Preoperative 3D-Reconstructions of Ultrafast-CT Images for the Planning of Minimally Invasive Direct Coronary Artery Bypass Operation (MIDCAB)

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ABSTRACT

Background: The direct left internal mammary artery (LIMA) bypass to the left anterior descending (LAD) without the use of extracorporal circulation through a small anterolateral thoracotomy has become established among the minimally invasive techniques in cardiac surgery. Technical difficulties may occur in patients with an enlarged left ventricle and subsequent lateral positioning of the LAD, a small LAD, or a small LIMA. We used electron beam tomography (EBT) for preoperative visualization of the topographical structures to seek out patients with potential technical difficulties.

Methods: Eighteen patients, mean age 62 ± 13 years, were entered in this study; in all cases the indication for revascularization was a significant stenosis of the LAD. Preoperatively an ECG-triggered EBT was performed. Following the image acquisition, a three-dimensional reconstruction of the data was performed. The LIMA, LAD, first diagonal branch, and chest wall were stained different colors for better visualization. Surgery was performed using a left anterolateral mini-thoracotomy and through this access, the LIMA was dissected and anastomosed using a stabilizer without the use of extracorporal circulation.

Results: In all but one of the 18 patients who had a preoperative EBT, the minimally invasive direct coronary artery bypass (MIDCAB) procedure was successfully performed using an anterolateral mini-thoracotomy. Based on the results of the EBT, the 5 centimeter incision was done parasternally in six patients, and more laterally (2–4 cm parasternally) in the other eleven cases. In 13 patients the access penetrated the fourth intercostal space; in four cases the fifth intercostal space was used. In one patient EBT revealed a very laterally positioned and diffusely arteriosclerotic LAD so the patient was operated using a median sternotomy, but without the use of extracorporal circulation. In all 18 patients the preoperatively acquired information of the anatomical topography was confirmed intraoperatively. One case without a preoperative EBT had to be converted to a conventional procedure due to a small, intramyocardial LAD and a very small LIMA. Postoperative angiography revealed patent LIMA grafts and uneventful anastomoses.

Conclusions: For minimally invasive direct coronary artery bypass (MIDCAB) the topography of the LIMA, LAD and intercostal spaces is of major importance. Using the ECG-triggered EBT with subsequent three-dimensional reconstruction these relationships can be visualized. This enables an individual planning of the operation and a minimalization of the skin incision.

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INTRODUCTION

The direct left internal mammary artery (LIMA) bypass to the left anterior descending (LAD) or to the first diagonal branch, through a small anterolateral thoracotomy

Figure 1. Sectional image showing the short distance between LAD and LIMA (arrows).

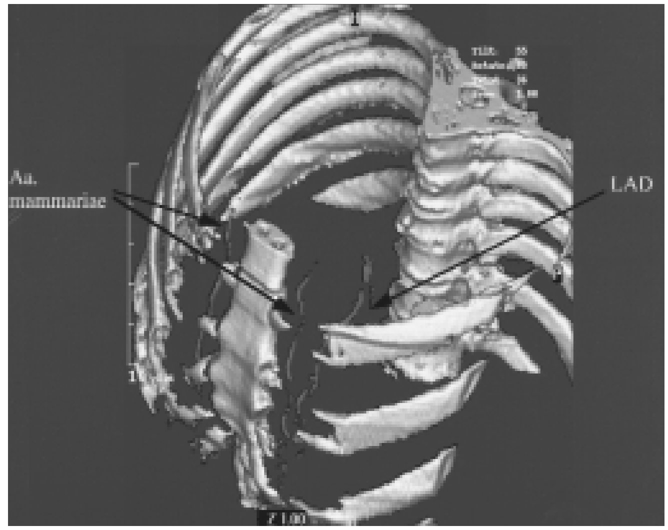

Figure 2. 3D-reconstruction of ribs, LIMA and LAD.

