Who needs preoperative routine chest computed tomography for prevention of stroke in cardiac surgery?

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Abstract

Although chest computed tomography (CT) is useful for identifying ascending aortic calcification before surgery, the efficacy of routine preoperative CT in cardiac surgery is unknown. We sought to clarify the role of routine preoperative chest CT for the determination of ascending aortic calcification before cardiac surgery to aid in the prevention of stroke. Three hundred consecutive patients who underwent elective cardiac operations excluding thoracic aortic surgery had preoperative non-contrast CT. Thirteen patients (4.3%) had severe calcification in the ascending aorta which required alteration of the cannulation site. Univariate analysis showed preoperative renal dysfunction, dialysis and aortic stenosis as predictors for ascending aortic calcification, but not history of stroke, peripheral vascular disease, and age. In multivariate analysis, aortic stenosis was found as the only predictor. The prevalence of severe ascending aortic calcification was 11.9% (10/84) in patients with aortic stenosis. Stroke occurred in two (0.67%) of the patients in the entire group but none in the 13 patients with surgical modification. For patients with aortic stenosis or hemodialysis, a low postoperative stroke rate can be achieved in elective cardiac surgery by use of routine preoperative chest CT to identify patients with ascending aortic calcification who require modification of the surgical technique.

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Keywords: Aorta; Computed tomography; Cardiac surgery; Pathological calcification; Stroke

1. Introduction

Severely calcified or porcelain ascending aorta causes difficulties in cardiac surgery. With the recent rise in the proportion of the elderly or high-risk patients undergoing cardiac surgery, atherosclerotic disease of the ascending aorta is becoming an increasingly recognized problem [1, 2]. The presence of severe, circumferential calcification of the ascending aorta causes complications in intraoperative management of cardiac surgery [3]. A severely calcified ascending aorta has the potential to release embolic debris and eventually result in a substantial rate of perioperative neurological events [4].

Intraoperative epiaortic scanning is generally considered to be a useful modality to detect calcification of the ascending aorta intraoperatively [5]. However, surgeons are able to recognize this difficult situation only after median sternotomy with this method. Porcelain aorta sometimes requires an alternative approach, such as an apico-aortic conduit [6], intra-aortic balloon [7], and circulatory arrest for ascending aortic segment replacement, particularly aortic valve replacement [8]. Also, the cannulation site must be changed because it is difficult to cannulate in the severely calcified ascending aorta. As these factors are associated with higher mortality and morbidity, it would be beneficial for surgeons to be aware of aortic calcification before surgery.

Non-contrast chest computed tomography (CT) is recognized as a useful method to detect calcification of the ascending aorta [9]. It is sometimes performed to assess calcification before cardiac surgery. Routine use of this modality gives surgeons important information which helps them to develop an appropriate surgical strategy. However, we also have to consider the economic impact of routine preoperative use of CT, and the efficacy of preoperative routine CT in cardiac surgery has yet to be established. The purpose of this study was to clarify the role of preoperative routine chest CT for prevention of stroke and to determine the prevalence of ascending aortic calcification in patients undergoing cardiac surgery.

2. Patients and methods

Between January 2005 and December 2008, 300 consecutive patients admitted for elective cardiac surgery excluding aortic surgery were enrolled in this study. Their demographic data are listed in Table 1. Mean age was 68.9 ± 10.6 years (range, 30–89 years) and 123 patients (41%) were female. Ninety-five patients required coronary artery bypass grafting (CABG), 173 patients required valve surgery, and 28 patients required both. Approval was obtained from the hospital Ethics Committee and informed consent was given by the patients.
Table 1
Patients’ demographics

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>68.9 ± 10.6 (30–89)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male/female)</td>
<td>177/123</td>
</tr>
</tbody>
</table>

Predisposing factors

- Hypertension: 152 (51%)
- Diabetes: 112 (37%)
- Hyperlipidemia: 102 (34%)
- Previous myocardium infarction: 32 (11%)
- Chronic renal failure: 49 (16%)
- Hemodialysis: 29 (10%)
- Peripheral vascular disease: 14 (5%)
- Cerebrovascular disease: 52 (17%)
- Smoking: 129 (43%)
- Previous cardiac surgery: 38 (13%)
- Left ventricular ejection fraction (%): 58.5 ± 14.5 (11–85)

Table 2
Patients with severe calcification of the ascending aorta

<table>
<thead>
<tr>
<th>Number</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>71.2 ± 7.0 (58–84)</td>
</tr>
<tr>
<td>&gt; 80 years old</td>
<td>1</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>7/6</td>
</tr>
</tbody>
</table>

Predisposing factors

- Previous myocardium infarction: 2 (15%)
- Chronic renal failure: 6 (46%)
- Hemodialysis: 5 (38%)

Operative procedures

- Coronary artery bypass grafting: 3 (23%)
- Aortic valve replacement + CABG: 2 (15%)
- Aortic valve replacement: 5 (39%)
- Aortic valve replacement + mitral valve surgery: 3 (23%)

CABG, coronary artery bypass grafting.

