Noninvasive Doppler Ultrasound Evaluation of Aortocoronary Bypass

J. Fabián, M.D., CSc., Q. Vo, M.D., CSc., J. Vojaček, M.D., A. Grošpic, Eng., I. Přerovský, M.D., DrSc., A. Belán, M.D., DrSc., and L. Hejhal, M.D., DrSc.

SUMMARY

Using ultrasound method, aortocoronary bypass patency was determined by means of bidirectional Doppler's flowmeter. In 8 (3%) of 302 subjects without aortocoronary bypass was recorded diastolic signal which might distort the results of postoperative evaluation of graft patency. Two-hundred and ninety-seven patients with 330 aortocoronary bypasses were studied at the mean time of 8 months after operation. The graft patency was 84.5%. Comparison of 89 ultrasound findings with angiographic results established considerable specificity (90%) and sufficient sensitivity (77%). Reproducibility of this method was also good. The method is inexpensive and not time consuming. The advantages are also its safety and convenience for the patient. In the present level of development it can be used mainly as screening test at long-term follow-up of aortocoronary graft patency.

Additional Indexing Words:
Graft patency  Doppler principle  Comparison with angiography

DETERMINATION of aortocoronary bypass patency has a decisive role in evaluation of the results of direct reconstruction of coronary arteries. Until present time it was possible only by angiography. However, angiography cannot be frequently repeated and also its cost is not negligible. These reasons were stimuli for developing a method which would enable a non-invasive, easily reproducible and enough sensitive and specific determination of bypass patency. Ultrasound method renders such assessment possible, based on Doppler's principle which was used for measurement of blood flow velocity in man at the beginning of the sixties. This method was lately used also for evaluation of venous or arterial aortocoronary bypass patency. However, so far some problems associated with this method have not been solved. Therefore it is necessary to seek further experience which...
could contribute to their solution. In this communication we describe our experience with a non-invasive assessment of aortocoronary bypass patency obtained in the control group and patients with aortocoronary grafts.

**SUBJECTS AND METHODS**

The examination was performed by using bidirectional ultrasound flowmeter (Delalande Electronique DUD 02.00). Later the apparatus was modified with a special filter developed at our Institute to eliminate oscillations below 1000 Hz.13) Patients were examined in supine position. Explorative ultrasound probe was placed at the second, third, and fourth intercostal spaces either at the left or right sternal border according to the site of examined aortocoronary bypass. Longitudinal axis of the ultrasonic probe always copied a part of the cone surface vertex of which was at the site of the probe location. The slope of the longitudinal axis to the thorax ranged between 50° and 70°.

Ultrasound tracing, standard lead II ECG and phonocardiogram from the second right intercostal space were simultaneously recorded on Mingograph 81. Moreover, all curves were watched on screen and ultrasonic signals were also followed by auscultation. In this way we were able to record blood flow velocity curves in the aorta, ventricular outflow tracts and pulmonary artery as well as in vena cava, atria and ventricular inflow tracts, manifested by typical systolic (Fig. 1) and diastolic signals, respectively. Diastolic wave higher than or equal to the systolic wave (Fig. 2) was considered as a sign of the aortocoronary bypass patency, provided that the direction of flow, localization and width corresponded to the presumed localization of the examined graft.

The basic data were obtained by examining a group of 302 subjects without aortocoronary bypass. This group was comprised of 115 healthy volunteers or patients admitted for surgery of various non-cardiac diseases and 187 candidates for coronary artery reconstruction. One-hundred and forty-two patients of this group and further 155 patients (altogether 297 operated patients with coronary artery disease) were submitted to ultrasound examination of aortocoronary bypass patency between 1 week and 65 months (mean 8 months) after the revascularization of the myocardium.

