Differences in LIMA Doppler characteristics for different LAD perfusion areas

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Abstract

Objectives: To correlate supraclavicular left internal mammary artery (LIMA) to left anterior descending artery (LAD) area Doppler characteristics with angiographically perfused area. Methods: Sixty patients (50 male, mean age 62 ± 7.3 years) with LIMA to LAD area grafting were prospectively entered in a follow up study. Supraclavicular echo Doppler of the LIMA was studied at the LIMA origin preoperatively, and at 4.8 ± 3 months and 1.8 ± 0.9 years postoperatively. The potential area to be revascularized judged from preoperative angiography was called the ‘target’ area. Control angiography (native and LIMA) was done at 1.5 ± 0.9 years. The perfused area % was classified into group I ≤17.0% (n = 16), group II >17.0% and <22.50% (n = 17), and group III ≥22.50% (n = 18) and related to LIMA Doppler characteristics. Multivariate linear regression analyses (MLRA) were performed to assess the relations between Doppler variables and the perfused area, target area and ratio of perfused/target area. Results: At MLRA perfused area was significantly related to the natural logarithm of diastolic peak velocity (DPV) (P = 0.013) and diastolic mean velocity (P = 0.048) and the ratio only to the degree of LAD stenosis (P = 0.004). In hyperaemic response maximal DPV (DPV max) showed significant correlation to the perfused area (P = 0.005) as well as to the ratio (P = 0.017). When analyzing the additive power of both investigations, only DPV max (P = 0.005) correlated significantly to the perfused area and for the ratio only the degree of stenosis of the LAD emerged as significant (P = 0.004). Conclusions: At MLRA the diastolic flow pattern at rest and the maximal DPV in hyperaemic response correlated significantly with the LIMA run-off area whereas the last variable is the strongest predictor of the LIMA run-off area. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Left internal mammary artery; Doppler characteristics; Left anterior descending artery

1. Introduction

The internal mammary artery (IMA) is the conduit of choice for single or sequential coronary artery revascularization in view of its long term patency [1–3]. In this regard postoperative control angiography is the gold standard for assessing IMA graft patency. Over the last years transthoracic echo Doppler has become a frequently used non-invasive method for postoperative assessment of the IMA graft patency. The IMA origin is close to the chest wall and can be detected at its origin or in the first or second intercostal space in order to evaluate IMA graft patency by Doppler velocity characteristics [4–6].

Differences in postoperative transthoracic echo Doppler velocity spectra caused by different degrees of left anterior descending artery (LAD) stenosis have already been described [7]. We analyzed whether left IMA (LIMA) Doppler velocity characteristics at late follow up at rest and in hyperaemic response correlate with perfusion areas, as determined at late postoperative angiography, in order to assess the reliability of echo Doppler studies as a non-invasive method for functional assessment of IMA grafts.

2. Materials and methods

Sixty consecutive patients (50 male, ten female, mean age 61.8 ± 7.3 years) who planned to undergo LIMA bypass surgery to the LAD area were prospectively entered in a follow up study. Exclusion criteria included an age of over 75 years, urgent coronary artery bypass surgery, patients with transmural infarction of the LAD perfusion area, previous LIMA grafting, serious co-morbidity (malign-

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nancy, previous radiation treatment of the chest), subclavian artery stenosis and other combined cardiac surgery. Informed consent was obtained from all patients. Aiming at total revascularization of the LAD area, all graftable and significantly stenotic diagonal branches were bypassed as well with the LIMA pedicle.

In each patient the LIMA was investigated at its origin shortly before the operation and twice postoperatively at 4.8 ± 3.8 months and 1.8 ± 0.9 years. At late follow up examination the echo Doppler analyses were performed at rest for 1 min and in hyperaemic response for 6 min to obtain a pulsed wave echo Doppler velocity pattern of the LIMA. For the purpose of this study we analyzed only patients in whom all LIMA velocity patterns were obtained from the supraclavicular approach.

Postoperative control angiography was performed at 1.5 ± 0.9 years. The angiograms were analyzed by two independent observers and assessed for the following aspects: native coronary artery stenosis [8], patency and proximal diameter of the LIMA grafts, percentage stenosis of distal anastomoses and native vessel competitive flow in the LIMA perfusion areas. Diameters of the proximal LIMA at angiography and of the tip of the catheter with a known diameter used for LIMA visualization were determined by callipers.

