stroke in octogenarians may result from not only the cross-clamp technique used but also several other factors. We found that both techniques yielded similar outcomes.

Keywords: octogenarians, aortic clamping, stroke, coronary artery bypass grafting

Over the last couple of decades, coronary artery bypass grafting (CABG) has been increasingly performed in octogenarians as the population ages.1 The incidence of cerebrovascular events following surgical coronary revascularisation ranges between one and 2.5%, which is remarkable.2 This proportion seems to be three-fold higher in elderly individuals.3 Irrespective of the age of the patient, neurological events dramatically increase mortality and morbidity rates after CABG.

Ischaemic stroke following CABG is a multifactorial disease. The main predictor of peri-operative stroke is previous stroke or transient ischaemic attack and cerebral thromboembolism originating from the aorta, aortic branches or the heart itself, most frequently resulting from micro- and macro-embolism if it is associated with the cardiopulmonary bypass (CPB) procedure.3 Aortic manipulation and cross-clamping during CABG have been thought to play a critical role in the mechanism of embolism formation in patients with atherosclerosis of the ascending aorta.4

In the technique described by Salerno,5 distal and proximal anastomoses are constructed during a single period of total aortic occlusion, reducing the risk of embolism during aortic manipulation. However, the single aortic cross-clamp technique (SCT) is associated with prolonged cross-clamping, increasing the risk of cardiac and cerebral air or particle embolisation.4

In the literature, while the importance has been emphasised of identifying and understanding pre-operative risk factors and co-morbidities for neurological complications, the aortic cross-clamp technique has been reported to be an important operative risk factor. Among the strategies developed to minimise trauma and therefore neurological complications in clamping the aorta, the benefits of using the single-clamp technique rather than the double-clamp technique, which requires the use of an aortic cross-clamp and side-bite clamp, have been supported.6,7

In this study, we hypothesised that intra-operative aortic manipulation would adversely affect elderly patients due to advanced aortic atherosclerosis. Therefore, we aimed to investigate the effect of SCT versus the multiple-clamp technique (MCT) on postoperative stroke in octogenarians undergoing isolated CABG.
Methods
This single-centre, retrospective study was conducted at the Department of Cardiovascular Surgery of Mersin City Training and Research Hospital between January 2016 and January 2020. Medical data of a total of 171 patients aged 80 years and older who underwent isolated CABG were retrospectively reviewed. The patients were divided into two groups according to the technique used during surgery: group 1 (n = 88) received the SCT and group 2 (n = 83) received the MCT.

All of the patients underwent pre-operative carotid artery colour Doppler ultrasonography. Patients with bilateral severe carotid bifurcation stenosis, a previous history of stroke or transient ischaemic attack, valvular lesions, ventricular aneurysms, single-vessel disease, pre- or postoperative atrial arrhythmia or intraoperative haemodynamic instability, and those scheduled for combined surgery (carotid endarterectomy + CABG) due to severe carotid artery disease were excluded.

Postoperative stroke was defined as a major neurological deficit of vascular origin presenting with global or focal dysfunction of longer than 24 hours. The diagnosis of stroke was confirmed by a neurologist based on postoperative computed tomography (CT) and magnetic resonance imaging (MRI) findings.

Written informed consent was obtained from each patient. The study protocol was approved by the Ministry of Health Mersin Provincial Health Directorate local ethics committee (02.04.2019/24). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All of the operations were performed by two cardiovascular surgeons. The patients underwent sternotomy with a midsternal incision. Once the aorta was reached, aortic calcifications and plaques were identified by palpation. Before CPB, anticoagulation was administered with 300 IU/kg heparin. During CPB, additional doses of heparin were administered to maintain an activated clotting time of > 400 s.

Aortic cannulation was applied to the distal segment of the ascending aorta below the innominate artery. For proximal anastomosis, an antegrade cardiopulmonary cannula was inserted into the most suitable side of the ascending aorta. Following two-stage venous cannulation, CPB was initiated. Myocardial protection was achieved by antegrade cold-blood cardiopulgia and moderate systemic hypothermia (28–32°C). Using the single-thread suture technique, distal and proximal anastomoses were performed. For proximal anastomoses, a side-biting clamp was used in the patients in whom MCT was applied.

