Saphenous Vein Conduits Harvested by Endoscopic Technique Exhibit Structural and Functional Damage

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Background. Injury to the saphenous vein endothelium during harvest impacts patency after coronary artery bypass graft surgery. Many centers are adopting endoscopic saphenous vein harvest (ESVH) instead of using the traditional open saphenous vein harvest (OSVH) technique. Our objective was to compare the effects of ESVH and OSVH on the structural and functional viability of saphenous vein endothelium using multiphoton imaging, immunofluorescence, and biochemical techniques.

Methods. Ten patients scheduled for coronary artery bypass graft surgery were prospectively identified. Each underwent ESVH for one portion and OSVH for another portion of the saphenous vein. A 1-cm segment from each portion was immediately transported to the laboratory for processing. The vessel segments were labeled with fluorescent markers to quantify cell viability (esterase activity), calcium mobilization, and generation of nitric oxide. Samples were also labeled with immunofluorescent antibodies to visualize caveolin, endothelial nitric oxide synthase, von Willebrand factor, and cadherin, and extracted to identify these proteins using Western blot techniques. All labeling, imaging, and image analysis was done in a blinded fashion.

Results. Esterase activity was significantly higher in the OSVH group (p < 0.0001). Similarly, calcium mobilization and nitric oxide production were significantly greater in the OSVH group (p = 0.0209, p < 0.0001, respectively). Immunofluorescence and Western blot techniques demonstrated an abnormal alteration in distribution of caveolin and endothelial nitric oxide synthase in the ESVH group.

Conclusions. Our study indicates that ESVH has a detrimental effect on the saphenous vein endothelium, which may lead to decreased graft patency and worse patient outcomes.


Prevention of injury to the saphenous vein endothelium during coronary artery bypass graft surgery impacts patency rates after coronary artery bypass graft surgery [1–11]. The endothelium serves as a physiologic barrier between blood components and the subendothelium, and endothelial injury during harvest can form an initiation site for the formation of later-stage atheromas and graft failure [1–11]. Surgical manipulation can also decrease the antithrombogenic nature of a SV graft's endothelium, increasing the risk of vasospasm, thrombogenesis, occlusive intimal hyperplasia, and stenosis [4, 5, 10, 11].

The integrity of the endothelial lining is affected by many factors. We have shown previously that the pH, temperature, distention, and composition of storage solution have an affect on the endothelial viability and functionality using epifluorescence multiphoton microscopy (MPM) [12–15]. The technique of harvest is another factor that might impact the endothelium and subsequent patient outcomes.

Greater saphenous vein has traditionally been harvested using an open surgical technique by which the vein is exposed through a long continuous incision from groin to ankle with minimal manipulation of the vein itself [16]. With the advent of new surgical technologies, endoscopic saphenous vein harvest (ESVH) has become the technique of choice at many centers because of both decreased lower extremity morbidity compared with the open technique and patient preference [17–19]. Complications in the lower extremity such as cellulitis and wound infection, hematoma, seroma, edema, and saphenous neuropathy and neuralgia are less common using ESVH compared with the open technique [20–25]. Lower extremity morbidity has also been shown to be lower among patients with risk factors such as obesity, smoking, hypertension, and diabetes mellitus [26]. However, the recently published PREVENT-IV study (Project of Ex Vivo Vein Graft Engineering Via Transfection) [27] compared outcomes after on-pump versus off-pump coronary artery bypass graft surgery; the investigators found ESVH to be an independent predictor of decreased SV patency at 1 year, the cause of which was not defined, warranting further investigations. Therefore, to address
these issues, we conducted our study as a starting point in the evaluation of ESVH and its impact on SV structure and function.

The effect of ESVH on SV endothelial structure and function has not been evaluated using MPM in combination with other biochemical techniques. Multiphoton microscopy has been shown to be a sensitive instrument to measure endothelial viability and functionality in real time [12–14]. In addition to the ESVH technique, further manipulation of the vein, use of cautery, and exposure to CO2 gas pressure may potentially damage the SV graft during harvest. Therefore, the main objective of this study was to compare the viability and functionality of SV endothelium after open saphenous vein harvest (OSVH) versus ESVH using three independent techniques: (1) epifluorescence MPM; (2) immunofluorescence; and (3) biochemical assays.