Fig. 1. Preoperative computed tomography revealed complete circumferential calcification at ascending aorta.

Fig. 2. Preoperative computed tomography revealed calcification of at ascending aorta. It was impossible to place the arterial cannula in the ascending aorta, and cannulation and/or the cross-clamp site was away from the usual sites.

\( P < 0.05 \) was defined for selecting variables for entry into the multivariate model. Statistical significance was defined by a \( P < 0.05 \).

3. Results

Thirteen patients (4.3%) had severe calcification in the ascending aorta which required alteration of the arterial cannulation site. The demographics of these patients are listed in Table 2. Eleven patients required femoral artery cannulation and one required axillary artery cannulation. One patient received aortic arch cannulation to avoid the severely calcified ascending aorta. One patient was more than 80 years old and five were undergoing hemodialysis. The prevalence of ascending aortic calcification was 11.9% (10/84) in patients with aortic stenosis, and 3.1% (3/95) in patients with isolated CABG.

A majority of patients underwent aortic valve replacement. On-pump beating CABG was performed in a patient who needed isolated coronary artery bypass surgery. No patient with a severely calcified ascending aorta experienced postoperative stroke, while stroke occurred in two (0.6%) of the patients in the entire group. One patient had a minor stroke after CABG and recovered completely at discharge. The other experienced hemiplegia after CABG, but had clear consciousness. He was transferred to the rehabilitation hospital. The 30-day mortality was 2.0% in the entire group and zero in the severely calcified group.

In univariate analysis, preoperative renal dysfunction, dialysis and aortic stenosis were shown as predictors for severe calcification of the ascending aorta (Table 3). History of stroke, peripheral vascular disease and age were not predictors of a severely calcified ascending aorta.
Table 3
Univariate analysis

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=13)</th>
<th>Group B (n=283)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>71.2 ± 7.0</td>
<td>68.8 ± 10.7</td>
<td>0.4245</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>6 (46%)</td>
<td>117 (41%)</td>
<td>0.6993</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9 (69%)</td>
<td>143 (50%)</td>
<td>0.1711</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>3 (23%)</td>
<td>109 (38%)</td>
<td>0.2773</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>2 (15%)</td>
<td>100 (35%)</td>
<td>0.1474</td>
</tr>
<tr>
<td>Previous myocardium infarction</td>
<td>2 (15%)</td>
<td>31 (11%)</td>
<td>0.6055</td>
</tr>
<tr>
<td>Chronic renal failure</td>
<td>6 (46%)</td>
<td>43 (15%)</td>
<td>0.0029</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>5 (38%)</td>
<td>24 (8%)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Smoking</td>
<td>7 (54%)</td>
<td>122 (43%)</td>
<td>0.4193</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>1 (8%)</td>
<td>13 (5%)</td>
<td>0.3870</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>2 (15%)</td>
<td>50 (17%)</td>
<td>0.8495</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>6 (46%)</td>
<td>97 (34%)</td>
<td>0.3588</td>
</tr>
<tr>
<td>Left ventricular ejection fraction</td>
<td>53.9 ± 13.5</td>
<td>58.7 ± 14.6</td>
<td>0.2474</td>
</tr>
<tr>
<td>New York Heart Association class</td>
<td>2.6 ± 0.8</td>
<td>2.4 ± 0.8</td>
<td>0.2741</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>6 (46%)</td>
<td>127 (44%)</td>
<td>0.8925</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>9 (69%)</td>
<td>76 (26%)</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

Multivariate analysis revealed that aortic stenosis was the only predictor of a calcified ascending aorta (Table 4).

4. Discussion

Stroke is one of the most devastating complications after cardiac surgery. Cerebrovascular complications result in not only increased perioperative and postoperative mortality but also poor long-term prognosis after surgical intervention [11]. Although the causes of strokes are multifactorial, several studies have established the role of the ascending aorta as a precursor to brain embolism during cardiac operations [2, 4]. In patients with severe aortic atherosclerosis, the risk was greatest, with 37% experiencing an embolic event [1]. Therefore, patients with a severely calcified ascending aorta are at particularly high-risk of stroke and death after cardiac surgery, and it is extremely important to detect calcification of the ascending aorta and to develop an adequate strategy before surgery.