Statistical analysis
Statistical analysis was performed using SPSS software, version 13.0 for Windows (SPSS Inc, Chicago, IL, USA). Descriptive data are expressed as the mean ± standard deviation (SD), median (min–max) or number and percentage. The Student’s t-test was used to compare normally distributed quantitative data, while the Mann–Whitney U-test was used to compare non-normally distributed quantitative data between the groups. The chi-squared test and Fisher’s exact chi-squared test were performed to compare qualitative data between the groups. A p-value of < 0.05 was considered statistically significant at the 95% confidence interval.

Results
Of the patients, 127 were men and 44 were women. The mean age was 83.05 ± 8.81 years in group 1 and 82.14 ± 8.92 years in group 2. All of the patients were operated on under CPB. The baseline demographic and clinical characteristics of the patients are shown in Table 1. The mean cross-clamp time was significantly longer in group 1 than in group 2 (p < 0.001) (Table 2). However, there was no statistically significant difference in the mean CPB time between the groups (p > 0.005). The mean number of grafts was 2.82 in group 1 and 2.98 in group 2. The ratio of cross-clamp time to the number of grafts was significantly higher in group 1 than in group 2 (p < 0.001).

Stroke was seen in one patient (1.13%) in group 1 and one patient (1.20%) in group 2, indicating no statistically significant difference between the groups (p > 0.005). In addition, two patients died from stroke, one in each group, indicating no significant difference in the mortality rate between the groups (p > 0.005).

The mean length of intensive care unit stay was significantly shorter in group 2 than in group 1 (p = 0.001); however, there was no significant difference in the mean length of hospital stay between the groups (p = 0.122) (Table 3). One patient in group 1 was diagnosed with stroke in the early postoperative period. Another patient in group 2 developed postoperative stroke and associated symptoms on the second day after surgery (Table 4). The number of patients undergoing urgent operations was significantly higher in group 2 (p = 0.008). There was

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**Table 1. Baseline demographic and clinical characteristics of the patients**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group 1 (n = 88)</th>
<th>%</th>
<th>Group 2 (n = 83)</th>
<th>%</th>
<th>Statistic of test; p-value</th>
</tr>
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<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<tr>
<td>Female</td>
<td>23</td>
<td>26.1</td>
<td>21</td>
<td>25.3</td>
<td>χ² = 0.001;</td>
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<tr>
<td>Male</td>
<td>66</td>
<td>75</td>
<td>61</td>
<td>74.9</td>
<td>0.980</td>
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<tr>
<td>Age, years</td>
<td>83.05 ± 8.81</td>
<td></td>
<td>82.14 ± 8.92</td>
<td></td>
<td>χ² = 0.001;</td>
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<tr>
<td>Diabetes mellitus</td>
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<td></td>
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<tr>
<td>yes</td>
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<td>34.9</td>
<td>38</td>
<td>45.7</td>
<td>χ² = 6.135;</td>
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<tr>
<td>no</td>
<td>58</td>
<td>65.1</td>
<td>45</td>
<td>54.3</td>
<td>0.012*</td>
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<tr>
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<td>67</td>
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<td>73</td>
<td>87.9</td>
<td>χ² = 7.236;</td>
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<tr>
<td>no</td>
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<td>23.8</td>
<td>17</td>
<td>12.1</td>
<td>0.007**</td>
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<tr>
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<td>22</td>
<td>26.5</td>
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<tr>
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<td>72</td>
<td>88.9</td>
<td>61</td>
<td>73.4</td>
<td>0.064</td>
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<tr>
<td>Chronic renal failure</td>
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<td></td>
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<tr>
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<td>98.8</td>
<td>82</td>
<td>98.7</td>
<td>1.000</td>
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<tr>
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<td>1.1</td>
<td>6</td>
<td>7.2</td>
<td>χ² = 7.123;</td>
</tr>
<tr>
<td>no</td>
<td>87</td>
<td>98.9</td>
<td>77</td>
<td>92.8</td>
<td>0.008**</td>
</tr>
</tbody>
</table>