In order to assess perfusion areas, the perfused areas at angiography were drawn on a graded left ventricular surface map. This map was constructed according to the ventricular-slice method described by Edwards et al. [9]. The proportional importance of the anterolateral, posterolateral and septal area as well as the subdivisions in proximal, middle and distal areas were based on analyses performed in five specimens in the Department of Pathology of the St. Antonius Hospital, Nieuwegein, The Netherlands. The obtained subdivisions of 33, 15, 11 and 7% were also extensively used and tested in studies on surface estimation for assessing left ventricular endocardial resection in postinfarction arrhythmia surgery [10] (Fig. 1).

As only anteroseptal areas were compared one can assume that between groups systematic deviation would be balanced. The same is true for transformation of areas into muscle mass: between groups no differences were present regarding the presence of hypertension and/or left ventricular hypertrophy; no patients with transmural anteroseptal infarction were included and any systematic under- or overestimation would probably be balanced within the subgroups analyzed. The ‘target’ area was the potential area intended to be revascularized by the LIMA graft as judged from the preoperative coronary angiography.

During late postoperative native and LIMA angiography the ‘perfusion’ area was drawn on the surface map and expressed as surface percentage. At both injections competitive flow was visually assessed by two independent observers looking at to and fro movements of contrast. The perfused area was the surface percentage obtained on repetitive estimations by adding two perfusion areas: the one exclusively filled at the LIMA injections counted for 100% and the competitive area – filled as well at the LAD as at the LIMA injection – was estimated to belong to the LIMA perfusion area for 0–100% depending on the severity of competition. The investigators grading the perfusion areas were blinded for the results obtained with the Doppler data analysis. Perfused areas served to classify patients into three almost equally sized groups: group I with a perfused area less than or equal to 17%; group II with a perfused area between 17.0 and 22.5%; and group III with a perfused area greater than or equal to 22.5%.

Group I consisted of 16 patients (12 male, four female, mean age 66.4 ± 4.5 years) with six single LIMA to LAD, eight LIMA jump grafts to the LAD area and two LIMA triple jump grafts to the LAD area. In group II were 17 patients (12 male, five female, mean age 57.8 ± 7.5 years) with four single LIMA to LAD, ten LIMA jump grafts to the LAD area and three LIMA triple jump grafts to the LAD area. In group III were 18 patients (17 male, one female, mean age 60.3 ± 7.1 years) with four single LIMA to LAD, 12 LIMA jump grafts to the LAD area and two LIMA triple jump grafts to the LAD area.

Nine patients were excluded from the study. In six patients the late postoperative echo Doppler investigation was not performed and in three patients technical failures in detecting echo Doppler signals occurred during the hyperaemic study.

2.1. Echo Doppler technique

Initially we used a model Sonos 2000 (Hewlett Packard, Andover, MA) and later a Sonos 2500 (Hewlett Packard, Andover, MA) duplex scanner that both combined B-mode imaging and pulsed Doppler ultrasound to evaluate blood velocity parameters of the LIMA. The echo Doppler investigation was performed with the patients in the supine position under continuous electrocardiographic and blood pressure control after 3 min of resting.
A 7.5 MHz sector scanner was held at an angle of approximately 60° of the long axis of the LIMA at the origin and software with correction for the angle of insonation was used. Only values obtained from the supraclavicular approach were used for the evaluation. The diameter of the proximal LIMA was also determined only at rest.

Spectral analysis of IMA Doppler velocity recording was performed during three to five cardiac cycles. The data of velocity parameters were analyzed off-line. The intraobserver variability was tested and was less than 2%.

Patients were allowed to use their usual medication except on the day of late postoperative echo Doppler study because of the hyperaemic response test. Before adenosine infusion was started the LIMA was localized at the origin and resting values were determined. After 1 min, adenosine infusion (0.14 mg/kg per min) was started for 6 min. Every minute echo Doppler characteristics and electrocardiograms were recorded. Of all Doppler registrations the following parameters were analyzed: diastolic and systolic peak velocity (DPV and SPV), diastolic, systolic and total mean velocity (DMV, SMV and TMV) and diastolic, systolic and total velocity integral (DVI, SVI and TVI).

The velocity–time integral is the integral of the Doppler spectral instantaneous velocity (V) over the time interval (T) [6,11].

