Risks of Using Internal Thoracic Artery Grafts in Patients in Chronic Hemodialysis via Upper Extremity Arteriovenous Fistula

Mario Gaudino, MD; Michele Serricchio, MD; Nicola Luciani, MD; Stefania Giungi, MD; Andrea Salica, MD; Roberto Pola, MD; Paolo Pola, MD; Giovanna Luciani, MD; Gianfederico Possati, MD

Background—In patients in chronic hemodialysis via upper extremity arteriovenous fistula in whom ipsilateral internal thoracic artery graft was used for myocardial revascularization, hemodynamic interference between the fistula and the graft during dialysis can be hypothesized.

Methods and Results—In 5 patients undergoing chronic hemodialysis via upper extremity arteriovenous fistula, ipsilateral to an internal thoracic to left anterior descending graft mammary flow was studied by means of transthoracic echo-color Doppler at baseline and during hemodialysis. Flow in the contralateral mammary artery was used as control. Transthoracic echocardiography was performed in concomitance with flow evaluation to assess eventual modifications of left ventricular segmental wall motion. Immediately after hemodialysis pump start there was a marked reduction of peak systolic and end-diastolic velocities and time average mean velocity and flow in the ITA ipsilateral to the fistula, whereas no substantial hemodynamic modification was evident in the contralateral artery. Dialysis-induced reduction of ipsilateral ITA flow was accompanied by evidence of hypokinesia of the anterior left ventricular wall. Three cases also experienced clinical angina.

Conclusions—Hemodynamically evident flow steal and consequent myocardial ischemia develop during hemodialysis in patients with upper extremity arteriovenous fistula and ipsilateral internal thoracic artery to coronary graft. These data have major implications for patients' management, both for nephrologists and cardiac surgeons. (Circulation. 2003;107:2653-2655.)

Key Words: hemodialysis ● fistula, arteriovenous ● arteries ● grafting

Patients in chronic hemodialysis have an accelerated incidence of coronary artery disease and, after the reported superior results achieved by surgical versus percutaneous revascularization, are referred with increasing frequency for coronary artery bypass graft (CABG).

One of the main surgical risks in hemodialysis patients is that in a high proportion of cases the ascending aorta is involved in the systemic atherosclerotic process and can constitute a dangerous source of systemic emboli after cannulation, cross-clamping, or proximal anastomosis performance.

For this reason, during coronary bypass operations great care must be paid to minimize aortic manipulation; in this setting, the adoption of internal thoracic artery (ITA) grafts seems particularly appropriate because it avoids the need for performance of the proximal aortic anastomosis and can allow less traumatic and neurologically safer myocardial revascularization procedures.

However, in those patients who undergo hemodialysis via an upper extremity arteriovenous fistula ipsilateral to the ITA used for CABG, both the bypass conduit and the fistula arise from the same vascular district (the subclavian artery) and, as flow in the fistula during dialysis is not negligible, the possibility of hemodynamic interference between the two cannot be excluded.

In this report, prompted by the clinical observation of angina episodes during hemodialysis in patients with normofunctioning ITA bypass grafts and ipsilateral fistula, we investigate the possibility of a flow steal from ITA graft by ipsilateral upper extremity arteriovenous fistula in patients in chronic hemodialysis submitted to coronary artery bypass surgery.

Methods

Inclusion Criteria and Patient Population

In order to exclude potential confounding factors and provide the best model to study ITA flow dynamics during hemodialysis, we defined the following inclusion criteria: (1) patients in chronic hemodialysis via a left upper extremity arteriovenous fistula in whom the pedicled left ITA was used as a coronary artery bypass conduit to the left anterior descending artery; (2) no history or evidence of previous anterior myocardial infarction; (3) echocardiographic documentation of normal anterior left ventricular wall...
motion; (4) recent (<6 months) myocardial scintigraphy or stress test showing absence of inducible ischemia; and (5) postoperative angiography documenting patency and normal function of all bypass grafts with absence of patent ITA side-branches.

According to these criteria we selected 5 of the 157 coronary patients in chronic hemodialysis operated at our institution during the last 8 years.

Three cases were in hemodialysis before the CABG operation, whereas two had a severely compromised renal function preoperatively and developed irreversible renal insufficiency requiring chronic hemodialysis (and fistula performance) in the postoperative period.

All patients gave their informed consent to participate to the study protocol.