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**Table 2. Intra-operative data**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group 1 (n = 88) Mean ± SD</th>
<th>Group 2 (n = 83) Mean ± SD</th>
<th>Statistic of test; p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of grafts, n</td>
<td>2.82 ± 0.50</td>
<td>2.98 ± 0.56</td>
<td>U = 11316.6; 0.001**</td>
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<tr>
<td>Cross-clamp time, min</td>
<td>58.30 ± 14.40</td>
<td>39.08 ± 14.11</td>
<td>U = 5008.9; 0.001**</td>
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<tr>
<td>Cross-clamp time/graft number ratio</td>
<td>21.15 ± 6.11</td>
<td>12.15 ± 6.01</td>
<td>U = 3001.0; 0.001**</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time, min</td>
<td>75.39 ± 20.12</td>
<td>73.58 ± 18.01</td>
<td>U = 12798.4; 0.383</td>
</tr>
</tbody>
</table>

SD: standard deviation.
no statistically significant difference in incidence of diabetes mellitus, congestive heart failure or hypertension between the groups ($p = 0.012, 0.064$ and $0.007$, respectively).

**Discussion**

In recent years, the evaluation of surgical outcomes after CABG in elderly individuals has gained importance. In our study, we included octogenarians who were definitely high-risk cases for CABG and investigated the effect of SCT versus the double-clamp technique (DCT) on postoperative stroke. Although there have been many studies investigating the effect of aortic cross-clamp techniques on postoperative stroke, to the best of our knowledge, we present one of the rare studies involving only octogenarians. Our study results showed that both techniques yielded similar outcomes regarding incidence of postoperative stroke in octogenarians undergoing open-heart surgery.

Following open-heart surgery, neurological complications increase morbidity and mortality rates, leading to catastrophic results for some patients and surgeons. Advanced age has been shown to be an independent risk factor associated with increased mortality of up to 15.9% and increased morbidity rates. The incidence of postoperative stroke has been reported to be one to 5% in published studies, and this rate can increase up to 9% in patients aged 75 years and older. In the Framingham Heart Study, aortic calcification, as evidenced by imaging modalities, increased stroke risk 3.5-fold in 65-year-old and older patients.

In the literature, there are studies recommending SCT for proximal and distal anastomoses in CABG to reduce neurological complications. Aranki et al. reported that SCT reduced in-hospital mortality and brain injury rates. In another study, Marshall et al. showed that the majority of embolisations occurred during aortic manipulation, particularly during removal of the aortic cross-clamp. Other authors also reported that the double clamp, on-pump strategy had a 2.5-fold increased risk of postoperative stroke compared with the SCT, even after controlling for epicardial grade.

Regarding trends in aortic clamp use during CABG surgery and the effect of aortic clamping strategies on neurological outcomes, aortic cross-clamping and manipulation are known risk factors for neurological complications. The factors that increase stroke risk include atherosclerotic disease involving the ascending aorta and intra-operative hyperperfusion. Therefore, the less often that aortic cross-clamps are used, the more neurological complications are avoided.

In a study, Us et al. observed no neurological complications with SCT, while the rate of neurological complications was significantly higher in patients in whom partial cross-clamping was applied. In addition, Güden et al. recommended using SCT to minimise possible aortic embolisation and prevent neurological complications in patients undergoing CABG. Conversely, Musumeci et al. found in their study that SCT was not effective in the prevention of myocardial ischaemia and neurological complications. McKhann et al. reported that previous cerebrovascular accidents and carotid lesions were the main risk factors for stroke after CABG. In another study, Grega et al. found the stroke rate to be 1.1 and 2.9% in patients undergoing SCT and DCT, respectively.