DMV, SMV and TMV are calculated as the averaged instantaneous mean of three to five cardiac cycles by manual tracing of the appropriate phasic velocity spectra.

2.2. Statistical analysis

Data entry, descriptive statistics and univariate statistical analyses were performed with the use of Epi Info 6.04c (CDC, Atlanta, GA). Non-parametric tests and multivariate linear regression analyses were performed with the use of SAS 8 (SAS Institute Inc., Cary, NC). Within groups linear regression analyses were performed with the use of Epi Info 6.04c (CDC, Atlanta, GA). Non-parametric tests and multivariate analyses were performed with the use of Epi Info 6.04c (CDC, Atlanta, GA).

The velocity–time integral is the integral of the Doppler spectral instantaneous velocity (V) over the time interval (T) [6,11].

Coronary angiography was performed 3.6 ± 3.0 months before operation. The degrees of native coronary vessel stenosis of the anterior wall are shown in Table 1. The target areas of the three subgroups were larger than the perfused areas as expected and were not statistically different between the three groups.

3. Results

3.1. Preoperative coronary angiography

Coronary angiography was performed 3.6 ± 3.0 months before operation. The degrees of native coronary vessel stenosis of the anterior wall are shown in Table 1. The target areas of the three subgroups were larger than the perfused areas as expected and were not statistically different between the three groups.

3.2. Early postoperative echo Doppler

The time interval between surgery and the early postoperative transthoracic echo Doppler evaluation was not different between the groups (P = 0.88). All patients were in sinus rhythm. No patients presented angina and no intercurrent infarction occurred. The mean proximal LIMA diameters were 2.69 ± 0.56 mm and were statistically significantly smaller than preoperative (P = 0.0012).

All diastolic echo Doppler velocity parameters increased significantly and all systolic parameters decreased significantly compared to the preoperative echo Doppler values while the total velocity integral did not change. These preoperative data are not included because they were not part of the present analysis. All early postoperative echo Doppler values are incorporated in Table 2.

3.3. Postoperative control angiography

The postoperative control angiography was performed 1.5 ± 0.9, 1.3 ± 0.5 and 1.7 ± 1.2 years after operation in groups I, II and III, respectively. The time intervals between late control angiography and operation (P = 0.51), late postoperative echo Doppler (P = 0.83) and preoperative angiography (P = 0.63) did not differ significantly between the groups. All LIMA grafts except one were selectively injected. All grafts were patent. The degrees of postoperative native coronary vessel stenoses of the anterior wall are shown in Table 1. The mean proximal LIMA diameter was 3.10 ± 0.64 mm.

3.4. Late postoperative echo Doppler

In all patients echo Doppler detection at the origin was successful and all signals could be used. The time interval between surgery and late supraclavicular echo Doppler evaluation was 1.8 ± 0.9, 1.8 ± 0.7 and 1.9 ± 1.1 years in groups I, II and III, respectively (P = 0.92). All patients were in sinus rhythm. The mean proximal LIMA diameter was 2.58 ± 0.75 mm and was significantly smaller than the early postoperative echo Doppler diameters (P = 0.03). The correlation coefficient of the proximal LIMA diameters between the control angiography and late postoperative echo Doppler was poor (0.13).

Supraclavicular echo Doppler values at rest and at hyper-
3.4.1. Echo Doppler at rest

At late echo Doppler some values increased significantly but inconsistently. At univariate analysis perfused areas as defined in the three subgroups were related significantly to the DMV, SPV, SMV and TMV (Table 2). Multivariate linear regression analysis showed significant differences for age \( (P = 0.048) \), smoking history \( (P = 0.039) \) and hypertension \( (P = 0.033) \) in group II versus groups I and III.