Material and Methods
From July 2007 to October 2007, 10 male patients aged 60 to 81 years scheduled for elective coronary artery bypass surgery at the VA Boston Healthcare System were prospectively identified for the evaluation of SV harvest technique. The vein samples were collected according to the protocol approved by the Human Studies Subcommittee, and after obtaining informed consent from the patients.

Each patient underwent ESVH for the proximal portion of the vein and OSVH for the distal portion of the vein (Fig 1). For the ESVH portion, CO2 insufflation was used for visualization and dissection of the tissues around the vein. Once the vein was mobilized, the side branches were cauterized with bipolar cautery. Finally, the endoscopic portion of the vein was excised with a stab incision at the groin. All endoscopic techniques were done according to the manufacturer’s guidelines. The ESVH was begun 5 cm below the knee with the standard 2-cm incision. To maintain a close sampling proximity, the OSVH vein was obtained through an incision in the lower leg as close to the endoscopic incision as possible using the standard “no touch” technique. Distance between the two sample areas was measured (6.9 ± 1.75 cm [mean ± SD]) in each case. Inclusion criteria were only that the SV was harvested for a coronary artery bypass conduit. Patients with inadequate SV conduit length for bypass were excluded.

Both harvest techniques were performed by one physician’s assistant experienced with more than 110 ESVH cases. All ESVH were performed using the VasoView endoscopic vessel harvesting system (Guidant-Maquet Cardiovascular, San Jose, CA). A 1-cm portion of the OSVH and ESVH vein was transported to the MPM laboratory immediately after the vein was removed. Time needed to harvest each section was recorded.

Multiphoton Analysis

STRUCTURAL AND FUNCTIONAL VIABILITY ASSAYS. Coronary artery segments from OSVH and ESVH regions were sized equally and were simultaneously labeled with fluorescent markers in Hank’s Balanced Salt Solution (HBSS).

CELL VIABILITY ASSAY. The structural and functional viability was assessed with a fluorescence-based supervitality Live-Dead assay (calcein AM/ethidium homodimer) that measures the viability of vascular endothelial cells [4, 12–14]. The viable cells fluoresce green because of the esterase activity; in contrast, the damaged cells fluoresce red because of the permeability to ethidium homodimer, a charged molecule, through the compromised membranes and binding to the nucleus. The SV segments were incubated with calcein AM and ethidium homodimer dyes (10 μM, final concentration) in 1.5 mL HBBS, pH 7.4, for 30 minutes at 21°C. After incubation, segments were washed three times with HBBS, mounted

**Fig 1. Schematic representation of the location and techniques used to harvest the saphenous vein. Endoscopic harvest was started below the knee (A) and proceeded all the way proximal (B). Endoscopic harvest was then begun down the leg to a distance approximately mid calf. At this point, an open incision (C) was made approximately 3 cm below the level where the endoscopic harvest was stopped. (D indicates end of open harvest.) Each sample was taken from a section of vein that would not be needed for bypass. (endo = endoscopic; ESVH = endoscopic saphenous vein harvest; OSVH = open saphenous vein harvest.)**
on the multiphoton microscope stage in an imaging chamber, and imaged as described below [4,12–14].

MEASUREMENT OF ESTERASE ACTIVITY. The conversion of calcein AM ester (nonfluorescent) to fluorescent calcein by the esterases in living cells was used as a marker of esterase activity in the endothelial cells of the vein segments [4, 12–14]. Segments were incubated with calcein AM as described above. The SV lumen and endothelial cell layer were identified by XYZ scanning using MPM. Specifically, five different regions of uniform size were marked on the endothelial cells in the lumen of each segment using image processing software (MetaMorph Imaging Series; Universal Imaging, West Chester, PA). Total integrated fluorescence intensity in the marked regions of the endothelium was measured as a function of esterase activity in the SV segments using MetaMorph software [4, 12–14].

INTRACELLULAR CALCIUM MOBILIZATION AND NITRIC OXIDE GENERATION. Calcium mobilization and nitric oxide (NO) generation in the endothelial cells of the SV was measured using calcium-sensitive calcium orange dye and NO-specific diaminofluorescein dye, as previously described [4, 12–14]. Resting calcium levels and basal activity of endothelial nitric oxide synthase (eNOS) were measured in the absence of bradykinin stimulation. The segments were imaged, and calcium mobilization and NO generation were assessed in real time over the course of 10 minutes and quantitated as described below.

