Three dimensional computed tomographic imaging in planning the surgical approach for redo cardiac surgery after coronary revascularization

Hrvoje Gasparovic\(^a\), Frank J. Rybicki\(^b\), John Millstine\(^b\), Daniel Unic\(^a\), John G. Byrne\(^a\), Kent Yucel\(^b\), Tomislav Mihaljevic\(^a\)*

\(^a\)Division of Cardiac Surgery, Brigham and Women’s Hospital, Boston, MA, USA
\(^b\)Department of Radiology, Brigham and Women’s Hospital, Boston, MA, USA

Received 25 November 2004; received in revised form 24 February 2005; accepted 9 March 2005

Abstract

Objective: Reoperative cardiac surgery after previous coronary artery bypass grafting represents a surgical challenge due to the potential for injury to patent coronary grafts, aorta or right ventricle. Standard preoperative imaging using a coronary angiogram and chest radiograph (CXR) often results in inaccurate assessment of mediastinal anatomy. We aimed to evaluate 3D volume rendered computed tomographic imaging as an adjunct to standard preoperative assessment of patients requiring cardiac surgery in whom coronary artery revascularization had been performed in the past.

Methods: Between January 2003 and January 2004, 33 patients with previous coronary revascularization referred for reoperative cardiac surgery underwent preoperative 3D CT imaging in order to optimize the surgical approach. The mean age in this patient population was 72 ± 8 years. The combined evaluation of CXR and conventional angiography offered incomplete insight into pertinent mediastinal topography in 85% of patients (28/33).

Results: The correlations for distances of the left internal mammary artery (LIMA) to left anterior descending artery (LAD) graft from the midline and posterior sternum obtained by CT angiography (CTA) and CXR were poor, \(R = 0.56\) and 0.49, respectively. The correlation coefficients for distances between the right ventricle and the aorta to the sternum obtained by the same methods were similarly marginal, 0.58 and 0.48, respectively. The correlation coefficients for distances between the LIMA to LAD, circumflex and right coronary artery grafts from the midline obtained by CTA and conventional angiography were 0.54, −0.13 and 0.43, respectively. In seven patients (21%) the surgical strategy was modified based on the location of patent grafts in the mediastinum. The hospital mortality was 17% (5/29). Intraoperative injuries to vital structures were encountered in two patients (7%). No injuries to patent LIMA or the aorta were encountered.

Conclusions: The 3D CT imaging technique is useful in defining the optimal surgical strategy for reoperative cardiac surgery. We found that CTA is superior to CXR and conventional angiography in defining the position of patent grafts and vital structures in relation to the midline and posterior sternum. Preoperative mapping of patent coronary grafts and other vital mediastinal structures reduces the morbidity of the reoperation through modification of surgical approaches.

© 2005 Elsevier B.V. All rights reserved.

Keywords: Cardiac reoperation; Computed tomography; Morbidity reduction

1. Introduction

The inadequacy of intraoperative visualization of patent coronary grafts and other vital mediastinal structures, such as the aorta and right ventricle, contributes to the complexity of reoperative cardiac surgery. Dense adhesions often cause distortion of normal anatomy and make safe dissection difficult. Standard preoperative evaluation using chest radiographs and coronary angiograms provides only limited and imprecise anatomic information. Emergence of multi-row breath hold computed tomography (CT) has enabled electrocardiographically (ECG) gated CT angiography (CTA) with three-dimensional (3D) volume rendering of the heart, coronary arteries, and bypass grafts [1]. This novel technology has provided us with detailed three-dimensional imaging of mediastinal anatomy, and an accurate preoperative identification of the position of patent grafts. The purpose of the present study is to quantify the value of the additional information offered by preoperative CTA, when performed in conjunction with the current standard of care, catheter coronary angiography and chest radiography.
2. Materials and methods

2.1. Patient population

In the period between January 2003 and January 2004, 33 patients planned for reoperative cardiac surgery at the Brigham and Women’s Hospital who had surgical coronary revascularization procedures performed in the past were analyzed in a retrospective fashion. The Institutional Review Board of the Brigham and Women’s Hospital approved this review. The focus of the study was on patients in whom computed tomographic mapping of their coronary grafts was performed. The patient demographic data are presented in Table 1. Catheterization films as well as chest X-rays were evaluated by an independent cardiac surgeon.