Study Protocol
ITA flow study was performed according to a methodology previously described. All echo-Doppler evaluations were performed using a computerized system (Acuson 128 XP/10 ART; Acuson, USA) equipped with a 7-MHz linear probe with 40-mm opening and 5-MHz pulsed Doppler. The ITA was initially detected in the supraclavicular region or in the third intercostals space in parasternal position.

Color-Doppler imaging was obtained using a constant angle of 60° between the ultrasound beam and the vessel long axis. Under color-Doppler guidance a pulsed Doppler evaluation of the flow velocities in the vessel using a sample volume of 1 mm^3 and taking into consideration the angle between the ultrasound beam and the axis of the vessel was performed.

The following parameters were calculated: peak systolic velocity (PSV; meters per second); end-diastolic velocity (EDV; meters per second); time average mean velocity (TAMV; meters per second); pulsatility index (PI=PSV−EDV/TAMV). The TAMV was defined as the area between the line traced on the Doppler wave and the baseline. The diameter of the ITA was calculated using internal electronic calipers on frozen frame images from the B-mode recording. Flow (F) was obtained using the formula: F (millimeters per minute)=time average mean velocity (centimeters per second)×(πr^2)/60, where r is half the internal diameter of the ITA expressed in centimeters.

Evaluations were performed at baseline and after the start of the hemodialysis pump at standard flow (300 mL/min) in both the left ITA (anastomosed to a coronary artery) and the right ITA (in situ and used to assess the effect of hemodialysis on systemic vascular flow in a region far from the arteriovenous fistula).

During all measurements noninvasive arterial pressure was recorded every 2 minutes and mean arterial pressure was maintained at around 70 mm Hg (using volume or sodium chloride infusion). All measurements were repeated at least 5 times by the operator to assure reliability.

In concomitance with the ITA flow evaluation, standard transthoracic echocardiography was performed to assess eventual modification of left ventricular segmental wall motion.

Echocardiographic findings were reviewed blindly and independently by two experienced external observers; discrepancies were resolved after common reevaluation.

Statistical Analysis
Data are expressed as mean±SD. Statistical analysis was performed with unpaired two-tailed t testing. Analysis was conducted by the software Statistica for Windows 4.1, Statsoft Inc,1993.

Results
Echo-Doppler results are summarized in the Table. At baseline, the arteriovenous fistula determines a reduction in local vascular resistance whose hemodynamic effect is transmitted to the ipsilateral ITA, as evident by the increase of the EDV, TAMV, and consequent reduction of the PI in this artery compared with the contralateral (control) ITA.

<table>
<thead>
<tr>
<th>Main Echo-Doppler Results</th>
<th>Baseline</th>
<th>Pump On</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral brachial artery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSV, m/s</td>
<td>1.23±0.42</td>
<td>1.28±0.39</td>
</tr>
<tr>
<td>EDV, m/s</td>
<td>0.32±0.05</td>
<td>0.48±0.07†</td>
</tr>
<tr>
<td>TAMV, m/s</td>
<td>0.59±0.09</td>
<td>0.63±0.08</td>
</tr>
<tr>
<td>PI</td>
<td>1.54±0.88</td>
<td>1.26±0.90</td>
</tr>
<tr>
<td>Diameter, mm</td>
<td>3.98±0.75</td>
<td>4.01±0.67</td>
</tr>
<tr>
<td>Ipsilateral ITA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSV, m/s</td>
<td>0.41±0.10*</td>
<td>0.25±0.11§</td>
</tr>
<tr>
<td>EDV, m/s</td>
<td>0.12±0.03§</td>
<td>0.08±0.02§</td>
</tr>
<tr>
<td>TAMV, m/s</td>
<td>0.24±0.06</td>
<td>0.13±0.03†‡</td>
</tr>
<tr>
<td>PI</td>
<td>1.18±0.53</td>
<td>1.29±0.45‡</td>
</tr>
<tr>
<td>Diameter, mm</td>
<td>2.02±0.41</td>
<td>1.98±0.37</td>
</tr>
<tr>
<td>Contralateral ITA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSV, m/s</td>
<td>0.63±0.17</td>
<td>0.61±0.15</td>
</tr>
<tr>
<td>EDV, m/s</td>
<td>0.04±0.01</td>
<td>0.03±0.01</td>
</tr>
<tr>
<td>TAMV, m/s</td>
<td>0.19±0.05</td>
<td>0.18±0.03</td>
</tr>
<tr>
<td>PI</td>
<td>3.03±1.91</td>
<td>3.12±1.80</td>
</tr>
<tr>
<td>Diameter, mm</td>
<td>1.99±0.53</td>
<td>1.98±0.51</td>
</tr>
</tbody>
</table>

EDV indicates end diastolic velocity; PI, pulsatility index; PSV, peak systolic velocity; TAMV, time average mean velocity.

