Original Article

Does preoperative screening with computed tomography of the chest decrease risk of stroke in patients undergoing coronary artery bypass grafting

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Background: Stroke is one of the most feared complications post coronary artery bypass with aortic calcifications being the commonest source of embolic stroke. The aim of our study was to determine the clinical impact and usefulness of routine use of plain chest computerised tomography to screen for aortic calcification on incidence of postoperative stroke in coronary artery bypass grafting (CABG) patients.

Methods: This is a retrospective case-control study that included four hundred and five patients who underwent primary isolated CABG and had preoperative plain chest computerised tomography as a screening for aortic calcification. Aortic calcification was classified according to the area involved (ascending, arch, arch vessels and descending aorta) and the pattern of calcification. Patients were divided into two groups according to the incidence of postoperative stroke and the aortic calcification distribution was compared between the two groups. Stroke predictors were studies using univariate and multivariate regression analysis.

Results: Fourteen patients (3.5%) developed postoperative stroke. There was no difference in preoperative and operative characteristics between patients who developed postoperative stroke and those who did not, except for the history of preoperative stroke or transient ischemic attack (TIA) that was higher in the group who developed postoperative stroke (50.00% *vs.* 6.19%, $P<0.001$). Patients who developed postoperative stroke had higher percentage of aortic root calcification (78.57% *vs.* 64.18%), ascending aortic calcification (28.57% *vs.* 19.07%) and descending aortic calcification (85.71% *vs.* 73.71%) but none of them reached statistical significance. History of preoperative stroke or TIA was the only significant predictor of postoperative stroke using both univariate and multivariate regression models.

Conclusions: Our study showed the importance of preoperative computed tomography (CT) scan of the chest as a screening tool as it detected a high prevalence of aortic calcification in our patients. However, its impact on prevention of postoperative stroke needs to be investigated further in future prospective studies.

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Introduction

Stroke is one of the most feared complications post coronary artery bypass grafting (CABG) occurring in up to 5% of patients (1,2) and leading to 20% mortality rate or permanent disability (3,4). The majority of postoperative strokes are embolic in nature with aortic calcifications being the commonest source of embolic stroke (5,6). A number of studies showed that the correlation between aortic calcification and postoperative stroke is dependent on the location and extent of the calcification with risk of stroke as high as 31% in cases of extensive circumferential ascending aortic calcification (porcelain aorta) (2,7-9).

Non-contrast chest computed tomography (CT) was advocated by many studies as a screening method for aortic calcification in Cardiac surgery patients to guide operative planning (10-14). However, given the limitations of non-contrasted CT of the chest and the questionable cost-effectiveness of its routine use as a screening test, there is still low utilization of this modality as a preoperative test in cardiac surgery patients.

Hence, the aim of our study was to determine the clinical impact and usefulness of routine use of plain chest CT to screen for aortic calcification on incidence of postoperative stroke in CABG patients. We present the following article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-22-1047/rc).

Methods

Study design and data collection

This is a retrospective case-control study that was conducted at a tertiary cardiac centre. It included all adult patients who underwent elective primary isolated CABG between 2012 and 2019 and had a preoperative plain CT of the chest (*Figure 1*). All procedures were performed with the use of cardiopulmonary bypass (CPB) with a single clamp technique and both arterial and venous grafts were used with central anastomoses of the venous graft to the ascending aorta. Patient who had redo, combined or emergency procedures were excluded. Patient data were collected from electronic medical records, including patients' demographics, preoperative, operative and postoperative characteristics as well as follow-up data. Stroke was defined according to Definition of the Society of Thoracic Surgeons database criteria for permanent stroke as: a central neurologic deficit with an event residual greater than 72 hours, which is confirmed by head CT, head magnetic resonance imaging (MRI). Neurologic deficits such as confusion, delirium, encephalopathic events, or transient ischemic attacks (TIAs) were excluded. The patients were divided into two groups according to the incidence of postoperative stroke.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Institutional Review Board of King Saud University Medical City (No. E-19-4174) approved this study and waived the need for patients' consent because of the retrospective nature of the study.