2.2. Computed tomographic imaging

Volumetric CT data was acquired using a 16-row multidetector CT (MDCT) scanner (Sensation 16, Siemens Medical Solutions) with 0.75 mm collimation. The thickness of the slices thus acquired was 0.75 mm. One-hundred and twenty-five milliliters of contrast was administered during the procedure. The study was electrocardiographically gated. The images were then reformatted by using maximum intensity projection and volume rendering techniques on a Voxar Workstation. A test bolus using 20 ml of contrast followed by 40 ml of saline was used to time the CTA acquisition. The purpose of the saline was to avoid dense opacification of the right heart and potential artifacts that could limit interpretation of the coronary arteries and the bypass grafts. Since it was often the case that the number of touch down locations of prior CABG grafts was not known at the time of scanning, the superior aspect of the field-of-view was chosen as 10 cm superior to the carina. The inferior aspect of the FOV included the base of the heart. Beta blockade in addition to the patients’ routine medications was not administered. Image interpretation included the 0.75 mm axial images, thin (2-3 mm) and thick (4-5 mm) maximum intensity projections, multiplanar reformatted images, and 3D volume rendering. The entire CTA data set, including those findings not related to the bypass graft position and patency, was interpreted by an attending radiologist with experience in cardiovascular imaging.

2.3. Statistical analysis

The data are presented as mean values ± standard deviation or as percentages. Comparisons between different imaging modalities were performed using correlation coefficient methodology. A correlation coefficient of \( R < 0.60 \) was considered to be indicative of poor correlation. The data was processed using the JMP IN v. 5.1 statistical package (SAS Institute, Cary, NC).

3. Results

3.1. Perioperative summary

The internal mammary graft was used as a conduit in the previous coronary revascularization in 27 patients. Twenty-nine of the 33 patients analyzed in this study underwent a redo cardiac surgical procedure. Table 2 summarizes the perioperative information. In one of the four patients in whom an operation was not undertaken, the LIMA graft was the only patent graft and the risk of injury to it was thought to be prohibitive since it crossed the midline and was adherent to the posterior sternal table. One patient had a vein graft to the LAD, which followed a similar course as the previously described LIMA graft. Both of these patients were referred for reoperative coronary revascularization. One of the patients who did not get surgically treated for his mitral regurgitation was found to be a poor surgical candidate secondary to his multiple comorbidities. The last of the four patients who did not get operated on, decided to indefinitely postpone the operation after the risks of the procedure were presented to him.

Table 2

Perioperative patient data

<table>
<thead>
<tr>
<th>Operation</th>
<th>Count (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVR</td>
<td>12</td>
</tr>
<tr>
<td>MVP/MVR</td>
<td>2</td>
</tr>
<tr>
<td>CABG</td>
<td>7</td>
</tr>
<tr>
<td>AVR/CABG</td>
<td>3</td>
</tr>
<tr>
<td>AVR/MVR</td>
<td>2</td>
</tr>
<tr>
<td>Pericardectomy</td>
<td>2</td>
</tr>
<tr>
<td>VSD closure</td>
<td>1</td>
</tr>
<tr>
<td>Operation canceled</td>
<td>4</td>
</tr>
<tr>
<td>Crossclamp time (min)</td>
<td>85 ± 36</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>167 ± 85</td>
</tr>
<tr>
<td>ICU (days)</td>
<td>10 ± 18</td>
</tr>
<tr>
<td>Hospitalization (days)</td>
<td>19 ± 19</td>
</tr>
<tr>
<td>Complications (n/%)</td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Reexploration for bleeding</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>1 (3)</td>
</tr>
<tr>
<td>New atrial fibrillation</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Pacemaker requirement</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Prolonged mechanical ventilation</td>
<td>4 (14)</td>
</tr>
<tr>
<td>Acute cholecystitis</td>
<td>1 (3)</td>
</tr>
<tr>
<td>IABP requirement</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Sternal wound infection</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Right ventricle injury</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Vein graft injury</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Death</td>
<td>5 (17)</td>
</tr>
</tbody>
</table>

