Routine Preoperative Screening Computed Tomography of the Thorax for Cardiac Surgery

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Research Article

Keywords: Computed tomography, aortic calcifications, operative strategy

Posted Date: May 17th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-529585/v1

Abstract

Purpose: This study aims to evaluate the role of screening computed tomography (CT) thorax in cardiac surgery by analysing presence of CT aortic calcifications in association with change of operative strategy and postoperative stroke, as well as CT features of emphysema with development of pneumonia.

Methods: All patients who underwent cardiac surgery from January 2013 to October 2017 by a single surgeon were retrospectively studied. Patients who underwent screening CT thorax prior to cardiac surgery (CT group) were compared with those who did not (no CT group). Multivariate subgroup analyses were performed to determine significant association with postoperative outcomes.

Results: 392 patients were included, of which 156 patients underwent preoperative screening CT thorax. Patients in the CT group were older (63.9 vs 59.0 years, p=0.001), had fewer recent myocardial infarction preoperatively (41 vs 56.4%, p=0.003) and better ejection fraction >30% (p=0.02). Operative strategy was changed in 4.3% of patients, and 4.9% suffered stroke postoperatively. Presence of CT aortic calcifications was significantly associated with change in operative strategy (OR 1.54, p=0.016) but not associated with postoperative stroke (OR 0.53, p=0.33). Age was an independent risk factor for change in operative strategy among patients with CT thorax (p=0.02). Multivariate age-adjusted analysis showed only palpable plaque to be significantly associated with change in operative strategy (p<0.001). None of the patients with CT emphysema features developed pneumonia.

Conclusion: The results do not support routine use of preoperative screening CT thorax. It should only be recommended in older patients.

Introduction

Postoperative stroke is a serious complication of cardiac surgeries with 1% risk for both early and delayed stroke.[1] Postoperative stroke is related to the location and extent of ascending aortic atherosclerotic disease,[2] which tends to increase with age. Because of this, routine preoperative computed tomography (CT) scan of the thorax has been recommended at least in elderly patients, as it provides essential information concerning ascending aorta calcification.[3] Preoperative CT thorax also gives information regarding emphysema, which may be associated with lung complications,[4] in addition to other anatomic features that may aid in operative planning.

This study aims to evaluate the role of CT thorax as part of routine preoperative work-up prior to cardiac surgery in association with change of operative strategy, and development of postoperative stroke and pneumonia.

Methods

This is a retrospective study of all patients who underwent cardiac surgery by a single lead surgeon from the National University Hospital, Singapore between January 2013 and October 2017. Most elective

patients undergoing surgery from May 2016 also underwent routine preoperative CT thorax, especially if they were older than 60 years of age, had pulmonary risk factors or if there was obvious aortic calcification seen on the chest x-ray (CXR), due to a conscious change in the surgeon's practice to obtain a screening CT for all elective patients above the age of 60 years. Standard spiral CT acquisition with 5mm cuts was used without contrast media where possible in most patients based on our institution's CT chest protocol.[5] Patients undergoing surgery for aortic dissection repairs were excluded as all these patients had complete CT of the whole aorta. The study was approved by the National University Health System ethics review board (2018/00147).

Information regarding patient demographics, past medical history, preoperative investigations, intra-operative findings and clinical outcome were obtained. CXR and CT thorax images were evaluated independently by 2 reviewers of the study team. CXR was assessed for presence of calcification within the aortic wall (Fig. 1). Aortic calcification on CT thorax was defined as calcifications evident within the wall of the ascending aorta and arch. CT thorax was also evaluated for features of pulmonary emphysema (Fig. 2). The primary outcome was any change to the operative strategy. Secondary outcomes included postoperative complications of in-hospital mortality, stroke, and pneumonia. Stroke was diagnosed as an area of infarct confirmed on CT or magnetic resonance imaging (MRI) of the brain.

Statistical analysis of the data was performed using SPSS v22 (IBM, Armonk, NY, USA) and STATA v13 (StataCorp, College Station, TX, USA). Outcomes were compared between patients with and without preoperative CT thorax. Univariate analysis was performed for demographics and intraoperative data with Chi^2 and student's *t*-test for categorical and continuous variables respectively. Multivariate logistic regression subgroup analysis was further performed for patients with change in operative strategy and those with post-operative stroke. Chi-square Automatic Interaction Detector (CHAID) was used to determine age cut-off for change in operative strategy and development of postoperative stroke.