Computerized tomography scans

Our standard protocol was to perform plain chest CT of the neck, chest, abdomen and pelvis 24–48 hr prior to surgery routinely in all elective patients older than 60 years or those younger than 60 years who had severe uncontrolled diabetes mellitus (DM) or severe peripheral vascular disease (PVD). All CT data and images were retrieved from the picture archiving and communication (PACS) system and reviewed by an expert radiologist for the purpose of this study. The calcifications were detected according to their density represented by white colour and measured Hounsfield units that is above 60 HU on unenhanced CT. The severity of calcification is usually measured by quantifying the volume and measured Hounsfield units of the calcium as performed with routine calcium scoring studies, however the exams need to be ECG gated and acquired in small field of view in order to quantify the severity which is not the case in our exams; instead we used the following three

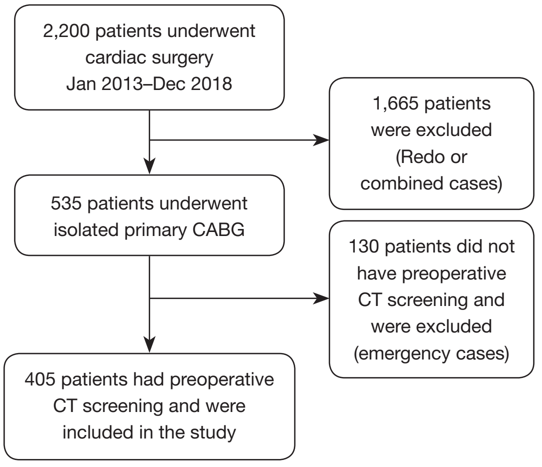

Figure 1 Flow diagram for patient inclusion in the study. CABG, coronary artery bypass grafting; CT, computed tomography.

subjective categories: focal (spotty), circumferential (ring of calcified plaque) and diffuse (involving multiple locations and can be spotty or circumferential). Additionally, the extent and location of calcification were also described as following: aortic root (including aortic valve, annulus and sinus of Valsalva), ascending aorta (from sino-tubular junction to the beginning of the origin of the innominate artery), aortic arch/arch branches (from beginning of the origin of innominate artery to the end of origin of left subclavian artery), descending thoracic aorta (from the end of the origin of left subclavian artery to the diaphragm and abdominal aorta (from the diaphragm to Aortic bifurcation). Distribution and different patterns of calcifications were compared between the two groups (stroke *vs.* no stroke) and were included in the univariate and multivariate regression.

Statistical analysis

Continuous patients' characteristics were reported using the mean and standard deviation if normally distributed and median and (25^{th}–50^{th} percentiles) if non-normally distributed. Categorical variables were reported as numbers and percentages. Comparison of continuous data was performed using the student *t*-test or the Mann-Whitney test and categorical data were compared using the Chi-squared or Fisher exact test when appropriate. Stroke predictors were studied using univariable and multivariable logistic regression analysis. Stepwise logistic regression with backward elimination was used and a P value of 0.1 was required to be included in the final model. Factors with a P value of 0.25 or less in the univariable analysis were included in the multivariable analysis. Collinearity for variables included in the multivariable regression was tested with variance inflation factor. Statistical analysis was performed using Stata 16.1 (Stata Corp, College Station, TX, USA).

Results

Patients' demographics and clinical characteristics

The study included four hundred and five patients who had preoperative chest CT screening for aortic calcification. Surgery was cancelled for three patients who had extensive circumferential ascending aortic calcification (porcelain aorta). Four hundred and two patients who underwent isolated primary CABG were included in the analysis. Fourteen patients (3.5%) developed postoperative stroke. There was no difference in preoperative and operative characteristics between patients who developed postoperative stroke and those who did not develop it (*Table 1*) except for the history of preoperative stroke or TIA that was higher in the group who developed postoperative stroke (50.00% *vs.* 6.19%, P<0.001). The stroke group had longer hospital stay than the group who did not develop stroke.

Aortic calcification patterns

A significant percentage of patients had aortic calcifications involving most of the aortic components including aortic root (78.57% *vs.* 64.18%), ascending aorta (28.57% *vs.* 19.07%) and descending aorta (85.71% *vs.* 73.71%) in those who had stroke *vs.* those who did not have stroke respectively (*Table 2*).

Predictors of postoperative stroke

Univariate regression analysis was performed to study the predictors of postoperative stroke (*Table 3*). The model included preoperative and operative characteristics, postoperative atrial fibrillation (AF) and aortic calcification patterns. History of preoperative stroke or TIA was the only significant predictor of postoperative stroke using both univariate and multivariate regression models (*Table 4*).