Table 1

Patient demographic data

<table>
<thead>
<tr>
<th>Age (n/%)</th>
<th>72 ± 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (n/%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>28 (85)</td>
</tr>
<tr>
<td>Female</td>
<td>5 (15 )</td>
</tr>
<tr>
<td>NYHA class (n/%)</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>3 (9 )</td>
</tr>
<tr>
<td>II</td>
<td>12 (36)</td>
</tr>
<tr>
<td>III</td>
<td>11 (33)</td>
</tr>
<tr>
<td>IV</td>
<td>7 (21)</td>
</tr>
<tr>
<td>Hypertension (n/%)</td>
<td>24 (73)</td>
</tr>
<tr>
<td>Diabetes mellitus (n/%)</td>
<td>12 (36)</td>
</tr>
<tr>
<td>Preop. stroke (n/%)</td>
<td>7 (21)</td>
</tr>
<tr>
<td>Myocardial infarction (n/%)</td>
<td>19 (58)</td>
</tr>
<tr>
<td>Unstable angina (n/%)</td>
<td>7 (21)</td>
</tr>
</tbody>
</table>
Cardiopulmonary bypass was used in the remaining 29 patients. The aorta was crossclamped in 24 patients. In three patients we used hypothermic circulatory arrest as a method for ensuring adequate exposure due to our inability to achieve a cardioplegic arrest. Those patients in whom the operation was performed without the use of an aortic crossclamp, uniformly had severe atherosclerotic disease of the ascending aorta which prevented safe application of an occluding clamp. The exception was a single patient in whom the operation was performed through a left thoracotomy, which precluded access to the ascending aorta. A vein graft injury was encountered in one patient. The injury was independent of sternal reentry. It occurred during a challenging dissection of the right side of the heart in a patient who presented with congestive heart failure secondary to constrictive pericarditis. The graft was firmly adherent to the diseased pericardium that was responsible for the constrictive physiology. The patient had also undergone bilateral pleurodeses, which made the pericardiectomy even more arduous. The right ventricle was injured during redo sternotomy in a patient with very dense adhesion secondary to previous radiation therapy for Hodgkin’s lymphoma. The patient was already on cardiopulmonary bypass via femoral vessels. The repair proved simple and did not cause any delayed morbidity. The expected mortality of our subgroup of patients that underwent redo cardiac surgery calculated by using the logistic Euro score was 25 ± 22% [2]. The observed mortality in the group was 17%.

3.2. Chest radiography evaluation

The mean distances of the LIMA-LAD graft from the midline and from the posterior table of the sternum estimated on the basis of a chest X-ray were 1.6 ± 1.0 and 0.9 ± 0.8 cm. In six patients we were unable to determine the distance of the LIMA from the midline, and in seven patients the distance from the posterior sternum remained unknown. The total number of patients in whom the LIMA-LAD grafts could not be evaluated in its relation to both the midline and the sternum was 9/27. Of those evaluated, we estimated that two LIMA grafts crossed the midline and 13 came within 1 cm of the posterior border of the sternum. Of the four vein grafts to the LAD we were able to evaluate three of them and found the mean distances from the midline and the posterior sternum to be 1.7 ± 0.8 and 1.7 ± 0.6 cm, respectively. The mean distance of the ascending aorta from the sternum was 1.9 ± 1.0 cm. The proximity of the aorta in the anterior-posterior diameter could not be evaluated in 3/32 patients due to radiographic summation of adjacent pacemaker generators or soft tissues. The mean distance of the right ventricle from the posterior table of the sternum was 0.7 ± 0.6 cm. No attempt was made to assess the position of the left circumflex (LCX) and right coronary artery (RCA) grafts by this method. A summary of the values obtained from the chest X-ray, coronary angiography as well as the chest computed tomographic angiography (CTA) is presented in Table 3. One patient did not have a lateral chest X-ray because he had an intraaortic balloon pump placed prior to X-ray evaluation.

