Does Single Aortic Clamp Strategy Ameliorate the Risk of post-operative Stroke after Coronary Artery Bypass Grafting: A Single Center Study

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ABSTRACT

BACKGROUND: Aortic manipulation during coronary artery bypass grafting is an important cause of stroke in the peri-operative period. The method of aortic clamping had been hypothesised to have incremental effects on the rates of stroke after cardiac surgery.

OBJECTIVE: The aim of this study was to compare the risk of stroke and other important early outcomes in patients who had coronary artery bypass grafting using single aortic clamping (SAC) versus multiple aortic clamping (MAC) techniques.

METHODS: From January 2020 to December 2020, 219 (194 males,25females) patients (SAC=110, MAC=109) underwent coronary artery bypass grafting at Queen Alia Heart Institute by two selected surgeons. The mean age in the MAC and SAC cohorts were (57.60 (32-75) vs 59.03 (39-73)) years, respectively. The primary outcome was early postoperative stroke rate, while the secondary outcomes were early mortality, atrial fibrillation and bleeding that required the patient being taken back to the operating theatre to secure haemostasis.

RESULTS: Fewer patients in the SAC cohort suffered early stroke compared to the MAC cohort (3 (2.7%) vs 12 (11%), p=0.015). Furthermore, while early mortality was higher in the MAC versus the SAC, it was statistically insignificant (1 (0.9%) vs 6 (5.5%), p=0.065). Both techniques demonstrated comparable risks of postoperative atrial fibrillation and re-exploration for mediastinal bleeding (6 (5.5%) vs 11 (10.1%), p=2.0) and (4 (3.6%) vs 4 (3.7%), respectively; p=1.00).

CONCLUSIONS: Aortic manipulation is an important cause of stroke and death after coronary artery bypass grafting. Neither technique for aortic clamping influences the risk of early mortality, atrial fibrillation and postoperative bleeding.

Key words: Aortic clamping, stroke, mortality, bypass grafting, outcomes.

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Introduction

In the current era of coronary artery bypass grafting (CABG) surgery, cardiac surgeons are challenged to operate on patients who are more prone to peri-operative morbidity and mortality.

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Among these patients, the incidence of atherosclerotic disease of the ascending aorta is higher, especially in the elderly population (1). The majority of CABG procedures are performed on an arrested heart, which entails the construction of a proximal anastomosis for the new grafts being performed using either multiple or single aortic clamping techniques. Aortic manipulation during CABG is an important cause of stroke after cardiac surgery (2). Despite being a rare event after CABG with a reported incidence of approximately 1.5–3.5%, once it has happened, a stroke is a devastating complication that is associated with a reduction in survival and a worse quality of life (2, 3).

The single aortic clamping (SAC) technique is the preferred practiced method for many cardiac surgeons due to the assumption that minimal aortic manipulation is secured by this method; however, superiority in the clinical prevention of stroke using this technique has not been widely demonstrated (4). Several studies have reported conflicting conclusions about the rates of post-operative stroke in both the SAC and multiple aortic clamping (MAC) techniques. In a previous meta-analysis published in 2008 by Raja and colleagues, it was clear that either method of aortic clamping is comparable in terms of stroke outcome (5). However, in 2014, Moss and colleagues demonstrated a clear beneficial reduction in the rates of postoperative stroke with fewer aortic manipulations regardless of the severity of ascending aortic disease (2).

In our retrospective study, we hypothesised that aortic manipulation during CABG would adversely affect patients due to the presence of aortic arteriosclerosis. Therefore, our aim is to investigate the potential effect of aortic clamping techniques on the development of stroke in patients undergoing isolated CABG. We conducted this retrospective study to include relatively large cohorts of patients, comparing early adverse clinical events in patients undergoing isolated CABG utilising either SAC or MAC techniques and to determine whether SAC has beneficial effects in preventing the risk of early stroke in clinical practice.