Results

156 patients underwent screening CT thorax (CT group) and 236 patients did not undergo prior CT thorax (no CT group). Only 2 patients in the cohort underwent redo surgeries, both for mitral valve replacement. Patient demographics are shown in Table 1. Patients who underwent routine screening CT thorax prior to cardiac surgery were significantly older (63.9 vs 59.0 years, p=0.001). More patients in the group that did not have screening CT had myocardial infarction (MI) within 90 days of surgery (56.4 vs 41.0%, p=0.003). While mean ejection fraction (EF) was similar between the 2 groups, more patients in the group that did not undergo preoperative screening CT had poor left ventricular ejection fraction (LVEF) of 30% or less (p=0.02). There were no significant differences in other preoperative variables. In the CT group, 55.8% had aortic calcifications and 6.5% had features of emphysema.

Table S1 shows the distribution of surgeries in both groups. There were no significant differences in cardiopulmonary bypass (CPB) or crossclamp times (Table S2). Use of intra-aortic balloon pump (IABP) was similar in both groups. Epiaortic ultrasound (EAUS) was used more frequently in the group without

preoperative CT thorax (p=0.03). There were no significant differences in the primary endpoint of change in operative strategy, and secondary endpoints of postoperative mortality, stroke and pneumonia (Table 2).

A total of 17 patients (4.3%) experienced change in the operative strategy (Fig. 3). Univariate analysis showed aortic calcifications present on preoperative CT thorax, aortic calcifications seen on preoperative CXR and intraoperative calcified aortic plaques felt on palpation to be significantly associated with change in operative strategy. However, age adjusted regression analysis showed only palpable plaques during surgery to be significantly associated with change in operative strategy (Table 3). Within the screening CT group, aortic calcifications on CT thorax were significantly associated with change in operative strategy (7/87 vs 0/69, OR 1.54, p=0.016).

Postoperative stroke occurred in 19 patients (4.9%), 10 in the CT group and 9 in the no CT group. Change of operative strategy, new onset atrial fibrillation, IABP use and presence of aortic calcifications were significantly associated with development of postoperative stroke on univariate analysis. However, when adjusted for age and LVEF, none of these were significantly associated with incidence of postoperative stroke (Table 4). Among patients who underwent screening CT, presence of aortic calcifications visualized on CT was not associated with the occurrence of postoperative stroke (7/85 vs 3/69, OR 0.53, p=0.33).

8 patients (2.0%) developed pneumonia postoperatively. Among those screened with CT thorax, 10 patients (6.5%) had features of emphysema. None of these patients developed pneumonia postoperatively, compared to 2 patients who did not have emphysema features (Kruskal's gamma = -1).

Age >61 years was a significant cut-off for change of operative strategy (6.9% change, p=0.007). Age was also an independent risk factor for change of operative strategy among patients with screening CT thorax (p=0.02). There was no significant association for development of postoperative stroke.

Discussion

CT of the thorax has been shown to aid routine preoperative planning for redo cardiac surgery in evaluating retrosternal anatomic relations,[6] and more recently in minimally invasive or catheter based cardiac procedures.[7] There are no guidelines to suggest its use in routine conventional cardiac surgical procedures done via sternotomy. In the authors' institution, the need for CT thorax as part of preoperative planning is left to the discretion of the performing surgeon.

There were some distinct differences in demographics between the groups that did and did not undergo routine preoperative screening CT thorax. Most of the patients who underwent surgeries after 2015 by the lead surgeon in this study routinely underwent CT thorax as part of preoperative planning especially if they were older (age >60 years), due to change in the surgeon's clinical practice. This likely explains the higher mean age in the screening CT group. Patients with recent MI and poor EF were more likely to be part of the subset of patients who warranted urgent surgery, and in whom obtaining a preoperative screening CT was not essential.