Multiphoton Fluorescence Imaging

Imaging and semiquantitative fluorescence measurements were performed with a Bio-Rad MRC 1024ES multiphoton imaging system (Bio-Rad, Hercules, CA) as described previously [4, 12–14]. A Zeiss Axiovert S100 (Carl Zeiss MicroImaging Inc, Thornwood, NY) inverted microscope equipped with a high-quality water immersion 40×/1.2 NA, C-apochroma objective was used to image the segments and quantitate fluorescence in trans-
mission and epifluorescence mode. The 512 × 512 pixel images were collected in direct detection configuration at a pixel resolution of 0.484 μm with a Kalman 3 collection filter. The endothelial cell layers were identified by XYZ scanning and imaged at depths of 100 μm away from the site of incision in transverse sections of the veins.

Quantitative Analysis of Calcium and Nitric Oxide
Calcium mobilization and NO generation were measured by recording changes in calcium orange and diaminofluorescein fluorescence before and after bradykinin treatment, as previously described [4,12–14]. Typically, five specific regions were drawn along the endothelial region of the lumen for each arterial segment using MetaMorph image processing software. Fluorescence intensity was integrated over all pixels within the boundary of each individually enclosed area and quantitated separately using MetaMorph in calcium and NO fluorescence channels, respectively. The fluorescence intensity from each image was normalized by values determined from a reference image recorded before bradykinin treatment [4, 12–14]. The fluorescence value variability between the regions was less than 10%.

All labeling, imaging, and image analysis was done in a double-blinded fashion.

Statistical Analyses
The differences between the two groups (OSVH and ESVH) were analyzed with one-way repeated-measures analysis of variance (Wilcoxon rank sum analysis). Statistical significance was accepted at the 95% confidence level ($p < 0.05$). The data are derived from $n = 250$ measurements for each group, and from $n = 50$ for calcium and NO assay, respectively, for each group investigated.

Fig 4. Quantitative representation of mean esterase activity (green fluorescence) from all samples in the open saphenous vein harvest (OSVH) versus endoscopic saphenous vein harvest (ESVH) greater saphenous veins (Fig 3a, b). As shown in the above images, the OSVH group has a significantly greater esterase activity than the ESVH group ($p < 0.0001$, Wilcoxon two-sample test; $n = 250$ measurements for each group).

Fig 5. Calcium mobilization and nitric oxide production in response to bradykinin. (A) Representative images of calcium mobilization before (pre) and after (post) bradykinin stimulation in the open saphenous vein harvest (OSVH) and endoscopic saphenous vein harvest (ESVH) groups. (B) Representative images of nitric oxide production before (pre) and after (post) bradykinin stimulation. (Magnification = ×320.)
Immunofluorescence
Saphenous vein frozen sections were labeled with primary caveolin 3, eNOS, cadherin, and von Willebrand factor (vWF) antibodies. In short, sections were blocked with 5% normal goat serum, 0.3% tritonX-100 in phosphate-buffered saline for 1 hour at 21°C, and then incubated with primary antibodies in buffered saline (1:200 to 1,000 dilution) at 4°C for 12 hours. Sections were washed three times with phosphate-buffered saline, and then further labeled with either fluorescein or rhodamine conjugated secondary antibodies (1:200 dilution) in buffered saline for 2 hours at 21°C. Labeled samples were washed three times with phosphate-buffered saline, mounted, and imaged using MPM.