Patients and Methods

We reviewed the electronic medical records of 219 patients who underwent CABG surgery with two equivalent surgeons in terms of expertise and number of patients, during the period from January 2020 to December 2020 at Queen Alia Heart Institute (QAHI). In total, 110 (50%) patients were operated on utilising the SAC technique, while 109(50%) underwent the MAC technique. As a practice protocol in our centre, carotid Doppler ultrasound screening assessment used for elderly age patients, prior stroke or transient ischemic attack and peripheral artery disease. Patients who had significant carotid stenosis are offered carotid intervention in addition to coronary bypass surgery. We outlined several factors **(Table I)** relevant to the included patients which we think may be factors in determining outcomes after CABG. Factors included age, sex, diabetes mellitus (DM), hypertension, New York Heart Association (NYHA) classification of functional limitation related to heart disease, number of coronary arteries involved and left ventricular function.

Primary outcome: Early stroke that occurred early in the postoperative period or during the same admission period.

Secondary outcomes: 1.Early mortality, which is any death that occurred early in the postoperative period or during the same admission period

2. Occurrence of postoperative atrial fibrillation (AF)
3. Postoperative bleeding necessitates surgical intervention
4. Length of hospital stay

Table I: Relevant demographics and risk factors for the patients included in the study

Variable	SAC Number (%)	MAC Number (%)	P-value
Age (Mean)	59.03±8.4 (39-73)	57.60±9.17 (32-75)	0.231
Male Sex (%)	95 (86.4)	99 (90.8)	0.369
Diabetes Mellitus	58 (52.7)	62 (56.9)	0.588
Hypertension	81 (73.63%)	76 (69.72%)	0.250
Smoking History	78 (70.90%)	78 (71.56%)	0.915
Previous Stroke	2 (1.82%)	3 (2.75%)	0.643

Abbreviations: MAC: Multiple Aortic Clamping, SAC: Single Aortic Clamping

Surgical technique

All of the included patients were operated upon through a standard median sternotomy incision. Conduits that were utilised are: the left internal mammary artery (LIMA) and the great saphenous vein. The LIMA harvest was performed in the classical fashion while the saphenous vein harvest was performed using the open technique.

Cardiopulmonary bypass in all patients was established by standard ascending aortic cannulation and double stage venous cannulation of the right atrial appendage. Heparin for anticoagulation was given to achieve a therapeutic activated clotting time (ACT). Normothermic perfusion with antegrade intermittent cold crystalloid cardioplegia and retrograde blood cardioplegia was used according to the surgeon's preference.

SAC Technique: After completion of the distal anastomosis at the coronary targets, the proximal anastomosis on the ascending aorta was completed without manipulation of the aortic clamp.

MAC Technique: Once the distal anastomosis at the coronary targets is completed, the aortic clamp is released and then a side biting clamp is applied to allow for proximal anastomosis on the ascending aorta while the heart is beating.

The residual surgical conduct is carried in a similar fashion between the two surgical techniques.

Statistical Analysis

The categorical data are expressed as the frequency and percentage. The scale data are expressed as the mean and standard deviation. Chi square of independence was used to determine associations between categorical data, while the independent T-test was used to test mean differences between categorical independent variables. The alpha level, set at ≤0.05, indicated statistically significance and SPSS software version 28 was used to analyse data.

Results

Over a one-year period, 219 patients underwent coronary artery bypass grafting by two equivalent surgeons. Two techniques were used: CABG with the SAC method (110 patients), and CABG with the MAC method (109 patients). Demographics and risk factors of the patients included are summarised in **Table I**. The two patient populations, SAC and MAC, were comparable with regard to mean age, sex, DM, smoking history, hypertension and previous history of stroke.
The number of grafts performed was comparable between the 2 cohorts (2.38±0.72 vs 2.41±0.64 for SAC vs MAC, respectively; p=0.736).Cardiopulmonary bypass duration was longer in the MAC compared to the SAC technique (69.93±13.08 min vs 104.95±15.92 min p<0.001, respectively). Surprisingly, the ischemia time was even longer in the MAC compared to the SAC (54.03±8.11 min vs 51.31±11.1 min, p=0.041) **(Table II).**