Despite the time lag between the no CT and CT groups, there was no significant difference between CPB and crossclamp times, which may have been expected with increasing surgeon experience. EAUS was used more often in the no CT group if there were palpable plaques felt on the aorta, to aid in finding the most appropriate cannulation or crossclamp sites, whereas in the CT group, the preoperative CT images were assessed for this purpose. The cost of epiaortic ultrasound and a non-contrasted CT thorax is similar. The CT thorax is able to provide additional anatomic information though not in real-time.

Change in operative strategy in this study was lower than the 9.2% in a more recent study by de Hartog-Dikhoff et al[3] and occurred due to palpable aortic calcified plaques intraoperatively rather than the presence of calcifications on the CT. In most patients who faced an altered operative strategy, the aorta was still cannulated for CPB, but some underwent off-pump or on-pump beating heart surgery. Majority of the cases were coronary artery bypass grafting (CABG) surgeries. The surgeon routinely performs left internal mammary artery (LIMA) to the left anterior descending (LAD), and aortocoronary grafts for the rest. While many cases were modified to single crossclamp technique, the modifications did not appear to affect routine graft configuration. All patients who had change of operative strategy within the screening CT group had aortic calcifications present on CT, suggesting that identifying aortic calcifications on a preoperative CT may help with operative planning for routine cardiac surgery.

A meta-analysis by den Harder et al showed 7 articles pertaining to primary cardiac operation of which 1194 subjects received a preoperative CT scan.[8] The study suggested preoperative CT may be beneficial, albeit with weak evidence. However, only 2 studies reported outcomes separately for a control group. These studies showed a decrease in mortality and stroke rates in favour of the CT group, and the main cause of death was stroke.[9,10] There was no significant difference in mortality or stroke between the two groups in this study, which included all-comers who underwent cardiac surgery. A recent propensity matched study by Sandner et al enrolling 2320 consecutive patients who underwent isolated CABG showed 11.2% of patients in the CT group received modifications of the conventional CABG procedure versus 3.3% in the non-CT group.[11] There was a significant reduction in stroke incidence among patients who underwent CT aortic angiography in both the matched and unmatched cohorts. The significant difference in stroke rates may be related to the use of contrasted CT-angiography instead of plain CT, which may have detected soft atheromas in addition to calcifications.

A study by Linden et al showed that the presence of ascending aortic atheroma was associated with increased postoperative stroke, was detected in 26.2% of patients and most often involved the distal anterior segment.[3] It showed an 8.7% incidence of stroke despite minor surgical modifications. This is in contrast to this study wherein none of the patients with a modified operative strategy developed stroke, as was the case in the study by Nishi et al.[12] Here too, change of operative strategy itself appeared to be protective of stroke. This is unsurprising as manipulation of a diseased aorta is often associated with stroke. The review by Gaudino et al suggested that early postoperative stroke was likely related to operative technique, and was inversely associated with off-pump surgery.[1] Also, the presence of aortic calcifications on CT alone was not associated with development of postoperative stroke when stratified

within the CT group. The relatively higher stroke rate overall may be related to the number of higher risk surgeries undertaken, evidenced by the proportion of patients with poor ejection fractions and combined surgeries.

While all the variables in Table 4 showed significance in relation to postoperative stroke individually, the effects were mitigated by adjusting for age and EF. This is likely because atrial fibrillation and aortic calcifications are both associated with increased age,[13] and the use of IABP is associated with poor EF. Analysis for an age cut-off for patients to undergo preoperative CT thorax showed a significant cut-off at 61 years for change in operative strategy. However, this did not translate to postoperative stroke. This suggests that performing preoperative CT thorax may be useful for preoperative planning in older patients, but not for reducing the incidence of stroke. The finding that palpable plaque was the most significant predictor for change in operative strategy when adjusted for age suggests that CT thorax may play a supportive role, rather than a definitive role in decision-making for altering surgical strategy.

This study also sought to reflect pulmonary infection in relation to CT features of emphysema. This has not been reported in other studies. In this study, the incidence of chronic pulmonary diseases of asthma and chronic obstructive pulmonary disease (COPD) were low in both groups. The presence of emphysema features on CT was also low despite more than half the study population in both groups comprising smokers. There was no significant association between emphysema features and pulmonary complications. Thus, preoperative screening CT thorax does not seem useful in determining risk of postoperative pneumonia for patients undergoing cardiac surgery.