At analysis of the relationship between the individual perfused area and the Doppler characteristics with multivariate linear regression the following factors were entered:

### Table 2

**Early and late postoperative values of supraclavicular LIMA echo Doppler parameters**

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early postoperative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPV (cm/s)</td>
<td>34.5 ± 16.5</td>
<td>31.3 ± 9.2</td>
<td>34.7 ± 14.0</td>
<td>NS</td>
</tr>
<tr>
<td>DVI (cm)</td>
<td>12.1 ± 5.5</td>
<td>11.0 ± 4.6</td>
<td>10.6 ± 4.7</td>
<td>NS</td>
</tr>
<tr>
<td>DMV (cm/s)</td>
<td>23.1 ± 11.1</td>
<td>22.3 ± 6.9</td>
<td>22.3 ± 9.8</td>
<td>NS</td>
</tr>
<tr>
<td>SPV (cm/s)</td>
<td>54.2 ± 14.7</td>
<td>56.2 ± 17.1</td>
<td>50.5 ± 21.2</td>
<td>NS</td>
</tr>
<tr>
<td>SVI (cm)</td>
<td>9.3 ± 2.1</td>
<td>9.3 ± 3.5</td>
<td>8.5 ± 3.2</td>
<td>NS</td>
</tr>
<tr>
<td>SMV (cm/s)</td>
<td>32.8 ± 7.1</td>
<td>32.8 ± 11.0</td>
<td>30.7 ± 10.9</td>
<td>NS</td>
</tr>
<tr>
<td>TVI (cm)</td>
<td>21.5 ± 7.3</td>
<td>20.2 ± 7.3</td>
<td>19.1 ± 7.2</td>
<td>NS</td>
</tr>
<tr>
<td>TMV (cm/s)</td>
<td>26.4 ± 9.6</td>
<td>26.0 ± 7.5</td>
<td>25.5 ± 9.7</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Late postoperative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DPV (cm/s)</td>
<td>29.8 ± 14.5</td>
<td>42.0 ± 16.3*</td>
<td>35.7 ± 10.8</td>
<td>NS</td>
</tr>
<tr>
<td>DVI (cm)</td>
<td>11.3 ± 6.8</td>
<td>13.3 ± 4.8*</td>
<td>13.0 ± 3.7*</td>
<td>NS</td>
</tr>
<tr>
<td>DMV (cm/s)</td>
<td>21.2 ± 11.6</td>
<td>29.9 ± 11.1*</td>
<td>24.1 ± 7.3*</td>
<td>0.049</td>
</tr>
<tr>
<td>SPV (cm/s)</td>
<td>43.1 ± 18.0</td>
<td>64.0 ± 18.3*</td>
<td>49.0 ± 15.4*</td>
<td>0.003</td>
</tr>
<tr>
<td>SVI (cm)</td>
<td>9.0 ± 4.3</td>
<td>10.9 ± 3.8*</td>
<td>8.5 ± 2.5</td>
<td>NS</td>
</tr>
<tr>
<td>SMV (cm/s)</td>
<td>29.3 ± 11.9</td>
<td>38.1 ± 12.3*</td>
<td>29.1 ± 8.4</td>
<td>0.031</td>
</tr>
<tr>
<td>TVI (cm)</td>
<td>20.3 ± 10.5</td>
<td>24.1 ± 7.7*</td>
<td>21.6 ± 5.3</td>
<td>NS</td>
</tr>
<tr>
<td>TMV (cm/s)</td>
<td>24.1 ± 11.2</td>
<td>33.0 ± 10.8*</td>
<td>25.9 ± 7.0</td>
<td>0.027</td>
</tr>
</tbody>
</table>

* Groups I, II and III are as described in Table 1. **P < 0.05 within groups for late postoperative versus early postoperative values. \( P \) value, ANOVA \( P \)-test for differences between groups. Data are the mean ± standard deviation. NS, not significant.