3.3. Coronary angiography findings

Native coronary artery and coronary artery bypass pathology was evaluated by conventional coronary angiography. We have also made the attempt to estimate the distance of patent grafts from the midline and from the posterior sternal plate. The mean distance of the LIMA-LAD grafts from the midline was 1.7 ± 1.1 cm. In two (7%) patients we were unable to estimate this distance because no sternal wires were used during the original operation. We estimated that five LIMA grafts crossed the midline, and an additional three came within 1 cm of it. Assessing the proximity of the LIMA graft to the posterior sternal table proved to be challenging because of the lack of lateral angiographic projections. Only 7% (two out of 27 patients) had projections that offered us the opportunity to evaluate the LIMA to sternum distance in the anterior-posterior direction. As expected, the single right internal mammary artery (RIMA) to the LAD was found to be crossing the midline. The mean distances of the left circumflex territory and right coronary artery grafts from the midline are presented in Table 3. The catheterization data suggested that 14 grafts to the left circumflex artery and five to the right coronary artery territory crossed the midline or came within 1 cm of it. In none of the 33 patients were we able to evaluate the distance of the LCX and RCA territory grafts from the posterior table of the sternum. Of the six patients that had patent grafts to a diagonal branch of the LAD we found that five crossed the midline. The remaining one graft to the diagonal branch could not be evaluated because of the technique of sternal closure that left no residual radiopaque material. Four patients were found to have vein grafts to the LAD. In three of these, we estimated that the graft crossed the midline, while in one patient it was 1 cm away from it. The lack of sternal wires prevented us from evaluating the proximity of a total of three vein grafts from the midline.

3.4. Computed tomography findings

Using CTA data for all patients, measurements of the distances of patent grafts, right ventricle and ascending aorta from the midline and the posterior sternum were obtained. The topographic data so gathered was complete for all patients. The distances of the LIMA-LAD grafts from

Table 3
Mean distances of grafts and vital structures from the midline and the posterior table of the sternum measured by different imaging methods

<table>
<thead>
<tr>
<th></th>
<th>LIMA-LAD</th>
<th>LCX graft</th>
<th>RCA graft</th>
<th>RV</th>
<th>Aorta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Midline</td>
<td>Sternal</td>
<td>Midline</td>
<td>Sternal</td>
<td>Midline</td>
</tr>
<tr>
<td>Catheterization</td>
<td>1.7±1.1</td>
<td>Unknown</td>
<td>0.7±0.8</td>
<td>Unknown</td>
<td>1.6±1.3</td>
</tr>
<tr>
<td>Chest X-ray</td>
<td>1.6±1.0</td>
<td>0.9±0.8</td>
<td>Unknown</td>
<td>Unknown</td>
<td>1.5±1.3</td>
</tr>
<tr>
<td>CTA</td>
<td>1.7±0.9</td>
<td>1.5±1.1</td>
<td>0.5±1.0</td>
<td>1.7±0.9</td>
<td>1.3±1.3</td>
</tr>
</tbody>
</table>

Downloaded from https://academic.oup.com/ejcts/article-abstract/28/2/244/362724 by guest on 18 March 2019
the midline and the posterior sternum are shown in Table 3. We found that one left internal mammary graft crossed the midline, an additional seven came within 1 cm of it, whereas 11 of them came within 1 cm of the posterior sternum (Fig. 1). Thirteen LCX grafts crossed the midline, an additional four came within 1 cm of it, and three were within 1 cm of the posterior table of the sternum. No RCA grafts crossed the midline but four were positioned within 1 cm of it, while seven were within 1 cm of the posterior sternum. We have identified eight patients in whom the ascending aorta was in close proximity (< 1 cm) of the posterior sternum, while the same was true for as many as 31 patients with respect to their right ventricle.

The mean distances of the vein grafts to the LCX and RCA territory from the midline and posterior table of the sternum, as well as the distance of the aorta and the right ventricle from the sternum are depicted in Table 3. The mean distances from the midline and the sternum of the four vein grafts to the LAD were 1.0 ± 1.7 and 1.8 ± 1.4 cm, respectively (Fig. 2). The single RIMA graft crossed the midline and was 0.6 cm beneath the sternum. Five out of six vein grafts to the diagonal branch crossed the midline and the mean distance from the posterior sternum was 2.0 ± 1.0 cm.