On the whole, this study provides a fair comparison between the screening CT group and control group without preoperative CT thorax, and outcomes were comparable despite increased age and poorer EF in the no CT group. Most of the CTs were non-contrasted, with low radiation dose. Almost all patients underwent primary cardiac surgery. However, there are several limitations that must be noted. First, this is a retrospective observational study with potential for selection bias. Second, the difference in time period between the 2 groups coincides with increased operative experience of the surgeon for the CT group, potentially taking on more complex or higher risk cases. The surgical risk is not reported in this study. Third, there were a few patients who did not undergo surgery due to discovery of a porcelain aorta on CT thorax, and are not captured in this study. Lastly, other embolic complications such as mesenteric ischemia are not reflected in this study, though these were very rare.

Conclusions

Routine preoperative screening CT thorax may assist in preoperative surgical planning, as concluded in the best evidence study by Merlo et al.[14] However, it does not necessarily contribute to decreased mortality or stroke rates. While modern technology allows markedly reduced radiation dose for CT thorax, these results do not support routine CT thorax prior to primary cardiac surgery. It may be considered for selected elderly patients with higher inherent stroke risk.

Declarations

Funding: There was no funding for this manuscript

Conflict of interest: The authors declare that they have no conflict of interest.

Author Contributions

Jai Ajitchandra Sule: Conceptualization, data curation, formal analysis, investigation, methodology, original draft writing, review and editing

Xue Wei Chan: Data curation, original draft writing

Hari Kumar Sampath: Data curation, original draft writing

Hai Dong Luo: Statistical analysis, methodology

Mofassel Uddin Ahmed: Data curation

Giap Swee Kang: Conceptualization, draft review

Ethics approval: National University Health System ethics review board (DSRB ref: 2018/00147). Waiver of consent was granted by the review board.

Acknowledgements

The authors would like to thank Dr Sheldon Ng for providing insight to the institution's CT radiation protocol. The authors also thank Lin Xiao Yun for the formatting of this manuscript.

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Tables

Table 1: Patient demographics

	No screening CT (n=236)	Screening CT (n=156)	p-value
Age (years)	59.0 ± 9.1	63.9 ± 9.1	<0.001*
Gender (% male)	79.2	82.9	0.56
BSA (m^2)	1.76 ± 0.19	1.73 ± 0.20	0.12
Smoker (%)	56.2	54.1	0.69
Diabetes mellitus (%)	51.3	55.2	0.45
Hypertension (%)	73.7	73.1	0.89
Hyperlipidaemia (%)	67.8	73.7	0.21
Asthma (%)	5.5	2.6	0.16
COPD (%)	5.1	2.6	0.21
Stroke prior (%)	9.3	11.5	0.48
Peripheral vascular disease (%)	7.2	6.4	0.76
Chronic kidney disease (%)	15.7	19.9	0.28
Myocardial infarction (%)	56.4	41.0	0.003*
Coronary artery disease (%)	90.2	86.5	0.26
Left main disease (%)	31.1	34.6	0.52
Aortic stenosis (%)	2.1	3.2	0.50
Aortic regurgitation (%)	4.2	6.4	0.34
Mitral stenosis (%)	1.7	0.6	0.36
Mitral regurgitation (%)	16.1	19.9	0.34
LVEF (%) >50 31-50 21-30 ≤20	50 ± 14 55.9 26.2 13.1 4.7	50 ± 13 48.7 40.4 8.3 2.6	0.94 0.02*
Atrial fibrillation prior (%)	5.5	7.1	0.53

*p<0.05; BSA: Body surface area; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction.

Table 2: Endpoints

Endpoint	No screening CT	Screening CT	p-value
Operative strategy changed (%)	4.2	3.9	0.91
In-hospital Mortality (%)	5.1	5.8	0.77
Stroke (%)	3.8	6.5	0.23
Pneumonia (%)	2.5	1.3	0.39

Table 3: Predictors for change of operative strategy

	Yes (n=17)	No (n=375)	p-value
CT calcifications (%)	41.2	21.3	0.46
CXR calcifications (%)	64.7	29.9	0.54
Palpable plaque (%)	88.2	4.3	<0.001*

*p<0.05, multivariate logistic regression adjusted for age.

CT: computed tomography; CXR: chest X-ray.

