Gastroepiploic artery coronary bypass graft: non-invasive patency evaluation using color and duplex Doppler ultrasonography

Stefaan Gryspeerdta, Lieven Van Hoea,*, Luc Mertens1,a, Guy Marchala, Luc Stockxa, Albert L. Baerta, Paul Sergeantb

aDepartment of Radiology, University Hospitals, Herestraat 49, B-3000 Leuven, Belgium
bDepartment of Cardiac Surgery, University Hospitals, Herestraat 49, B-3000 Leuven, Belgium

Received 23 April 1996; revised 12 July 1996; accepted 31 July 1996

Abstract

Objective: Color and duplex Doppler ultrasound and digital subtraction angiography were compared for the evaluation of graft patency of the gastroepiploic artery (GEA). Methods: In 77 observations, ultrasound and digital subtraction angiography were compared. The coronary resistance index (cRI) was defined as the maximal systolic flow velocity minus the maximal diastolic flow velocity, divided by the maximal systolic flow velocity. On digital subtraction angiography, the graft was considered patent, occluded, or patent but non-functional. Grafts were defined as non-functional when they had a diameter of less than 5F with the absence of opacification of the native coronary artery. Results: Of the 77 observations, 64 GEA's were patent angiographically, three were occluded and ten grafts were considered as patent but non-functional. Using color and duplex ultrasound, the GEA was identified in 65 out of 77 observations. There were no cases of false positive visualization of the GEA. All sonographically detected non-functional grafts (n = 7) had a cRI of greater than 0.60. When the non-visualized grafts are considered either non-functional or occluded, a cut-off value for a cRI of 0.60 results in a sensitivity and specificity of 100 and 75%, respectively. Conclusion: We propose ultrasound as a primary screening tool for evaluating graft patency. While color Doppler is a suitable technique for graft visualization, spectral analysis with the calculation of a cRI is required for functional evaluation. Copyright © 1997 Elsevier Science B.V.

Keywords: Coronary artery bypass grafting; Arterial graft; Gastroepiploic artery; Color Doppler ultrasound; Duplex Doppler ultrasound

1. Introduction

During the last few years the superiority of arterial grafts to venous grafts used as coronary bypass grafts has been extensively demonstrated [4,5]. Histological and functional studies of the right gastroepiploic artery (GEA) showed a marked similarity between the GEA and ITA [8,16] and several studies have recently demonstrated that the GEA is a suitable conduit for CABG [15].

One of the advantages of the extrathoracic conduit is that it is potentially more easily accessible for non-invasive techniques like Doppler ultrasound (US) [7,9].

The aim of this study was to evaluate the feasibility and utility of color and duplex Doppler sonography in evaluating patency and functionality of the GEA bypass graft. Therefore color and duplex Doppler sonography were compared to digital subtraction angiography (DSA).
2. Material and methods

2.1. Patients population and study design

From January 1990 to May 1993, 109 patients underwent coronary artery bypass grafting with the GEA graft. The study population consisted of 77 patients in which patency evaluation took place 1 year after surgery. There were 68 men and 9 women, with a mean age of 56.3 years (range 38–73 years). All patients were randomly selected. DSA, color and duplex Doppler sonography were performed on the same day. Operators and interpreters of one technique were blinded to the results of the other technique.

In all patients the surgical technique consisted of mobilizing the right GEA to the pericardial cavity, ventrally to the left liver lobe [16]. In 54 patients the GEA was anastomosed on the posterior descending artery, in nine on the coronary artery in the AV groove, in five on the right coronary artery, in six on the circumflex artery, in two on the inferolateral branch of the right coronary artery and finally in one on the left anterior descending artery.

2.2. Color and duplex Doppler sonography

Color and duplex Doppler sonography were performed with a 5 MHz linear transducer (color imaging and pulsed Doppler; model 128; Acuson, Mountain View, CA) as recently described by Nishida et al. [7].

The GEA was considered ‘visualized’ when the following criteria were fulfilled: (1) detection of an artery in the epigastric region; (2) located posterior to the rectal muscle, anterior to the left liver lobe; and (3) running caudocranially. When not all criteria were fulfilled, the GEA was coded as ‘not visualized’.

2.3. Signal analysis

A semi-quantitative analysis of the obtained arterial time-velocity spectra was performed. The resistance index (RI) has been used for studying blood flow in renal transplants and is designed to record velocity changes that reflect an increased resistance to flow at points distal to the recording site [12]. The RI was defined as peak systolic flow velocity (PSV) minus end diastolic flow velocity divided by PSV. This value is independent from the angle between Doppler probe and blood flow direction. As end diastolic flow is strongly influenced by heart rate, the resistance index calculated this way is dependent on heart rate. In recent studies on coronary artery flow, peak systolic and diastolic velocities were determined [10,13] and were used for describing blood flow patterns in coronary bypass grafts which were reported to be similar to blood flow patterns in native coronary arteries [1,17]. Therefore a coronary resistance index (cRI) was calculated in this study. This index was defined as maximal systolic flow velocity minus maximal diastolic flow velocity, divided by maximal systolic flow velocity. Since maximal diastolic flow is not dependent on heart rate, there is no need to correct for heart rate when assessing cRI. The cRI was determined as an average value obtained from a minimum of three arterial Doppler waveforms.