Fig. 1. Ultrasound record (=US) of blood flow velocity in the ascending aorta with simultaneous record of ECG and phonocardiogram (=PCG).
Results of ultrasonic examination were compared with angiographic findings only in patients in whom interfering methodic side-effects were excluded. Therefore the comparison was carried out only in patients with technically perfect, unequivocal and valuable ultrasound record without diagnostically significant diastolic waves before operation and in whom the postoperative ultrasound findings were evaluated independently of the knowledge of the angiography.

Reproducibility of Doppler ultrasonic method was evaluated from the results of repeated examinations performed within 1–3 weeks separately in 57 patients with 64 bypasses and in 56 subjects of the control group in whom we evaluated the ultrasound findings along the expected course of the graft bypassing the left anterior descending and the right coronary artery, respectively (altogether 112 examined sites).

**Results**

1. **Results in subjects without aortocoronary bypass:**

   In the group of 302 subjects, 8 (3%) had diastolic signal which could
distort the interpretation of the postoperative ultrasound finding. Two of them had aneurysm of the left ventricle, while the remaining 6 had no cardiac disease explaining the presence of significant diastolic waves.

2. Results in patients with aortocoronary bypass:

Three-hundred and thirty aortocoronary bypasses in 297 patients were examined between 1 week and 65 months (average 8 months) postoperatively (Table I). Ultrasound signs of patency were found in 173 of 204 grafts bypassing the left anterior descending coronary artery (patency rate 84.8%) and in 106 of 126 grafts bypassing the right coronary artery (patency rate 84.1%).

3. Comparison with results of angiography:

Results of ultrasound examination of 89 venous grafts were compared with the angiographic findings. Fifty-six of the examined grafts bypassed the left anterior descending and 33 the right coronary artery. The results of comparison are shown in Fig. 3. Ultrasound and angiographic results corresponded in 79% of examined grafts. True positive and true negative results were established in 69% and 10%, respectively. Disagreement occurred in

Table 1. Noninvasive Ultrasound Evaluation of Aortocoronary Bypass Patency

<table>
<thead>
<tr>
<th>Graft to</th>
<th>Ultrasound</th>
<th>Patency of Grafts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patient (N)</td>
<td>Closed (N)</td>
</tr>
<tr>
<td>LAD</td>
<td>173</td>
<td>31</td>
</tr>
<tr>
<td>RCA</td>
<td>106</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>279</td>
<td>51</td>
</tr>
</tbody>
</table>

LAD=left anterior descending ; RCA=right coronary artery.

Fig. 3. Comparison of ultrasound and angiographic data in 89 aorto-coronary bypasses.
the remaining 21% of the grafts, however false positive results was recorded in 1 case only (1%).

4. Reproducibility of the ultrasound method:

In patients without aortocoronary bypass total agreement between the results of repeated examinations was demonstrated. In 64 patients with 72 aortocoronary venous bypasses were found identical results in repeated examinations, while disagreement was seen in 8 grafts. Six of them were found abnormal only at the second examination and in 2 cases we were not able to confirm positive results in the first examination (Fig. 4).

**GROUP**

<table>
<thead>
<tr>
<th>without by-passes</th>
<th>with by-passes</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>89%</td>
</tr>
<tr>
<td>□ agreement</td>
<td>□ disagreement</td>
</tr>
</tbody>
</table>

Fig. 4. Reproducibility of ultrasound results in the groups with and without aortocoronary bypasses.

**DISCUSSION**

The form of ultrasound wave depends on the velocity and direction of blood flow in the vessel. In the coronary arteries the diastolic flow rate is higher or at least the same as the systolic flow rate.14)

Flow pattern in the aortocoronary bypass depends on the site of measuring, bypassed artery, its outflow tract and supplied area. The systolic component is more evident at the proximal anastomosis of the bypass than at its distal end.15)

Nevertheless, diastolic flow rate is predominant and becomes more apparent along the course of the bypass, although greater differences between systolic and diastolic flow rate values in grafts bypassing the right coronary artery were not reported.16) The ratio of the systolic and diastolic flow rates in the graft undoubtedly depends also on the severity of impairment of the outflow vascular bed of the bypassed coronary artery and the functional state of the myocardium in the area supplied by this artery.5,16) The systolic com-
ponent is more evident in the bypasses with low flow rate. We observed the increasing systolic amplitude of the ultrasound waves during peroperative artificial compression of the graft. Based on this data as well as on our previous experience we considered the presence of the diastolic wave higher than or equal to the systolic wave at Doppler ultrasound examination as the sign of aortocoronary bypass patency.