Table 4: Variables contributing to postoperative stroke

	Stroke (n=19)	No stroke (n=371)	p-value
Operative strategy changed (%)	0	4.3	0.28
New atrial fibrillation (%)	31.6	24.3	0.99
IABP used (%)	31.6	13.2	0.15
Aortic calcifications (%) CT calcifications	36.8	21.0	0.40
CXR calcifications	26.3	31.3	0.13
Palpable plaques	5.3	7.8	0.83

Multivariate logistic regression adjusted for age and ejection fraction.

IABP: intra-aortic balloon pump.

Figures

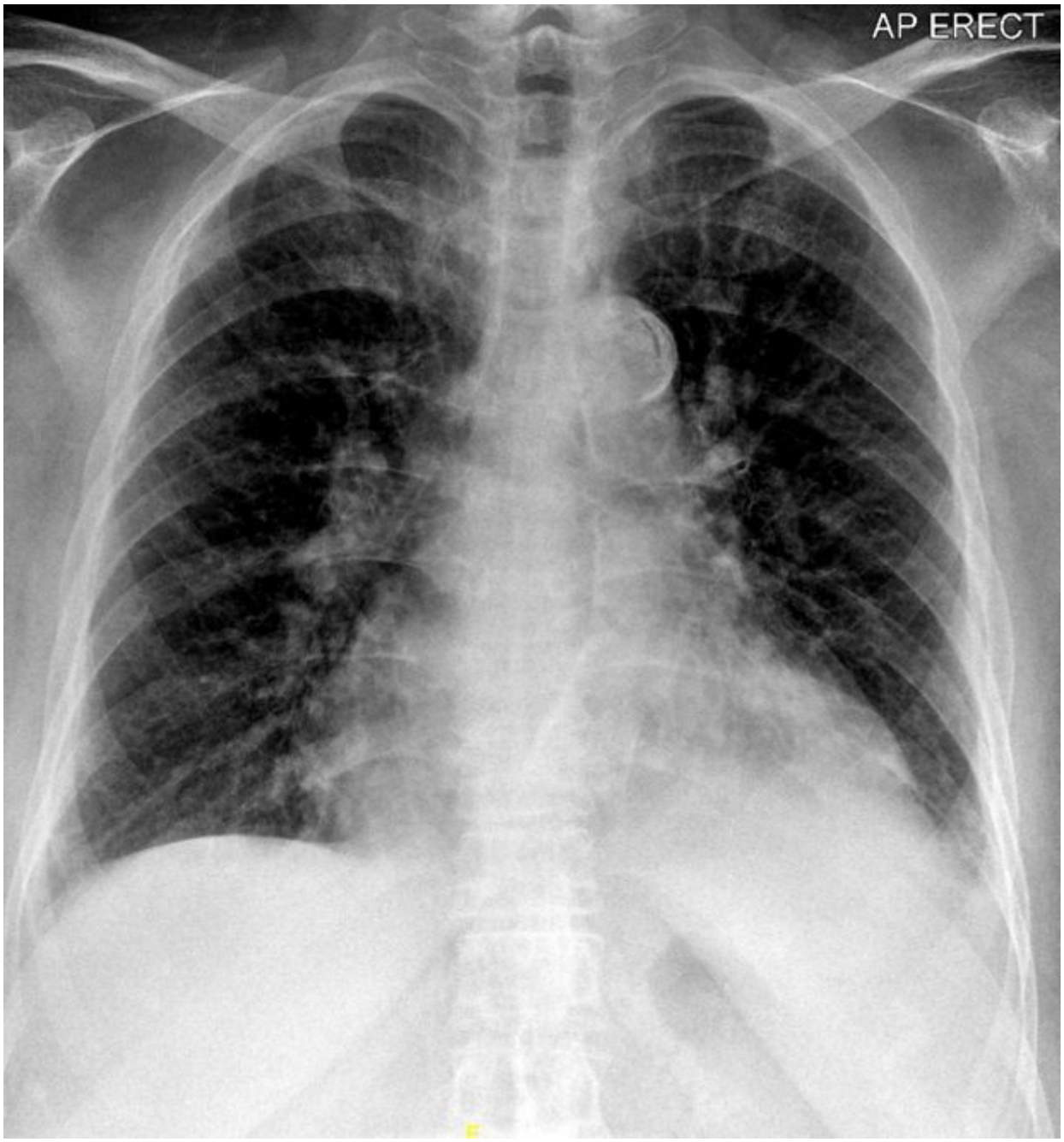

Figure 1

Chest X-ray showing aortic calcification

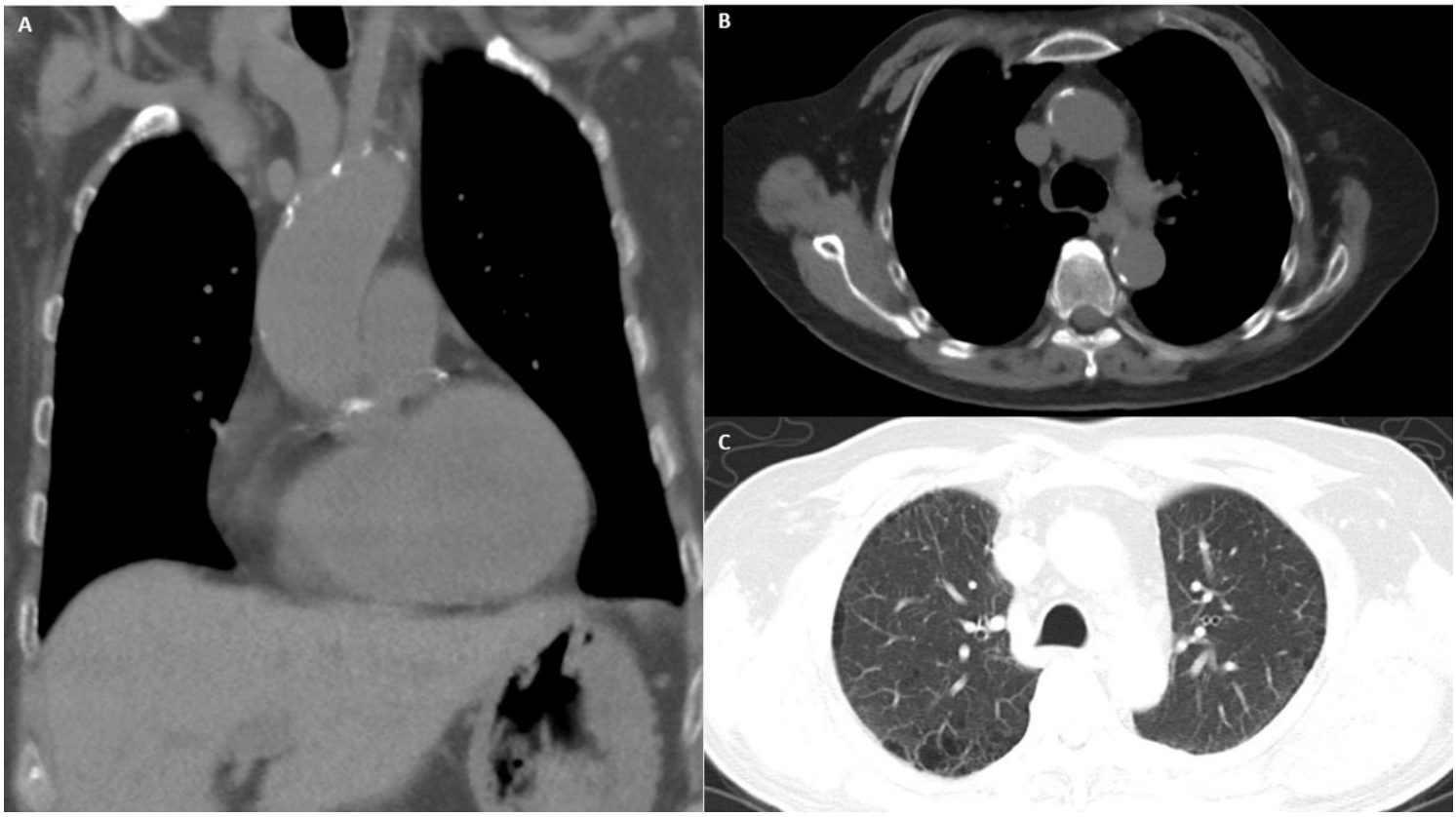

Figure 2

(A) Coronal and (B) axial images demonstrating aortic calcification visualised on non-contrast CT thorax. (C) Lung window showing features of pulmonary emphysema.