2.4. Digital subtraction angiography

DSA was performed via a 5F side winder or cobra catheter inserted transfemorally [7].

Based on the images obtained, graft patency and functionality was evaluated.

Slender sign was defined as the presence of a graft diameter smaller than a 5F catheter with absence of opacification of the anastomosed native coronary artery on DSA [6]. The grafts in which the slender sign is present are considered as patent, but non-functional grafts [6].

The GEA was considered patent and functional when the GEA as well as the anastomosed native coronary artery were visualized.

The GEA was considered occluded when there was no, or only a proximal opacification of the GEA. Based on the angiographic characteristics, GEAs were thus divided into three groups: (1) patent; (2) patent but non-functional; and (3) occluded.

2.5. Data analysis

Data obtained with color and duplex Doppler sonography were compared to DSA which was considered the gold standard for patency evaluation [7]. Sensitivity and specificity were calculated by using graft occlusion or non-function as the positive diagnosis. In this way a sensitivity for graft non-function or occlusion is obtained. Statistics were done using the two-tailed Students’ t-test.

3. Results

3.1. Angiography

Of the 77 observations, 64 GEAs were patent angiographically, three were occluded and ten grafts were found to show the ‘slender sign’ and were consequently considered as patent, but non-functional.
Table 1
Results of color and Doppler sonography and its correlation with DSA in evaluation of graft patency

<table>
<thead>
<tr>
<th></th>
<th>Normal patent</th>
<th>Abnormal patent but non-functional</th>
<th>Abnormal occluded</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSA</td>
<td>64</td>
<td>10</td>
<td>3</td>
<td>77</td>
</tr>
<tr>
<td>Color Doppler sonography</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visualized</td>
<td>58</td>
<td>7</td>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>Non visualized</td>
<td>6</td>
<td>3</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

3.2. Color and duplex Doppler sonography and its correlation with DSA

3.2.1. Color Doppler sonography versus DSA

In 65 out of 77 observations an artery running caudocranially in the epigastric region and located posterior to the rectal muscle was detected using color Doppler sonography. There were no cases of false positive visualization of the GEA. In 58 out of these 65 observations the detected GEA was shown to be patent on DSA. In seven out of 65 observations the detected artery by color Doppler sonography was shown to be non-functional. In 12 out of 77 observations, no artery fulfilling the criteria, was detected. Of these 12 negative observations, six had a patent graft on DSA.

The remaining six out of 12 GEAs which could not be visualized, were either non-functional (n = 3) or occluded (n = 3) (Table 1).

3.2.2. Duplex Doppler sonography versus DSA

calculation of cRI

In all visualized GEAs, a biphasic flow pattern was observed, with peak velocity being higher during systole (see Fig. 1). The waveform observed in GEA consisted of two discrete periods of forward velocity acceleration and deceleration in the cardiac cycle. One is during the systole, and one is during the diastole. Maximal forward flow velocity occurs during systole. Immediately prior to the forward flow during systole, there is a reversed flow. The same flow pattern was also reported by Nishida et al. [7].

The PSV, peak diastolic velocity (PDV) and cRI of the visualized normal grafts were compared to the cRI of the visualized abnormal grafts.

Mean PSV was 36 ± 13 (S.D.) cm/s for patent and functional grafts, and 26 ± 14 (S.D.) cm/s for visualized non-functional grafts.

Mean PDV was 22 ± 10 (S.D.) cm/s for patent and functional grafts and 12 ± 8 (S.D.) cm/s for visualized non-functional grafts.

This means a significant difference between PSV and PDV between functional and non-functional visualized grafts (P = 0.0002 for PDV and P = 0.01 for PSV).

A significant difference was also obtained between the cRI of both groups (normal mean, 0.52 ± S.D. 0.11; vs. abnormal, 0.85 ± S.D. 0.15; P < 0.0001, (Fig. 3)).

This suggests that a high cRI and low-flow in a visualized graft can be taken as an indication for non-functionality.

4. Discussion

4.1. Detection of the GEAs and patency evaluation

The possible use of color and duplex Doppler sonography has been reported previously [7,9]. When used as coronary bypass graft, the typical location and flow directionality of the GEA makes the artery to be easily differentiated from other arteries, with no false positive visualization of the GEA in our series, nor in those reported by Nishida et al. [7].