The chest CT provided additional insight into intrathoracic pathology. We identified atherosclerotic ascending aortic and aortic arch disease (Fig. 3) in 14 patients (42%). One patient was found to have an ascending aortic aneurysm. Atherosclerotic descending aortic disease was seen in three patients (9%). Coronary artery, aortic and mitral valve calcifications were seen in seven (21%), 11 (33%) and two (6%) patients, respectively. Pericardial thickening was seen in one (3%) and reflux of contrast into hepatic veins consistent with constrictive physiology in two (6%) patients. A persistent left superior vena cava, brachio-cephalic vein stenosis and superior vena caval stenosis were systemic venous abnormalities identified in three different patients (9.1%). Intracardiac pathology consistent with a left ventricular thrombus was diagnosed in one patient. Lung nodules, thyroid nodules and mediastinal lymphadenopathy were recognized in four (12%), one (3%) and five (15%) patients, respectively.

3.5. Comparison between CT angiography and chest X-ray findings

We compared the distances of vital structures to the sternum and the midline obtained from the chest CTA to those obtained by chest X-ray. The comparisons were only performed for those patients in whom the measurement could be obtained by both methods. The mean of individual differences between the distances of the LIMA-LAD graft from the midline and the posterior table of the sternum were 0.8 ± 0.6 and 0.9 ± 0.7 cm, respectively. The correlation coefficients for these distances were $R = 0.56$ and 0.49, respectively. The mean difference in the distance between the right ventricle and the sternum was 0.4 ± 0.5 cm, with a correlation coefficient of $R = 0.58$. The mean difference in the distances from the aorta to the posterior sternum obtained by CTA and CXR was 0.9 ± 0.6, with a correlation coefficient $R = 0.48$. The graphic representation of the statistical analyses is presented in Fig. 4.
3.6. Comparison between CTA and conventional angiography

Correlation coefficient methodology was used for statistical analysis of findings obtained from CTA and conventional angiography. The mean of individual differences between the distance of the LIMA–LAD graft to the midline was $0.8 \pm 0.5$ cm, with a calculated correlation coefficient of $R = 0.54$. The mean of differences in the distances of the LCX and RCA grafts from the midline were $0.6 \pm 0.7$ and $1.1 \pm 0.7$ cm, with the respective correlation coefficients being $R = -0.13$ and $0.43$. No comparison between the distances of the grafts, aorta or right ventricle to the posterior table of the sternum was made due to the inadequacy of conventional angiography in providing that information. The graphic summary of the statistical analysis is presented in Fig. 5.

Fig. 4. Correlation coefficient ($R$) analysis of CTA and CXR of the measured distances from the LIMA graft to the midline and the sternum as well as the RV and aorta to the sternum.

4. Discussion

The results of our study confirmed that CT angiography with volume rendering methods allows precise and reproducible localization of vital mediastinal structures in patients undergoing reoperative cardiac surgery. The results of preoperative imaging are superior to those obtained by left heart catheterization and two view chest X-ray. Chest computed tomography has been recognized as an effective tool for identifying patients at higher risk for injury to the aorta and right ventricle [3]. Catastrophic hemorrhagic events have been reported to occur in 2-6% of cases during sternal reentry with the stated mortality of 37% [4]. The incidence of left internal mammary artery graft injury during sternal reentry has been reported to range from 5 to 38% [5–9]. In the largest reported series the injury to the LIMA graft was followed by the evolution of a perioperative infarction in 40% of patients [6]. None of the patients in our study have suffered an injury to the LIMA graft, as a result of improved preoperative visualization of the mediastinal anatomy.