without the use of extracorporal circulation is a new minimally invasive technique in cardiac surgery [Garrett 1997, Alessandrini 1997, Izzat 1997, Mariani 1997, Cremer 1997, Calafiore 1997, Stanbridge 1997, Mishra 1997, Acuff 1996]. As the full length of the LIMA cannot always be dissected through the small access of a skin incision (approximately 5 cm), technical difficulties may occur in patients with an intramyocardial LAD or an enlarged left ventricle and subsequent lateral positioning of the LAD. Another potential problem can be caused by a small LIMA, necessitating a venous aorto-coronary bypass [Alessandrini 1997, Calafiore 1997]; this can be performed through the same incision only by using the Port-Access method [Reichenspurner 1997, Gulielmos 1997], thus avoiding a median sternotomy. Both approaches should be planned and discussed with the patient preoperatively. Therefore it would be very helpful to have a diagnostic tool to clear the topographical situation preoperatively for the planning of the minimally invasive direct coronary artery bypass operation (MIDCAB). Electron beam tomography (EBT) has been shown to be effective in detecting coronary calcifications, imaging of epicardial vessels and coronary artery stenoses, and evaluating coronary artery bypass graft patency, respectively [Moshage 1997, Knez 1996, Hernigou 1996, Schmermund 1996, Achenbach 1996]. We used EBT for preoperative visualization of the LAD, LIMA and the chest wall in planning MIDCAB procedures.

MATERIALS AND METHODS

Eighteen patients, whose indications for revascularization were posed by significant stenosis of the LAD, were entered into this study. Mean patient age was 62 ± 13 years. An ECG-triggered electron beam tomography (Ultrafast-CT, EBT) was performed preoperatively in each case, using the Imatron 100C scanner. An electron beam was focused by an electromagnetic field and sent to four target rings surrounding the patient. X-rays were produced when this electron beam hit these wolfram anodes. Two detectors positioned on opposite sides of the anodes registered these x-rays. Using scan-times between 50 and 100 ms, all ECG-triggered images were received at exactly the same heart cycle. The images were triggered to the mid-diastole with an 80% R-R interval in single-breath-hold technique. This led to a high temporal and spatial resolution with nearly motion-free images and thus only a few artifacts. The sections were started at the thoracic inlet; about 50 to 55 consecutive sectional images were acquired. Slice thickness was 3 mm; scan time was100 ms. Contrast media was continuously administered with a flow rate of 3 mL/s for a total dose of about 160 milliliters. Using a matrix of 512 x 512 and a field of view of 21 cm, the pixel size was 0.17 mm^2.

Following the image acquisition, the distance between the LAD and the mammary artery was measured in the corresponding sectional image. Three-dimensional reconstruction of the data was then performed on a work station (Magic View, Siemens AG, Erlangen). It was essential to overview the entire LAD angiographically in order to plan the location of the anastomosis.

For better visualization of the individual structures, the LAD, LIMA, and the chest wall were stained different colors (the vessels in red and the thorax in yellow). In these pictures, measurements of the distances between the structures were also possible. It took about 15 minutes to achieve bi-colored 3D-reconstruction, whereas the colored reconstruction required an average of 45 minutes.

Surgery was performed using a left anterolateral mini-thoracotomy with a skin incision of about 5–6 cm. The lateral placement of this incision depended on the results of the preoperative EBT. Also based on the results of the preoperative EBT, either the fourth or the fifth intercostal space was chosen. Through this access the LIMA was dissected. Then the pericardium was opened and the LAD prepared for the anastomosis. The anastomosis was per-

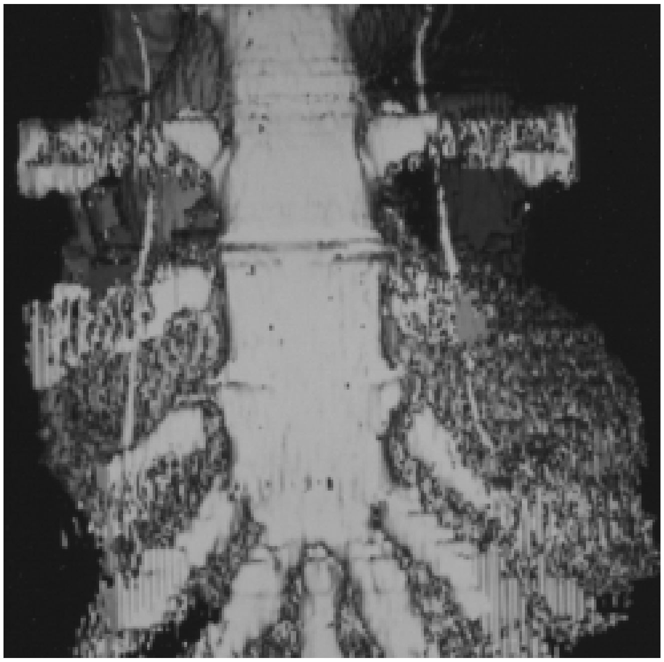

Figure 3. 3D-surface reconstruction showing both internal mammary arteries.

formed using a pressure stabilizer (CTS, Cardiothoracic Systems, Cupertino, CA) in a blood-free technique. The whole procedure was done without the use of extracorporal circulation. Postoperative angiographic follow-up was complete in all cases.