Several factors however, potentially render a sonographic evaluation difficult, possibly resulting in false negative diagnosis of graft patency. Some of those are patient-related, such as the inability to stop breathing. Other factors seem to be related to graft characteristics. Recent studies on postoperative angiographical evaluation of GEAs, reported a ‘thinning down’ of the graft in some cases. This phenomenon was defined by a graft diameter smaller than a 5F catheter with absence of opacification of the anastomosed native coronary artery and was named ‘slender sign’ [6]. A low graft flow and/or a very thin artery may cause problems when visualizing the graft using color Doppler sonography.
This especially holds true for non-functional grafts which were found to have lower PSV as well as PDV when compared with functional grafts. This is reflected in our study where three of the ten arteries showing slender sign on DSA could not be visualized by color Doppler. These findings are similar to those reported by Nishida et al. [7], who found false negative visualization of the GEA in four out of six patients with poor graft flow. Because of the possible false positive diagnosis of graft occlusion, DSA remains necessary when the GEA cannot be visualized sonographically.

4.2. Flow pattern in GEA graft

The flow pattern in a patent GEA is characterized by an important diastolic forward flow, different from the biphasic or triphasic flow pattern found in peripheral arteries.

This flow pattern however, is different from the one observed in internal mammary artery or saphenous vein graft [2]: in GEA, peak velocity occurs during systole and not during diastole. A possible explanation for this phenomenon might be found in the muscular nature of
the GEA [18]. Second, the right GEA is longer than the ITA graft, and thus the resistance to flow may be higher. Both characteristics, the muscular nature and the length of the graft affect flow characteristics during diastole, but not during systole [7]. As coronary perfusion mainly occurs during diastole, changes in diastolic flow velocity will reflect coronary perfusion.

4.3. Evaluation of graft function: cRI

In this study the cRI was used for evaluating the graft flow. A significant correlation was found between cRI and graft function. Moreover, in the follow-up of two patients, important changes in graft flow were noted. Both GEAs were easily identified during the first evaluation and had a cRI of 0.45 and 0.50, respectively. DSA confirmed normal patency, with a diameter larger than a 5F catheter, showing a good opacification of the anastomosed native coronary artery. Both GEAs were again identified on color Doppler flow imaging, 1 year later, but showed a decreased diastolic forward flow on duplex Doppler evaluation, resulting in higher cRIs (0.70 and 0.75, respectively). In both patients, DSA showed slender sign on second evaluation. Moreover, we obtained a significant difference between the cRI of the visualized normal grafts, and the cRI of the visualized abnormal grafts (see Fig. 2). All these findings suggest that a high cRI in a visualized graft can be taken as an indication for non-functionality.

As the pedicled GEA has only recently been introduced as a coronary artery bypass graft, little is known about the normal physiology of the graft. However, histological and physiological data indicate that the GEA is comparable to the ITA [3,11]. So it may be presumed that data obtained with the ITA as a graft can be applied to the GEA. Singh et al. [14] described the physiological adaptability of the ITA meaning that when this artery is used as a coronary graft, its postoperative diameter is responsive to graft flow. So the ITA has been shown to expand in response to an increase in graft flow. Opposite changes have been observed in GEAs where the ‘slender sign’ (graft diameter < 5F with no opacification of the anastomosed native coronary artery) is thought to be caused by a good competitive native flow from the coronary artery on which the graft is implanted. This reduces the forward flow through the graft [6]. Since the slender sign seems to be caused by good native coronary flow [6], this also explains the absence of increased signs of ischemia in the perfused regions in the three patients reported by Nakao et al. [6]. Slender sign and poor usage of the CABG does not necessarily cause the cardiac region to become ischemic. So the ‘slender sign’ corresponds to a patent but low or non-functional graft. The importance of the diastolic flow component is reflected in the calculated cRI which decreases when maximal diastolic flow increases compared to maximal systolic flow.

We propose a cut-off value of 0.60 for identifying patent and functional GEAs for the detection of occluded or non-functional graft. This results in a sensitivity of 100% which makes the technique suitable to be used as primary diagnostic modality. This certainly accounts for patients in whom postoperative angiography is not indicated because of unstable cardiac function or marginal renal failure.

There is however an overlap in cRI between functional and non-functional GEAs, resulting in a specificity of only 75% (see Fig. 3). The Doppler technique proposed therefore does not replace DSA.

The finding of reduced diastolic forward flow in case of graft dysfunction, was also reported by Nishida et al. [7]. These authors, however, calculated the percent diastolic fraction. The percent diastolic fraction was defined as the ratio of time velocity integral in diastole to total
time velocity integral (time velocity integral in diastole + time velocity integral in systole). Time velocity integral, however, is dependent on both vessel diameter and transducer angle. In this respect, using cRI could be theoretically more reliable, although no comparison was made between both parameters.

The major drawback of this study is the relative low number of occluded or non-functional GEAs, and the fact that the cut-off point was based on retrospective analysis of the data. This certainly leaves open the possibility that the sensitivity is below 100%. Further prospective studies are therefore needed and are currently performed at our institution.

In conclusion, color and duplex Doppler ultrasound, with the calculation of the proposed cRI is a promising screening tool for the evaluation of graft patency and function.

References