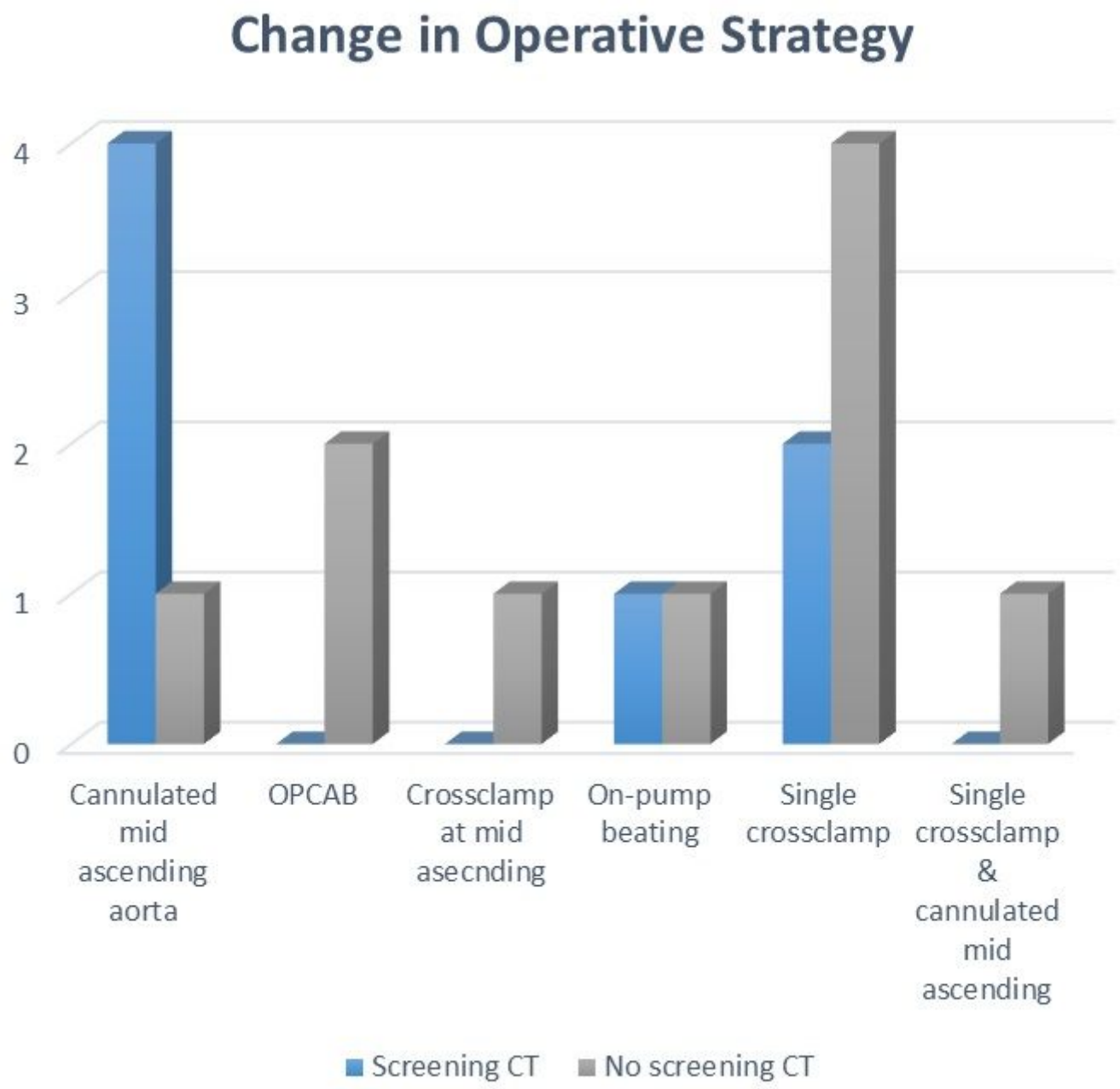

Figure 3

Change of operative strategy among patients with and without screening CT thorax.

Supplementary Files

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