RESULTS

It was technically possible to visualize the topographic anatomy within the chests of all 18 patients by the EBT, and to measure the distance between the LIMA and the LAD using the sectional images (see Figure 1 ◎). The stained images provided a clear three-dimensional view of the chest wall, the bones, and the LAD (see Figure 2 ◎).

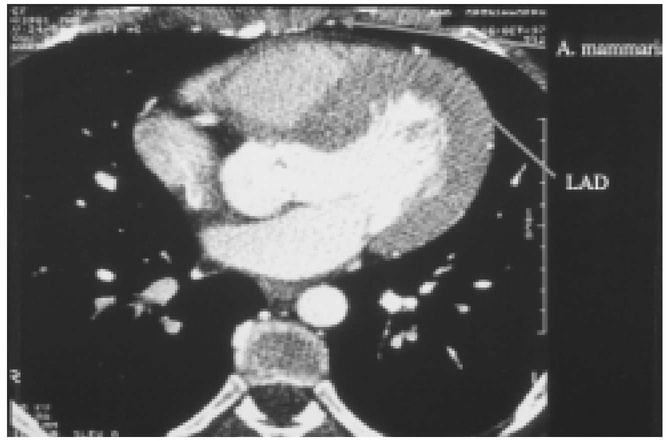

Figure 4. Sectional image of a patient with laterally positioned epicardial LAD (arrows).

The three-dimensional reconstruction can be rotated 360 degrees. In the frontal view, both mammary arteries can be visualized perfectly (see Figure 3 ◎).

In one patient a lateral positioning of the LAD was detected (see Figures 4 and 5 ◎); the diffusely diseased LAD was buried in epicardial fat mass and ran partially intramyocardially. In this case we decided to use a median sternotomy. Intraoperatively the findings were confirmed. The LIMA was dissected in the routinely used manner. The anastomosis to the LAD was then performed in a bloodless technique with a suction-stabilizer (Octopus, Medtronic GmbH, Düsseldorf) and without the use of extracorporal circulation.

In another patient without a preoperative EBT, a very small LIMA and a small, intramyocardial LAD were found intraoperatively. The findings led to a conversion to a median sternotomy in this case. An aorto-coronary venous bypass to the LAD was then performed using a saphenous vein graft. Postoperative EBT revealed an uneventful bypass and confirmed the intramyocardial run of the LAD (see Figure 6 ◎).

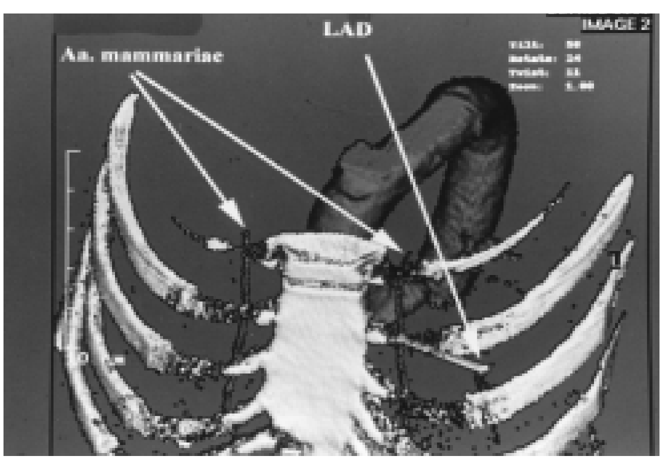

Figure 5. Laterally positioned LAD. The measured distance between the LAD and LIMA is approximately 5 cm.