### Table 3

**Maximal hyperaemic values of supraclavicular LIMA echo Doppler parameters**

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPV (cm/s)</td>
<td>86.0 ± 27.1</td>
<td>96.8 ± 30.4</td>
<td>110.6 ± 23.4</td>
<td>0.036</td>
</tr>
<tr>
<td>DVI (cm)</td>
<td>26.0 ± 11.4</td>
<td>26.9 ± 8.5</td>
<td>32.8 ± 10.1</td>
<td>NS</td>
</tr>
<tr>
<td>DMV (cm/s)</td>
<td>63.8 ± 24.2</td>
<td>71.9 ± 23.0</td>
<td>80.9 ± 20.0</td>
<td>NS</td>
</tr>
<tr>
<td>SPV (cm/s)</td>
<td>83.1 ± 21.2</td>
<td>92.2 ± 24.4</td>
<td>90.2 ± 22.3</td>
<td>NS</td>
</tr>
<tr>
<td>SVI (cm)</td>
<td>17.6 ± 4.8</td>
<td>18.2 ± 5.8</td>
<td>18.5 ± 5.0</td>
<td>NS</td>
</tr>
<tr>
<td>SMV (cm/s)</td>
<td>62.2 ± 17.3</td>
<td>68.1 ± 21.0</td>
<td>67.5 ± 17.2</td>
<td>NS</td>
</tr>
<tr>
<td>TVI (cm)</td>
<td>42.9 ± 15.5</td>
<td>44.6 ± 13.3</td>
<td>50.6 ± 12.7</td>
<td>NS</td>
</tr>
<tr>
<td>TMV (cm/s)</td>
<td>62.5 ± 20.5</td>
<td>70.4 ± 21.4</td>
<td>75.6 ± 17.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Groups I, II and III are as described in Table 1 and echo Doppler velocity parameters are as described in Table 2. \( P \) value, ANOVA \( P \)-test for differences between groups. Data are the mean ± standard deviation. NS, not significant.
absolute values. Between groups only diastolic peak velocity maximal hyperaemic values (DPV max) differ significantly: 86.0 ± 27.1 cm/s (group I) versus 96.8 ± 30.4 cm/s (group II) versus 110.6 ± 23.4 cm/s (group III) \((P = 0.036)\) (Table 3).

At multivariate linear regression analysis only maximal DPV (cm/s) was related to the perfused area in hyperaemic response. For the target area no single hyperaemic response factor was related. Again for the ratio perfused over target area only the maximal diastolic peak velocity emerged as significant (Table 4).

### 3.4.3. Analyses for combined values at rest and at maximal hyperaemic response

At multivariate linear regression analyses for parameters at rest and at maximal hyperaemic response only the DPV max (cm/s) was related to the perfused area. For the target area no factor was related. For the ratio perfused over target area only the degree of stenosis of the LAD emerged as significant (Table 4).

### 4. Discussion

We confirm that preoperative and postoperative LIMA velocity patterns can be obtained by echo Doppler from the supraclavicular approach in the majority of patients. This confirms findings by other groups [12,13]. Some investigators determined the LIMA diameter using echo Doppler from the supraclavicular fossa and transformed the velocity measurements into LIMA graft flow [6].

We agree with others [13–15] that it is difficult to reliably measure vessel diameter transcutaneously especially in small calibre vessels. We found a correlation coefficient of 0.13 between the control angiography and late postoperative echo Doppler for proximal LIMA diameter measurements. Therefore, we did not transform velocity data into flow and evaluated only the supraclavicular echo Doppler parameters of the LIMA pre- and postoperatively.

As described by other groups [16,17] preoperative trans-thoracic echo Doppler of the LIMA shows predominantly systolic velocity patterns as can be expected from a systemic artery and postoperatively LIMA echo Doppler characteristics show a shift towards diastolic coronary velocity spectra [4,17]. In all patients in our study systolic velocity parameters decreased and all diastolic velocity parameters increased significantly early postoperatively versus preoperatively. Although no early postoperative coronary angiogram was performed we concluded that all LIMA grafts were patent because all echo Dopplers showed these high diastolic velocity patterns and no patients presented angina [18]. In all patients control angiography was performed and LAD stenosis and perfused areas were analyzed quantitatively [8]. Leta Petracca et al. [19] reported that the presence of competitive flow or predominant native coronary arterial flow may lead to a predominantly systolic echo Doppler flow pattern. Evaluating our postoperative control angiograms revealed large competitive coronary flow in some patients. Therefore, we graded perfusion areas and analyzed the target as well as the perfused areas in which we visually accounted for the competitive flow. We explored the correlation between echo Doppler velocity parameters with LIMA target areas as well as the perfused areas – corrected for competitive flow – at late postoperative angiographic follow up. To our knowledge this has never been reported previously.
We evaluated hyperaemic response, a measure of coronary reserve, and correlated maximal hyperaemic response values to values at rest and to the perfused areas. We estimated the predicting parameters at rest as well as at maximal hyperaemic response in order to determine if analysis at hyperaemic response added any additional information to analysis at rest.

All systolic, diastolic and total velocity parameters increased significantly during adenosine infusion compared to baseline values within all groups. The increase in diastolic parameters was more pronounced compared to the other parameters.