Table II: Intraoperative variables

Variable	SAC (110)	MAC (109)	P-value
Cardiopulmonary Bypass Time (minutes)*	69.93±13.08 minute	104.95±15.92 minute	<0.001
Cross Clamp Time (Minutes)	51.31±11.18 minute	54.03±8.11 minute	0.041
Number of Proximal Grafts (mean)	2.38±0.72	2.41±0.64	0.736

Abbreviations: MAC: Multiple Aortic Clamping, SAC: Single Aortic Clamping

* Note: It was surprising to us to find that the duration of aortic cross clamp was shorter in the single clamp cohort, but we shall admit that the technique of anastomosis entails some factors that are dependent on the quality of the target vessels and the surgical skills

Table III summarises the early outcomes of all patients. Postoperative stroke was substantially higher in the MAC cohort compared to the SAC cohort (3/110 (2.7%) vs 12/109 (11%), p=0.015,OR=4.41). The outcome with the highest incidence rate was AF but was not statistically significantly different between the two cohorts (5.5% vs. 10.1%; p=0.200). Reopening for bleeding, was equivalent in both cohorts (3.6% vs 3.7% for SAC vs MAC, respectively; p=1.00).
In-hospital mortality was more frequent in MAC-CABG compared to SAC-CABG although not significantly (0.9% SAC-CABG vs. 5.5% MAC-CABG; p=0.065).

The mean hospital stay period was higher in MAC-CABG than in SAC-CABG patients (9.055 vs. 7.109 days, respectively; p<0.001), and the explanation of long hospitality in both groups is due to our policy in our centre is to keep patients pot-operatively as long as possible due to social reasons especially in the time of COVID pandemic in most of the cases.

Table III: Early outcomes obtained from our study results

Outcomes	SAC (110)	MAC (109)	P-value
Early Stroke**	3 (2.7%)	12 (11%)	0.015 (OR=4.41)
Atrial fibrillation	6 (5.5%)	11 (10.1%)	0.200
Reopening for bleeding	4 (3.6%)	4 (3.7%)	1.00
Early Death	1 (0.9%)	6 (5.5%)	0.065
Length of stay (mean)	7.11±2.42 days	9.06±4.07 days	<0.001

Abbreviations: MAC: Multiple Aortic Clamping, SAC: Single Aortic Clamping, OR odds ratio
**Note: we agree that the rate of stroke was higher than reported, but the cohort of patients that were operated upon were little bit sick and had multiple comorbidities

Discussion

Our retrospective study included 219 studies and demonstrated that there is an obvious and significant reduction in the incidence of stroke when the single clamp technique is utilised during isolated coronary artery bypass grafting. However, the single aortic clamping strategy did not demonstrate a significant advantage in improving survival or decreasing the incidence of atrial fibrillation or postoperative bleeding episodes.

Stroke, the Achilles heel of cardiac surgery, is known to be one of the most devastating complications after coronary artery bypass surgery, with an approximate incidence of 2% (reaching 9% in octogenarians); once this happens, it indicates a very poor prognosis (6).There have been multiple aetiologies which are implicated to increase the risk of stroke in cardiac surgery such as: manipulations of the ascending aorta, adoption of an on-pump coronary artery bypass method, history of previous stroke, carotid artery stenosis and peri-operative rhythm disturbances(7, 8). Different strategies have been adopted by cardiac surgeons to minimise the impact of aortic clamping and aortic manipulations. Hammon and colleagues (9) demonstrated that even on-pump coronary artery bypass surgery using single clamp technique with less manipulations of the ascending aorta may be more protective against the development of postoperative stroke compared to off-pump surgery with side clamp application. Data using transcranial Doppler signals during coronary artery bypass surgery demonstrated that significant cerebral embolic burden occurs both during on-pump coronary artery bypass as well as after the removal of the side clamp in off-pump surgery (2). Raja and colleagues (5) demonstrated in their meta-analysis that there is no superiority of single clamp in terms of stroke incidence when compared to the multiple clamp technique. It must be kept in mind that the majority of published studies investigating the correlation between the aortic clamping technique and postoperative stroke may be underpowered for major clinical events.