Western Blotting
PROTEIN EXTRACTION. All SV samples were processed at 4°C. Twenty milligrams of SV was cut into 300 small pieces and suspended in 200 mL CelLytic MT Lysis/Extraction buffer (Sigma, St. Louis, MO) containing a protease inhibitor cocktail (Sigma) in a 2-mL tube. The tissue was homogenized for 30 s with Brinkmann homogenizer and then centrifuged at 16,100g for 10 minutes. The supernatant was collected, and the protein concentration was measured using the Bio-Rad protein assay. Equal amount of total proteins (50 μg) from different samples were mixed with Laemmli sample buffer (Bio-Rad) containing 5% β-mercaptoethanol and were heated at 100°C for 3 minutes. ELECTROPHORESIS. The proteins were resolved on 7.5%, 10% or 12% SDS-PAGE, and were electroblotted onto the nitrocellulose membrane (Bio-Rad). The blots were then blocked with 5% nonfat dry milk powder in Tris-buffered saline (TBS [20 mM Tris, 500 mM NaCl, pH 7.5]) for 60 minutes at 4°C, and washed twice with Tris-Tween buffered saline (TTBS [20 mM Tris, 500 mM NaCl, 0.05% Tween-20, pH 7.5]). Blots were incubated with primary antibodies (at 1:1000; anticaveolin 1, eNOS, cadherin, and vWF for the saphenous vein samples) in TTBS containing 1% bovine serum albumin (BSA) for 12 hours at 4°C with gentle shaking. Blots were washed three times with TTBS.
and subsequently incubated with horseradish peroxidase conjugated secondary antibodies (1:8000; Dako, Carpen-teria, CA) in TTBS for 2 hours at 21°C. Blots were washed three times with TTBS and then once with TBS, and the bound antibodies were detected using euglobulin clot lysis (Amersham Biosciences, Uppsala, Sweden). The blots were imaged and analyzed using MetaMorph.

Results

Multiphoton imaging in transmission mode revealed no gross breaks in the endothelium in any of the SV samples analyzed. However, we consistently observed what appeared to be a “stretched” or redundant endothelial layer in the ESVH (Fig 2). Mean esterase activity was significantly higher in the OSVH group, indicating greater endothelial cell viability ($p < 0.0001$), as shown in Figure 3A and B and quantitated in Figure 4. Endothelial and smooth muscle cells showed minimum damage in veins harvested by the OSVH technique, as indicated by minimal red fluorescence in these regions of the vessel (Fig 3A). In contrast, both the endothelial and smooth muscle regions of the ESVH veins showed robust red fluorescence, representing substantial membrane damage (Fig 3B). Similarly, Calcium mobilization and NO production in response to bradykinin stimulation were significantly greater in the OSVH group, indicating that eNOS-dependent vasomotor function is well maintained compared with the ESVH group (Figs 5 and 6).

Caveolin, an important structural component of the endothelial cell membrane involved in cell signaling, eNOS, which generates NO, vWF, an endothelial cell marker participating in the clotting cascade, and cadherin, a component of endothelial cell adhesion were identified with immunofluorescence in the saphehnous vein samples. A noticeable disruption or decrease in fluorescence of caveolin and eNOS was observed in the endothelium of the ESVH group in comparison with the OSVH group (Fig 7). Quantitative analysis show a significant decrease in caveolin, eNOS, and vWF immunofluorescence in ESVH in comparison with OSVH samples (Table 1). However, there does not appear to be a

### Table 1. Changes in Quantitative Immunofluorescence Between the Two Saphenous Vein Harvesting Techniques

<table>
<thead>
<tr>
<th>Labeled Protein</th>
<th>OSVH (Mean ± SD)</th>
<th>ESVH (Mean ± SD)</th>
<th>$p$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caveolin</td>
<td>77.9 ± 20.90</td>
<td>41.3 ± 12.10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>eNOS</td>
<td>78.63 ± 12.56</td>
<td>34.11 ± 16.23</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>vWF</td>
<td>83.83 ± 26.68</td>
<td>61.78 ± 23.51</td>
<td>&lt;0.0032</td>
</tr>
<tr>
<td>Cadherin</td>
<td>101.66 ± 30.12</td>
<td>98.23 ± 22.75</td>
<td>NS</td>
</tr>
</tbody>
</table>

eNOS = endothelial nitric oxide synthase; ESVH = endoscopic saphenous vein harvest; NS = not significant; OSVH = open saphenous vein harvest; vWF = von Willebrand factor.

### Table 2. Western Blot Analysis: Percent Decrease in Quantified Protein After ESVH Compared With OSVH

<table>
<thead>
<tr>
<th>Protein</th>
<th>ESVH Versus OSVH (% less)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eNOS</td>
<td>37.6</td>
</tr>
<tr>
<td>Cadherin</td>
<td>12.7</td>
</tr>
<tr>
<td>vWF (60 kd)</td>
<td>42.7</td>
</tr>
<tr>
<td>vWF (24 kd)</td>
<td>48.5</td>
</tr>
<tr>
<td>Caveolin</td>
<td>40.9</td>
</tr>
</tbody>
</table>

eNOS = endothelial nitric oxide synthase; ESVH = endoscopic saphenous vein harvest; OSVH = open saphenous vein harvest; vWF = von Willebrand factor.