The traditional way of assessing the risk of graft, right ventricle or aortic injury during redo sternotomy has been by combining the findings of the coronary angiography and chest X-ray. We have found that in one-third of patients the chest X-ray failed to provide both the distance of the LIMA-LAD graft from the midline and the posterior sternum. The position of the aorta and the right ventricle remained unknown from the evaluation of the chest X-ray in 3/32 patients. The grounds for these deficits were the paucity or complete lack of hemoclips used for the left internal mammary artery branches as well as radiographic superposition of pacemaker generators or soft tissues. We have, also, found that the chest X-ray alone offers little information about any other graft other than the LAD graft. Its ability to project the position of a graft is solely dependent on the availability of hemoclips. The estimation of the distance of other vital structures from the posterior table of the sternum is often hindered by radiographic superposition of various obstacles. Coronary angiography grants us crucial information about the patency of previously positioned coronary bypass grafts, and remains the gold standard in this respect. The advances in computed tomographic technology have led to substantial improvement in non-invasive imaging of the coronary arteries. The limitation of CT angiographic evaluation of native coronary arteries are related to motion artifacts, its dependence upon a regular and lower heart rate and patient compliance in suppression of respirations [10,11]. It also remains less reliable than conventional coronary angiography in the evaluation of distal coronary arteries as well as the left circumflex territory. Conventional coronary angiography, however, often provides insufficient clues as to the position of coronary artery bypass grafts, as documented by low correlation coefficients when comparing these measurements with those obtained by CT angiography. The widespread uses of anterior oblique projections have made lateral and anterior-posterior (A-P) projections obsolete. The lack of lateral and A-P projections, however, makes assessment of the intrathoracic topography of coronary
grafts difficult. Catheter angiography overestimated the number of LIMA grafts that crossed the midline, in our study. We were unable to assess the distance of the grafts to the posterior table of the sternum in all but two patients. We found that three vein grafts were not assessable in their distance from the midline because of the lack of anatomical landmarks visible in the projections used to portray the grafts. Complete coronary angiography with lateral projections represents a useful imaging modality for the assessment of the position of patent grafts in relationship to the chest wall. A minority of patients in our study, however, had a complete angiogram that included lateral projections. Although this problem can be avoided through appropriate communication between the surgeon and the cardiologist, it is often difficult to accomplish for patients who are catheterized at other institutions and than referred for surgery. We do feel that the precise assessment of the position of patent grafts is more accurate using CT angiography. Furthermore, CT angiography provides additional important anatomic information regarding the relationship of other mediastinal structures, i.e. right ventricle, aorta and innominate vein, to the chest wall.

We found that in as many 85% of patients (28/33) we were unable to obtain all pertinent topographic information about vital mediastinal structures from the standard methods of evaluation.

The operative strategy was influenced by accurate positioning of the grafts in seven patients (21%). We have opted to use a right thoracotomy approach rather than a median sternotomy in a patient requiring aortic and mitral valve replacements because his LIMA graft was in close proximity to the posterior table of the sternum and the midline. Right thoracotomy was used in another patient requiring isolated aortic valve replacement because of the potential LIMA graft injury. In two patients we have documented that safe entry via a median sternotomy was feasible for reoperative mitral valve surgery. In two patients we decided to avoid redo coronary artery revascularization because both patients had only patent LAD grafts which crossed the midline. We felt that the risk of injury to these grafts was prohibitively high. In one patient with two arterial grafts which both crossed the midline the mitral and aortic valve pathology was addressed through a left thoracotomy, rather than a sternotomy.

The expected mortality in our group of patients was 25±22%. We believe that the modification of standard surgical approaches for patients requiring redo cardiac surgery contributed to the fact that the observed mortality of 17% in the studied group was lower than expected. None of the patients in our study suffered injury to the left internal mammary artery graft, which is an event that carries potentially catastrophic consequences.

In conclusion, this study confirms that both the chest X-ray and the conventional angiography provide only an estimate of the position of the grafts from the midline and from the posterior table of the sternum. In contrast, the computed tomographic images provide an accurate assessment of the position of various mediastinal vital structures. The chest CT provides invaluable information about the relationships of the patent grafts, right ventricle and aorta to the posterior table of the sternum. In addition, CT angiography provides accurate assessment of the atherosclerotic burden of the thoracic aorta, which represents relevant information for preoperative risk assessment and definition of surgical strategy. The data relating to the position of mediastinal structures from the conventional angiography and chest radiography are both deficient and inexact. In selected patients CTA justifies revisions of the standard surgical strategy and it should, therefore, be implemented into the routine preoperative evaluation of cardiac surgical patients with previous CABG.

References