Discussion

Postoperative stroke is the most feared complication post

Table 1 Patients' characteristics

Variable	No stroke (n=388)	Stroke (n=14)	P value
Male, n (%)	318 (81.96)	12 (85.71)	>0.99
Age (years), median [range]	65 [62–71]	69 [66–73]	0.053
DM, n (%)	311 (80.20)	12 (85.71)	>0.99
HTN, n (%)	317 (81.70)	14 (100)	0.14
Dyslipidaemia, n (%)	153 (39.43)	5 (35.71)	>0.99
CKD/ERD, n (%)	23 (5.93)	0 (0)	>0.99
History of stroke or TIA, n (%)	24 (6.19)	7 (50.00)	<0.001
PVD, n (%)	15 (3.86)	0 (0)	>0.99
Carotid disease, n (%)	17 (4.38)	1 (7.14)	0.45
Smokers, n (%)	102 (26.29)	0 (0)	0.04
Number of grafts, mean ± standard deviation	3.01±0.79	3.23±0.92	0.33
IABP, n (%)	27 (6.96)	0 (0)	>0.99
Bypass time (minutes), median [range]	93 [64–127]	78 [69–117]	0.41
Cross clamp time (minutes), median [range]	72 [36–101]	62 [0–102]	0.46
Postoperative AF, n (%)	22 (5.67)	1 (7.14)	0.51
Length of hospital stay (days), median [range]	12 [9–17]	16 [13–31]	0.01

DM, diabetes mellitus; HTN, hypertension; CKD, chronic kidney disease; ERD, end stage renal disease; TIA, transient ischemic attack; PVD, peripheral vascular disease; IABP, intra-aortic balloon pump; AF, atrial fibrillation.

Table 2 Aortic calcification patterns

Calcification	No stroke (n=388), n (%)	Stroke (n=14), n (%)	P value
Aortic root	249 (64.18)	11 (78.57)	0.40
Ascending aorta	74 (19.07)	4 (28.57)	0.49
Aortic arch	337 (86.86)	13 (92.86)	>0.99
Proximal	45 (11.59)	1 (7.14)	>0.99
Distal	336 (86.56)	13 (92.86)	>0.99
Arch branches	244 (62.89)	10 (71.43)	0.59
Innominate A.	113 (29.12)	3 (21.43)	0.77
Left carotid A.	126 (32.47)	3 (21.43)	0.56
Left subclavian A.	213 (54.89)	10 (71.43)	0.28
Descending aorta	286 (73.71)	12 (85.71)	0.53
Abdominal aorta	352 (90.72)	12 (85.71)	0.63

cardiac surgery especially in patients undergoing CABG who usually have higher risk factors for stroke such as DM, hypertension (HTN), PVD and aortic calcification. Hence investigating risk factors for stroke and studying different methods to decrease or modify their effect is of paramount importance. In this study we showed an incidence of 3.5% for postoperative stroke in isolated primary CABG patients, which is in line with reported incidence of stroke in other studies (1,2).

The prevalence of ascending aortic and arch calcification varied across studies reaching up to 38% depending on the patients' risk factors (6,15-17). A high correlation between atherosclerosis of the ascending aorta and atheroembolism during CABG surgery has been established by several studies (2,7-9). In a prospective multicentre study including more than 2,000 patients, atherosclerosis of the ascending aorta was the strongest independent predictor of stroke associated

Table 3 Univariable predictors of postoperative stroke

Variable	OR (95% CI)	P value
Gender	0.83 (0.18–3.80)	0.81
Age	1.07 (0.98–1.17)	0.11
DM	1.34 (0.29–6.24)	0.70
Dyslipidaemia	0.96 (0.31–3.01)	0.95
History of stroke or TIA	17.79 (5.46–57.93)	<0.001
Carotid disease	1.85 (0.22–15.25)	0.57
Number of grafts	1.41 (0.70–2.86)	0.33
Bypass time	1.33 (0.72–2.48)	0.36
Cross clamp time	0.99 (0.98–1.01)	0.48
Aortic root calcification	1.97 (0.54–7.20)	0.30
Ascending aorta calcification	1.69 (0.52–5.54)	0.39
Aortic arch calcification	1.97 (0.25–15.36)	0.52
Proximal aortic arch calcification	0.54 (0.70–4.21)	0.56
Distal aortic arch calcification	1.93 (0.25–15.11)	0.53
Aortic arch branches calcification	1.48 (0.45–4.79)	0.52
Innominate A. calcification	0.66 (0.18–2.42)	0.54
Left carotid A. calcification	0.57 (0.16–2.07)	0.39
Left subclavian A. calcification	2.04 (0.63–6.62)	0.23
Descending aorta calcification	2.14 (0.47–9.72)	0.33
Abdominal aorta calcification	0.61 (0.13–2.82)	0.52

OR, odds ratios; CI, confidence interval; DM, diabetes mellitus; TIA, transient ischemic attack.