The prevalence of a severe atherosclerotic aorta has been reported to be 2–28% in open heart surgery patients [2, 8, 12], and approximately one fifth of this group have a porcelain aorta. This prevalence depends on the definition of severity of the calcification, on the sensitivity of the diagnostic procedures and on the subset of operative procedures considered. In this study, we defined a severely calcified aorta as nearly complete circumferential calcification of the ascending aorta because we believe this condition influences the operative strategy. In the entire study group, 4.3% were diagnosed with a severely calcified ascending aorta by non-contrast CT, and this rate is comparable to previous reports [3, 9].

There are several modalities for assessing ascending aortic calcification. Conventional chest X-rays can be used to evaluate calcification. Although we can obtain more accurate and detailed information about the ascending aorta from CT-scans, routine use of CT-scans should be warranted due to the high dose of radiation compared to chest X-rays.

Intraoperative epiaortic scanning is one of the most frequent methods for detecting atherosclerotic disease of the ascending aorta [5]. This modality easily evaluates the status of the intima and ascending aortic wall. Also, we have occasionally also used this modality when it has been necessary to evaluate the ascending aorta as a result of the CT-scan. This is a very efficient method to detect and assess severe calcification ‘intraoperatively’. Because a severely diseased ascending aorta requires surgeons to choose different procedures, such as off-pump CABG, aortic conduit [6], endo-aortic balloon occlusion [7], and hypothermic circulatory arrest [8], it would be more beneficial for surgeons to obtain the information on severe calcification of the ascending aorta prior to patients going to theater.

CT is also a useful modality to evaluate the status of the ascending aorta. The images provide reproducible and more accurate information not only on circumferential severity of the calcification but also on the extent of the calcification both proximally and distally. Some studies reported routine use of non-contrast chest CT for all elective cardiac surgery patients [9]. However, we must consider the economic impact of treatment for cardiovascular surgery patients because routine use of CT results in extra costs. Few studies have investigated the cost and benefits of routine use of preoperative non-contrast CT for patients with open heart surgery. Although the prevention of postoperative neurological complications reduces the total cost of the management of cardiac surgical patients, it is necessary to clarify which patients would obtain a benefit from use of CT.

In the present study, we found that aortic stenosis, renal failure and hemodialysis were predictors of severe ascending aorta calcification. Regarding the management of patients with a severely calcified ascending aorta, we can easily choose an alternative approach, off-pump CABG, for patients who need coronary revascularization [13]. The aorta-non-touch technique can be effective in preventing strokes, especially in patients with a severely calcified ascending aorta. However, surgeons require the use of a variety of alternative approaches for patients who need aortic valve surgery. Previous reports regarding the management of patients with a severely calcified ascending aorta usually referred to patients who needed aortic valve replacement [3, 7, 9]. Thus, we believe that it is valid to consider routine use of preoperative CT in patients with aortic stenosis.

Hemodialysis was also found to be a predictor of a severely calcified ascending aorta in patients requiring open heart surgery. It is well known that there is a high prevalence of vascular atherosclerosis in patients undergoing hemodialysis [9]. With the recent increase in the population of concomitant chronic kidney disease and cardiovascular disease patients, it is more important to assess aortic calcification carefully. Chronic kidney disease is one of the risk factors of postoperative morbidity or mortality [14]. It would be
informative for surgeons to know whether this kind of patient has a compromised aorta preoperatively.

We could not detect peripheral artery disease, age, and history of stroke, as risk factors for a severely calcified ascending aorta. Although these are well known as risk factors for stroke [15], they are not reliable predictors of ascending aortic calcification. Ascending aortic calcification is not the only risk factor for postoperative stroke and it would be reasonable to consider different risk factors at the time of assessment of the status of the ascending aorta. Thus, to develop an appropriate operative strategy for patients with aortic valve replacement, hemodialysis or chronic renal dysfunction, it is necessary to be aware of the possibility of a severely calcified ascending aorta. Because we could recognize this difficult condition by non-contrast CT before surgery, we were able to achieve a low stroke rate in elective cardiac surgery. Non-contrast CT may have an important role in reducing this catastrophic postoperative complication after open heart surgery. Also, an alternative approach, such as deep hypothermia or an apico-aortic conduit, requires meticulous preparation. Thus, the benefit of non-contrast CT is undoubted and we can obtain important information about the ascending aorta prior to surgery.

This study was non-randomized with a retrospective analysis, and conclusions from this kind of study should be interpreted with caution. However, we believe there is a benefit in the use of routine preoperative non-contrast CT, and this may more than compensate for the cost disadvantage of routine CT.

In conclusion, preoperative non-contrast CT is useful in patients with aortic stenosis or hemodialysis to determine those with ascending aortic calcification who would benefit from an altered cardiac surgical strategy. We recommend routine use of preoperative non-contrast CT-scan for this population to aid in identifying the best surgical approach to prevent postoperative stroke.

References