However, such diastolic waves were observed also in 3% of subjects without aortocoronary bypass. They are thought to originate in the vena cava, mammary veins, atria, ventricular inflow tracts as well as in the movement of ventricular wall or valves. This was corroborated in our previous experiments on animals and in direct measurements on patients during heart surgery. Our findings agree with those reported by others. Diastolic waves can be present probably also in patients with heart diseases associated with abnormal diastolic blood flow patterns (aneurysm, intracardiac shunts, semilunar valves incompetency). These reasons can be the source of false positive results in some patients with aortocoronary bypass. Therefore it is necessary to perform a thorough preoperative ultrasonic examination and exclude, by further evaluation, all patients in whom diagnostically significant diastolic wave was detected already before surgery.

Results of ultrasonic examination of our patients well corresponded with angiography, as compared with the results reported by others (Table II). In our group the incidence of false positive results was low (1%). However, on the other hand, we failed to detect by ultrasound 18 (20%) of angiographically proved patent grafts. We have no unequivocal explanation for these facts. Different criteria of ultrasound evaluation of bypass patency, effort to exclude all factors leading to false positive postoperative results as

<table>
<thead>
<tr>
<th>Authors</th>
<th>Graft Type</th>
<th>Test Result</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gould et al (1972)</td>
<td>venous</td>
<td>41</td>
<td>59 (83)</td>
</tr>
<tr>
<td>Warnke et al (1973)</td>
<td>venous</td>
<td>40</td>
<td>89</td>
</tr>
<tr>
<td>Theroux et al (1977)</td>
<td>venous</td>
<td>116</td>
<td>93</td>
</tr>
<tr>
<td>Benchimol et al (1978)</td>
<td>arterial</td>
<td>14</td>
<td>92</td>
</tr>
<tr>
<td>Diebold et al (1979)</td>
<td>venous</td>
<td>163</td>
<td>92</td>
</tr>
<tr>
<td>Our series (1979)</td>
<td>venous</td>
<td>89</td>
<td>77</td>
</tr>
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well as experience of examining physician may play a significant role.

Graft patency in our patients shows the average patency rate of reconstructive coronary surgery. However, so far we are not able to detect by ultrasound patency of grafts bypassing other than the left anterior descending or the right coronary artery. Differentiation of multiple grafts which are becoming still more frequent also has not been solved. We attempted to solve these problems by using pulsed Doppler echocardiography. According to our preliminary experience it appears that pulsed Doppler echocardiography offers more detailed topographical data and further improves the non-invasive diagnosis of aortocoronary bypass patency. Moreover, it seems that further precision of this method will permit to broaden the spectrum of obtained data and perhaps dynamically follow the effect of various interventions on the aortocoronary bypass flow rate.

There is no doubt about advantages of the non-invasive ultrasonic method for determination of aortocoronary bypass patency. The results hitherto obtained clearly indicate that this method permits to determine the patency of the most frequently applied grafts. In this field the ultrasound technique yields reliable and for indirect method sufficiently sensitive results. Reproducibility of the results is also good. In addition, the cost and the time demands are not great. The method is also convenient and safe for the patients. However, the ultrasound method cannot fully substitute angio-ography. Nowadays Doppler principle can be used as a screening method during repeated long-term follow-up of bypass patency rate in patients after direct reconstruction of coronary arteries.

References

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