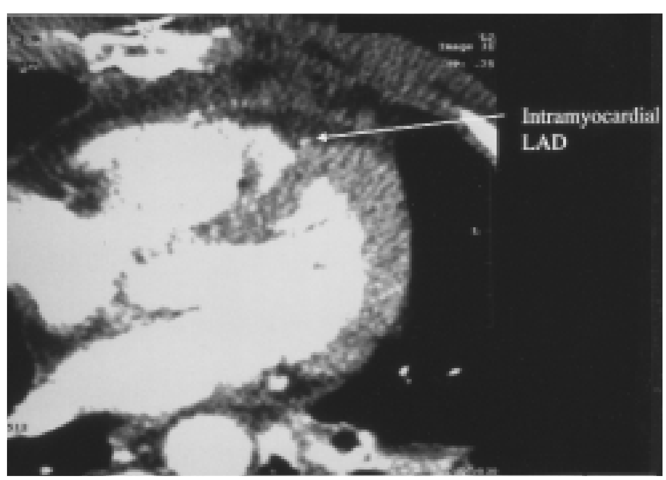

Figure 6. Intramyocardial LAD.

Table 1. Localization of the skin incision and the penetrated intercostal space. The decision depended on the information acquired preoperatively by the EBT.

Distribution of the incisions to the different localizations		
	Incision parasternally	Incision approx. 4 cm lat.
4. ICR	6	7
5. ICR	0	4

In all other 17 patients a LIMA bypass was performed through a left anterolateral mini-thoracotomy. In patients with a preoperative EBT the surgical access was planned based on the results of the EBT and on the localization of the stenosis discovered in the angiography. In thirteen patients the fourth intercostal space was penetrated, and in four patients the fifth intercostal space was used (see Table 1). The placement of the incision depended on the relation of the planned position of the anastomosis to the intercostal spaces. In six patients the incision was made parasternally; in eleven patients it was placed more laterally (about 2-4 cm parasternally). Positioning depended on the distances between the LIMA and LAD in the three-dimensional reconstruction of the EBT and the corresponding sectional images.

Calcifications within the LAD were detected in five patients by EBT. These calcified plaques were not localized in the planned anastomosis area in any case, so surgery was not affected by these findings.

In none of the 18 cases with a preoperative EBT was an intraoperative conversion to a conventional procedure necessary. All patients tolerated the operation without extracorporal circulation. On perioperative ECG only slight reversible changes in the repolarization were seen, and none of the patients showed a rise of the CK above 400 U/l and/or CK-MB above 6% of total CK. In all 18 patients the preoperatively achieved information about the anatomical topography was confirmed intraoperatively. Postoperative angiography revealed patent LIMA grafts and uneventful anastomoses in all cases.

DISCUSSION

For the success of the MIDCAB procedure the topographic correlations between LAD, LIMA, and the intercostal spaces are very important. With the use of the EBT there exists a diagnostic tool that can visualize the structures of the chest including epicardial vessels and mammary arteries [Moshage 1997, Schmermund 1996, Achenbach 1996]. The distances between the LAD and LIMA within different intercostal spaces can be measured and, using three-dimensional reconstruction, the topographic anatomy can be demonstrated. The structures can be stained different colors, e.g., the vessels in red and the chest wall in yellow. Since bi-colored 3D-reconstruction is achieved in about 15 minutes and in combination with the sectional images, it provides valid information and can be used as part of clinical routine.

When a MIDCAB procedure is planned, it is possible to use the EBT to detect cases with potential technical difficultiesand modify the procedure before the actual surgery. Cases with a laterally positioned, small and diffusely diseased LAD, a small LIMA, heavy epicardial fat mass or an intramyocardial LAD, may require an enlargement of the skin incision, an additional incision in the adjacent intercostal space or even an intraoperative conversion to a median sternotomy [Calafiore 1997].

In our study, the selection of both the intercostal space and the position and length of the skin incision depended on the preoperative EBT results. Our goals were to optimize the access and to reduce surgical trauma. In all cases the findings of the EBT were confirmed intraoperatively and there was no need for an intraoperative conversion or additional skin incision.

In addition, EBT is sensitive enough to detect calcifications and therefore allows the localization of calcified plaques within the epicardial vessels. This information might also be important in planning the MIDCAB procedure and in selecting the site of the anastomosis.

We conclude that EBT (especially visualization of the epicardial vessels in relation to the LIMA) is a very useful tool for the planning of MIDCAB procedures. It enables an individualized positioning of the skin incision and can minimize the risk of intraoperatively-occurring technical difficulties caused by the topographic anatomy.

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