Table 4 Multivariable predictors of postoperative stroke

Variable*	OR (95% CI)	P value
Age	1.10 (0.99–1.2)	0.054
History of stroke	21.01 (6.06–72.85)	<0.001
Left subclavian calcification	0.45 (0.11–1.86)	0.27

*, factors with a P value of 0.25 or less in the univariable analysis were included in the multivariable analysis. OR, odds ratios; CI, confidence interval.

with CABG (2). In the study by Bergman *et al.*, extensive atherosclerotic disease of the ascending aorta was associated with a 31% risk of post-operative stroke (7). The risk depends on the presence, location and extent of disease when the aorta is surgically manipulated. Even mild to moderate atheromatous disease of the ascending aorta and the aortic arch (intimal thickness 2 mm) is a major contributor to ischemic brain injury after cardiac surgery (18).

The prevalence of aortic calcification in our study was much higher than the ones reported in the literature with prevalence of 64% in the aortic root, 19.5% in the ascending aorta, 87% in the aortic arch, 74% in the descending aorta and 90.6% in the abdominal aorta. This could be attributed to the high prevalence of familial hypercholesterolemia in out patient population in the Arabian gulf region that is 1:112 (about 3-fold the estimated prevalence worldwide) as reported by Alhabib *et al.* (19). To our knowledge, this is the first report describing aortic calcification prevalence and distribution in such high-risk group. To our surprise, the higher prevalence in aortic calcification in this group did not translate into higher incidence of postoperative stroke in our study. This brings up the question whether discovering the presence of these aortic calcification has led to a change in operative technique or change in the site of clamp or positioning of proximal anastomoses. These data could not be captured due to the retrospective nature of the study. In our study, 3 patients with porcelain aorta who were not operated were excluded from the analysis. However, they represent a very small number that will not affect the overall results of the study from statistical point of view (to operate *vs.* not to operate). Additionally, those patients would have clear classification in the CXR or the coronary angiogram that will trigger the performance of CT scan even if there was no protocol for routine preoperative screening. Many studies recommended the routine use of preoperative chest CT scan in elective cardiac surgery to help modifying surgical technique leading to decreased risk of stroke (13,14,20). However, our findings in this study does not support this recommendation despite the high prevalence of aortic calcification in our patients. This is really critical when we consider the risk of radiation on the patients when performing CT scan as a screening tool that would include the neck, chest, abdomen and pelvis for complete aortic assessment resulting in high exposure dose.

Epi-aortic ultrasound scan has been suggested as a useful screening tool for aortic calcification but it was not used routinely in our patient population because of its multiple disadvantages including the operator dependency, the limited anatomical coverage and the poor acoustic window (21). The major drawback of epi-aortic scan, however, is its intraoperative use after sternotomy that would be too late in patients with porcelain aortas. Furthermore, several studies have shown that epi-aortic scan is inferior to CT and leads to an underestimation of the calcium burden (10,21-23).

Among all the other risk factors, the only predictor of postoperative stroke in our study was the preoperative history of stroke or TIA. This brings the possibility of other subtle risk factors such as intracerebral arterial atherosclerosis which is not investigated in most cardiac surgery studies.

Limitations

This is a retrospective study with all possible biases that it could introduce. The small number of events may have not allowed adequate regression analysis to detect the relationship between different calcification areas and their interaction or combinations with the risk of stroke. Additionally, given the retrospective nature of the study, we could not capture the data about planning decisions that were made based on the calcification data obtained from the chest CT and how it has impacted the overall incidence of stroke in this group of patients.

Conclusions

Our study showed the importance of preoperative CT scan of the chest as a screening tool as it detected a high prevalence of aortic calcification in our patients. However, its impact on prevention of postoperative stroke needs to be investigated further in future prospective studies.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-22-1047/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-1047/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Institutional Review Board of King Saud University Medical City (No. E-19-4174) approved this study and waived the need for patients' consent because of the retrospective nature of the study.

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