*P<0.05 compared with baseline.
†P<0.01 compared with baseline.
‡P<0.05 compared with contralateral ITA in the same condition.
§P<0.01 compared with contralateral ITA in the same condition.

When the dialysis pump is switched on, there is an increase in the flow through the fistula (expressed by an increase in PSV, EDV, and TAMV with reduction PI in the tributary brachial artery). More interestingly immediately after hemodialysis pump start there is a marked reduction of PSV and EDV with increase in PI and reduction of TAMV and flow in the ipsilateral ITA, whereas no substantial hemodynamic modification is evident in the contralateral artery (see Table and Figure). This hemodynamic situation remains practically unchanged during all the dialysis period and returns rapidly to baseline when the dialysis pump is turned off. Increase in the pump flow rate leads to more pronounced flow modifications in the ipsilateral ITA.

In all our cases this dialysis-induced reduction of ipsilateral ITA flow was accompanied by the development of hypokinesia of the anterior left ventricular wall that began almost in concomitance with ITA flow modifications and disappeared few minutes after the end of the dialysis period. Three of the 5 patients also referred clinical symptoms suggestive of myocardial ischemia.

Discussion
The use of the ITA can lead to important clinical advantages in patients in chronic hemodialysis submitted to CABG: in fact, ITA grafts not only assure higher patency rate and mid- and long-term survival, but consent to minimize the manipulation of the ascending aorta (which is often severely atherosclerotic and can constitute a lethal source of intraoperative systemic and cerebral emboli).1
However, although the possibility of a ITA graft flow steal has been considered in case of patent intercostals branches or subclavian stenosis, to date no study on the ITA graft flow dynamics in patients with an ipsilateral upper extremity arteriovenous fistula has been reported.

As the arteriovenous fistula is performed in the same vascular district of the ITA (the subclavian artery) and carries not-negligible flow rate during hemodialysis, it is conceivable, at least theoretically, that some type of hemodynamic interferences between the two can exist.

Crowley and colleagues reported a case of suspected coronary steal from a left ITA graft from an ipsilateral arm fistula in an hemodialysis patients; however, this anecdotal report, although highly suggestive, was not demonstrative as these authors based their conclusions mainly on the comparison of left and right subclavian pressures, with and without fistula occlusion, but could not provide objective evidence of ITA flow reduction or myocardial ischemia.

More recently Kato and associates reported diastolic retrograde flow in the in situ ITA in a patient with ipsilateral arteriovenous fistula and suggested (but could not prove) the possibility of flow steal in case that the ITA had been used for CABG.

In the present report, a clear ITA flow reduction was directly recorded in all cases in concomitance with the start of the hemodialysis pump (see Figure and Table); this flow reduction remained constant during all the dialysis period and was accompanied by ischemic modifications of anterior left ventricular wall motion in all patients and to clinically evident angina in 3 of the 5 cases (those where the LAD perfusion was totally dependent on the ITA, whereas the asymptomatic patients had a subocclusive LAD stenosis and could probably benefit from residual native coronary perfusion).

The fact that the flow in the contralateral ITA was not affected by the pump start (see Table) and that the hemodynamic of all patients was stable during the all measurement period argues against a possible systemic effect related to dialysis-induced hypotension or hypovolemia and suggests that a local flow steal from the ipsilateral fistula is the cause of the observed modifications.

These findings have major clinical implications for both cardiac surgeons and nephrologists. It seems in fact that when a patient in chronic hemodialysis is referred for CABG, the use of ITA should be better reserved to the site contralateral to the arm fistula, and conversely, when planning the performance of an arm fistula for dialysis access in a patient previously submitted to CABG, a detailed description of the cardiac operative procedure should be obtained and the arm contralateral to the ITA used for coronary revascularization selected for the fistula.

Moreover, these data should be kept in mind when selecting the type of bypass conduits to be used in patients with severely compromised preoperative renal function that are likely to progress to dialysis in the years after surgery.

**References**

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