### Table 3. Summary of Results

<table>
<thead>
<tr>
<th>Technique</th>
<th>OSVH Versus ESVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiphoton microscopy</td>
<td>↑</td>
</tr>
<tr>
<td>Esterase activity</td>
<td>↑</td>
</tr>
<tr>
<td>Calcium mobilization after BK stimulation</td>
<td>↑</td>
</tr>
<tr>
<td>NO production after BK stimulation</td>
<td>↑</td>
</tr>
<tr>
<td>Immunofluorescence</td>
<td></td>
</tr>
<tr>
<td>Caveolin</td>
<td>↑</td>
</tr>
<tr>
<td>eNOS</td>
<td>↑</td>
</tr>
<tr>
<td>vWF</td>
<td>↑</td>
</tr>
<tr>
<td>Cadherin</td>
<td></td>
</tr>
<tr>
<td>Western blot</td>
<td></td>
</tr>
<tr>
<td>Caveolin</td>
<td>↑</td>
</tr>
<tr>
<td>eNOS</td>
<td>↑</td>
</tr>
<tr>
<td>vWF</td>
<td>↑</td>
</tr>
<tr>
<td>Cadherin</td>
<td></td>
</tr>
</tbody>
</table>

Up arrows indicate greater values in OSVH than in ESVH. BK = bradykinin; eNOS = endothelial nitric oxide synthase; ESVH = endoscopic saphenous vein harvest; NO = nitric oxide; OSVH = open saphenous vein harvest; vWF = von Willebrand factor.
significant difference in cadherin between the two groups (Fig 7, Table 1).

Finally, Western blot analysis of protein extracts from the SV samples is shown in Figure 8. The protein extracts revealed substantially decreased amounts of caveolin, eNOS, and vWF, and a moderate decrease in cadherin in the ESVH group in comparison with the OSVH group (Table 2). These results are consistent with the immunofluorescence results discussed above (Fig 7, Table 1). The measurable changes observed in structural and functional proteins between the two harvesting techniques as measured by the three different assaying techniques are summarized in Table 3.

Comment

Significant lower extremity wound morbidity associated with the OSVH technique has led to the development of minimally invasive techniques for SV harvest [17–19]. The mounting evidence that ESVH can reduce lower extremity morbidity has led many surgeons to adopt this technique [20–26]. However, the endoscopic technique involves increased traction on the vein, use of cautery near the vein, and exposure to CO₂ pressure that might result in impaired endothelial function of the venous conduits.

The principal findings of our study indicate that there is damage to SV endothelium using the endoscopic technique. The esterase activity in the SV endothelium is significantly greater in the OSVH group (p < 0.0001), indicating higher cellular metabolic activity, viability, and less membrane damage. In contrast, the ESVH group showed attenuated cell viability and extensive membrane damage in the intimal and medial regions of the blood vessels. Similarly, calcium mobilization in response to bradykinin is impaired after using the ESVH technique. Calcium is an important upstream second messenger for a multitude of cellular processes including NO production and endothelial-dependent vasomotor function. Nitric oxide production is decreased in the ESVH group to a greater extent than calcium mobilization, indicating impaired agonist-responsive eNOS function, demonstrating another defect in the pathway for the production of NO.

These findings were confirmed using two additional independent techniques. Immunofluorescence (Fig 7, Table 1) and Western blot (Fig 8, Table 2) provided further information on abnormally distributed and decreased amounts of caveolin and eNOS. Caveolin is a docking protein in the membrane that is required for the activation of eNOS and production of NO, whereas eNOS is responsible for the synthesis of NO itself. Damaged or displaced caveolin and eNOS, or decreased expression of caveolin and eNOS, is further evidence of endothelial damage resulting in impaired endothelial function in SVs harvested by the endoscopic technique. Loss of caveolin may also explain the decrease in production of NO to a greater extent than the mobilization of calcium when exposed to bradykinin (Fig 6).