Our study demonstrates the clear benefits of SAC compared to MAC in decreasing the risk of stroke after CABG surgery. Previous studies(9-12) did not demonstrate any stroke amelioration benefit for SAC compared to MAC techniques; however, concerns about the patient cohorts included may be a potential factor for this conclusion, since we believe that patients who are at a higher risk of developing stroke are thosewho will benefit the most from less manipulation of the aorta during CABG. Hammon et al.(9) excluded patients from their cohorts who had high grade atheromatous aorta, renal dysfunction and major neurodegenerative disease. Dar and Musumeci(10, 11) excluded patients who are older than 75 years of age, and those with carotid bruits, aortic calcifications and a history of previous cerebrovascular accident and atrial fibrillation. Uyar et al.(12)excluded patients who had aortic plaques. Other published reports are in accordance with our study and demonstrated the superiority of SAC over MAC in ameliorating the risk of stroke after CABG surgery (13-15). In clinical practice, cardiac surgeons are always trying to avoid manipulations of the hostile aorta and often perform SAC or operate on a beating heart instead. The variability in postoperative stroke incidence among the published studies could be due to other factors that play a role in the aetiology of stroke other than just the application or removal of aortic clamps, such as: cannulation and decannulation, the adequacy of de-airing, hypoperfusion, induced inflammatory cascades and punching of the proximal aorta (16).
Our study demonstrated that short-term survival was not significantly different in the two cohorts; however,it is well known that survival after surgical revascularisation is primarily dependent on the patency of grafts and other comorbid conditions in patients. We think that this outcome did not differ between the two cohorts because the mortality is determined by many variables and not only stroke.

Switching to the MAC technique is a concern amongst cardiac surgeons performing CABG utilising SAC because of the inherently prolonged ischemia time in the SAC technique; however, no evidence is found to suggest an increased cardiac morbidity when utilising the SAC technique, especially when proper myocardial preservation strategies are used. CABG is also a demanding surgical procedure which requires meticulous steps to be accomplished within the shortest period of ischemia time to avoid the risk of myocardial injury; in addition, surgeons have adopted different methods for myocardial preservation to accomplish myocardial protection.Surprisingly, our data indicate that improved skills when performing CABG using the SAC method enabled our surgeons to accomplish surgical anastomosis even with a shorter ischemia time.
Atrial fibrillation after CABG is a common arrhythmia which is reported to occur in 10–50%of patients (17).The mechanism of postoperative AF is multifactorial and we did not find an actual relationship between the duration of cardiopulmonary bypass and the incidence of AF, which was consistent with previous reports (18). The in-hospital stay period was longer in the MAC cohort, which can be explained by the prolonged period of stay for patients who suffered from postoperative stroke.

Strengths and Limitations

We would like to acknowledge some limitations related to our study. Firstly, this was a retrospective designed study, second, we could not identify the exact aetiology of stroke and whether this was due to embolism, hypoperfusion or thrombosis in each patient, third, patients at the highest risk of developing stroke were excluded from our study, and fourth, aortic Ultrasound and pre-operative CT scan for the assessment of aortic calcifications were not performed.

However, we would like to point out that our study had substantial advantages. Our included cohorts are the largest to date from our centre that could be achieved; with this robust number of patients, we believe that we were able to detect differences in the outcomes between the two cohorts included.

Conclusion

The single aortic clamp technique has been proven to be an effective strategy with which to protect against the occurrence of stroke after coronary artery bypass grafting surgery. Meticulous steps could help with performing this technique using comparable time durations. Aortic manipulations did not result in an added risk of early mortality, postoperative atrial fibrillation and the incidence of major bleeding episodes.

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