In contrast to the hypothesis that the incidence of aortic embolism could be reduced by avoiding manipulation with a second clamp, the SCT has been proposed to prolong the cross-clamp time and open the closed system, leading to cardiac or cerebral air embolism risks. However, some authors who recommend using the SCT have claimed that this technique allows for a more uniform cardioplegic delivery during anastomosis of the grafts and immediate myocardial reperfusion when the cross-clamp is released. Those who recommend using the DCT however have argued that none of the techniques are better than the early removal of the aortic cross-clamp and that DCT allows for the immediate use of the internal mammary artery for perfusion.

SCT indicates only one potential factor and is overshadowed by the effects of other potential causes of stroke. More importantly, SCT itself does not solely explain cerebral protection and stroke, and a multifactorial approach is needed to prevent post-CABG stroke and cerebrovascular accidents. Embolic material might depend not only on the side-biting clamp but could also result from the cross-clamp itself, CPB-related jet perfusion, aortic cannulation, and aortic punch. None of these sources of emboli would be affected by the application of a side-biting clamp.

A study demonstrated that the investigation of atherosclerotic lesions through epicardial scanning before aortic manipulation and cannulation could be helpful to reduce stroke risk. In their study, Uyar et al. utilised intra-operative ultrasonography to detect plaques located in the ascending aorta and concluded that this was the best method for preventing neurological complications due to possible embolisations from the aorta.

Previous studies have shown improved morbidity outcomes following off-pump CABG in high-risk patients with lower cardiac, pulmonary and renal complications and bleeding, shorter lengths of hospital stay, fewer neurological complications and lower costs. Conversely, Tugtekin et al. performed on- and off-pump CABG in 344 and 237 octogenarians, respectively. They found similar morbidity and mortality rates in both groups; however, lower morbidity in the on-pump CABG group was attributed to relatively short cross-clamping and perfusion times. In another study, prolonged aortic cross-clamp time was associated with unfavourable postoperative outcomes in elderly individuals.
Due to the increased incidence of arteriosclerosis of the ascending aorta, neurological complications, such as CABG-related stroke, are a major concern in octogenarians. During off-pump surgery, cross-clamping and aortic cannulation are avoided to reduce the stroke risk due to decreased manipulation of the ascending aorta. Off-pump surgery offers a no-touch technique and therefore reduces the incidence of stroke by 78%.  

In this study, 88 octogenarian patients underwent CABG with SCT (group 1) and 83 patients underwent CABG with MCT (group 2). One patient in each group (1.13% in group 1 and 1.20% in group 2) developed postoperative stroke, indicating no statistically significant difference between the groups (p > 0.005). In addition, one patient in each group died, indicating similar mortality rates between the groups (p > 0.005).

Several authors have reported that cerebral micro-embolisation during CPB mostly occurs during aortic cannulation and insertion and removal of the aortic cross-clamp. However, it is difficult to identify the true source of embolism since atherosclerosis of the ascending aorta and carotid and cerebral arteries themselves can result in cerebral embolism. In an autopsy study of 1,486 patients, Sterney reported that severe atherosclerotic disease was more frequently located in the aortic arch and descending aorta.

There were some limitations to this study. First, it had a retrospective design with a relatively small sample size. Second, it had a single design that precluded the generalisation of the findings. Third, we were unable to identify the aetiology of stroke and whether it was caused by thrombosis, embolism or hypoperfusion in each individual patient. Further large-scale, prospective studies are needed to confirm these findings.

Conclusion

Stroke is a major concern in elderly individuals who undergo open-heart surgery. It not only could result from cross-clamping, but there are also several factors playing a role in its aetiology. Existing data on stroke have yielded conflicting results regarding the use of the SCT and MCT. Therefore, the selection of alternative treatment methods, such as CABG on a beating heart, to be used on an individual basis, might reduce the stroke rate, particularly in elderly individuals. Based on our study results, both the SCT and MCT yielded similar outcomes, and there is no additional contribution to the comfort of the surgeon or the quality of life of patients.

References