We found a significant correlation between two diastolic echo Doppler parameters at rest (natural logarithm of DPV and DMV) and the perfused area indicating that the diastolic flow pattern was correlated with the LIMA run-off area even after correction for competitive flow. The target area was not significantly related with diastolic parameters. Looking at the ratio of perfused over target area the only determinant was the percentage LAD stenosis at late angiography. Hence, notwithstanding variable flow competition our data demonstrated that these diastolic Doppler parameters at rest are related to the actual perfusion area.

At the maximal hyperaemic response by adenosine infusion the perfused area correlated significantly with maximal diastolic peak velocity while no factor could significantly predict the target area. However, the ratio of perfused over target area was not further significantly related to the degree of LAD stenosis but showed a correlation with the maximal diastolic hyperaemic velocity.

Looking at the resting as well as the hyperaemic echo Doppler parameters the maximal diastolic peak velocity remained the only significant predictor of the perfused areas. Hence, adenosine testing response reinforces the correlation between diastolic velocity parameters and the perfused area. Even though the competitive flow is determined by the degree of LAD stenosis the diastolic Doppler parameters remain significantly related with the perfused area. This supports the validity of echo Doppler as a tool to investigate and follow patients with LIMA revascularization of the anterior myocardium.

Our study does not allow anatomical remodelling to be determined [20] as only the proximal diameter of the LIMA was investigated and in our findings a further decrease rather than an increase in diameter was found between both Doppler investigations.

During adenosine testing we did not study instantaneous changes in the proximal LIMA diameter. However, according to our findings in adenosine testing all Doppler velocity parameters doubled their absolute values with a stronger diastolic hyperaemic response, expressing the instantaneous ‘flow’ increase, which can be considered the expression of the ‘functional’ remodelling. At maximal hyperaemic response the ratio of perfused over target area was not further determined by the degree of stenosis of the LAD suggesting that the increased LAD % stenosis at follow up angiography, which was severe in all patients, could be a limiting factor for native flow competition at hyperaemia.

Our study does not allow us to distinguish between instantaneous ‘flow’ increase related to coronary reserve or increased perfusion area at hyperaemia.

5. Conclusions

Pre- and postoperative LIMA velocity patterns can be obtained by echo Doppler from the supraclavicular approach in the majority of patients. LIMA Doppler characteristics show postoperatively a shift towards coronary Doppler velocity spectra. All echo Doppler parameters increased significantly during adenosine infusion compared to baseline values and the increase of the diastolic parameters was more pronounced.

At multivariate linear regression analyses the diastolic flow pattern at rest and the maximal diastolic peak velocity in hyperaemic response correlated significantly with the LIMA run-off area. Maximal diastolic peak velocity in hyperaemic response is the strongest predictor in determining the LIMA run-off area.

Acknowledgements

This study was funded by The Netherlands Heart Foundation Grant 89.258.

References

Appendix A. Conference discussion

Dr D. Bimmel (Bonn, Germany): What kind of operation did you perform, was it a MIDCAB LIMA to LAD?

Dr Hartman: No, just a conventional LIMA to LAD with extracorporeal circulation.

Dr Bimmel: How did you prepare the LIMA, up to the angle, because I am not quite sure how you can catch the Doppler signal?

Dr Hartman: The preparing technique of the LIMA does not have any influence in finding the Doppler signal from the supraclavicular fossa. The patients are lying down and with the probe well positioned in the supraclavicular fossa you can find the long axis of the LIMA at an angle of approximately 60 degrees.

Dr Bimmel: I just have a supplementary question. How did you differentiate the signal preoperatively to be the signal of the subclavian artery and not that of the mammary artery?

Dr Hartman: This is determined by the diameter of the vessel you are looking for. You are looking for a small caliber vessel. There are some technical clues. First you find the subclavian artery. The first side branch directing to cranial is the vertebral artery. Following the subclavian artery to distal with the small subclavian arch, the first side branch directing caudal is the left internal mammary artery.

Dr F. Wellens (Aalst, Germany): What is the clinical implementation in daily practice of this approach?

Dr Hartman: To demonstrate with a non-invasive method LIMA graft patency. Furthermore we demonstrated that in large LIMA perfusion areas with the LIMA large diastolic velocity parameters can be accomplished. This indicates that there is adequate support for the LIMA graft in sequential grafting or large perfusion areas. We are aware of the fact that the follow up was 1.8 years and additional and longer follow up is needed for further conclusions.