Several groups have investigated the ultrastructural and functional effects of ESVH versus the open technique using histological grading, ring studies, or immunohistochemistry. Fabricius and coworkers [28], Crouch and colleagues [29], and Griffith and coworkers [30] each used a histological grading system, which failed to demonstrate a difference between the two techniques. These findings are in agreement with our study finding, which did not demonstrate any endothelial disruption on multiphoton transmission imaging. Even though this observation may be a contradiction to our functional assays, immunofluorescence studies, and Western blot analysis, it is imperative to observe disrupted endothelium to observe attenuated function. Perhaps the stretching of endothelium (Fig 1) by the ESVH technique was sufficient to impair endothelium function, as indicated by our independent assays. Meyer and associates [31], who examined histologic grading as well as immunohistochemical staining for VIII:vWF and CD34, failed to show a difference between the two harvest techniques; in contrast, we observe a significant decrease in the vWF protein in the ESVH group (Tables 1 and 2), indicating endothelial damage. Finally, Rinia-Feenstra and associates [32] and Cable and colleagues [33] compared veins harvested by these techniques using functional ring studies and failed to show a difference.

Our findings are likely different from the above studies because we employed a technique that is a more sensitive indicator (MPM) of endothelial function and metabolic activity in real time. We also looked at different markers for endothelial function in our biochemical techniques (eNOS activity, calcium mobilization, vWF, and caveolin protein). There is also the possibility that CO₂ insufflation used as aid in visualization and dissection of the surrounding tissue in ESVH techniques could potentially be harmful to the vein and may be responsible for our observed changes. We are in the process of evaluating the effects that CO₂ itself has on vein structure and function to eliminate this possibility.

Preservation of conduit NO secretion has important implications on immediate graft function, long-term patency, and ultimately, patient outcomes. Impaired secretion of NO from damaged endothelial cells leads to platelet activation, recruitment, and aggregation [6, 9, 34–39]. Aggregation of platelets can initiate subsequent thrombus formation, leading to conduit occlusion or embolus. Nitric oxide secreted by endothelial cells also brings about the relaxation of smooth muscle by increasing platelet and smooth muscle cell cyclic guanosine monophosphate [39]. Endothelial injury impairs this biochemical pathway, leading to the loss of vasomotor function and contributing to graft occlusion. Nitric oxide, along with other factors, demonstrates antiadhesive properties that prevent neutrophil-endothelial adhesion under normal physiologic conditions [9, 34]. As such, absence of or low levels of NO contribute to the development of atherosclerosis. Because NO induces vasodilation, inhibits platelet and neutrophil adhesion, and prevents atherosclerosis, the inability of the endoscopically harvested greater SV endothelium to produce NO likely has significant implications on graft patency and patient outcomes.
There are limitations inherent to our study. First, the internal control samples were taken from different portions of the vein by necessity of the experimental design. However, we attempted to limit this variable by taking samples of vein from as close together as possible. Although the samples were taken at times from above and below the knee, the mean distance between the two samples was only 6.9 ± 1.75 cm. Second, given the sensitivity of MPM for the detection of agonist-activated eNOS-mediated NO production, it is possible that the level of dysfunction we found is not clinically significant. However, known mechanisms for the development of graft failure suggest that any endothelial dysfunction would accelerate the processes of intimal hyperplasia, thrombosis, and atherosclerosis. Also, the loss of eNOS and caveolin in our immunofluorescence studies and immunoblots suggests that these defects may indeed be of clinical significance. Another potential limitation is that we do not know if the endothelial dysfunction we observed is reversible, once the vessel is placed into the circulation. Again, this is unlikely, given the known detrimental effects of high oxygen content and higher pressure can have on venous conduits. This in vitro study was designed to be a first step in evaluating the biochemical and pathophysiologic effects of ESVH on the endothelium. The next step would involve attempting to correlate the observed structural and functional changes in these vessels with clinical sequelae.

The principal findings of our study suggest that ESVH has a detrimental effect on the function and structure of the vein endothelium. Ultimately, randomized controlled trials should be done to determine whether this level of endothelial dysfunction is clinically relevant. Studies need to be done to examine not only graft patency rates at 1 year postoperatively but also patient outcomes with respect to the technique used to harvest the saphenous vein.

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References


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**Notice From the American Board of Thoracic Surgery**

The 2009 Part I (written) examination will be held on Monday, November 30, 2009. It is planned that the examination will be given at multiple sites throughout the United States using an electronic format. The closing date for registration is August 1, 2009. Those wishing to be considered for examination must apply online at www.abts.org.

To be admissible to the Part II (oral) examination, a candidate must have successfully completed the Part I (written) examination. A candidate applying for admission to the certifying examination must fulfill all the requirements of the Board in force at the time the application is received.

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