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Minimally Invasive Saphenous Vein Harvesting Using a Laryngoscope: Procedural, Functional, and Morphologic Evaluation

Basbug HS,[1] Tasatargil A,[2] Aksoy NH,[3] Golbasi I,[1] Turkay C,[1] Mete A,[1] Sadan G,[2] Bayezid O[1]

[1]Department of Cardiovascular Surgery, [2]Department of Pharmacology, [3]Department of Pathology, Akdeniz University, Faculty of Medicine, Antalya, Turkey

ABSTRACT

Background: Because commercial minimally invasive harvesting equipments significantly increase operation costs, they are not always available in all clinics worldwide. The aim of this study was to investigate whether minimally invasive saphenous vein harvesting using a laryngoscope can be applied efficiently and successfully.

Methods: Thirty patients were prospectively randomized into two groups. One group underwent a minimally invasive technique using a laryngoscope; the other, open saphenous vein harvest. A modified bridging technique, in which tissue retraction and illumination is achieved with a sterilized laryngoscope, was used for minimally invasive harvesting. Smooth muscle contractile and endothelial functions were tested in vitro using an organ chamber. Morphology was examined with light microscopy.

Results: There was no statistically significant difference in harvest times or length of the vein harvested by either of the abovementioned techniques. Total length of the incision in the minimally invasive group was significantly shorter than that in the open group. In follow-ups, no significant complications occured in either group. Pain and leg edema were significantly less in the minimally invasive group compared to those of the open group. There was no significant difference in response to acetylcholine and 80 mM KCl between veins taken with the laryngoscope compared to veins taken with the traditional open technique. Similarly, histological data was unable to show any significant damage to the vessel wall.

Conclusions: Because the laryngoscopic saphenectomy does not harm the harvested graft, it can be applied, instead of other minimally invasive saphenous vein harvesting systems, with a zero cost, efficiently, successfully, and with satisfactory speed and significant reduction of postoperative leg pain and wound complications.

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Address correspondence and reprint requests to: Hamit Serdar Basbug, Department of Cardiovascular Surgery, Akdeniz University, Faculty of Medicine, Antalya, Turkey, 90 242 2274343; fax: 90 242 2274482 (e-mail: ardatas@akdeniz.edu.tr).

INTRODUCTION

Coronary artery bypasss graft (CABG) surgery is the most common procedure performed in adult cardiovascular operations; it is widely used and still maintains its importance for the treatment of coronary artery disease [Eagle 1999]. Although arterial grafts are being performed more frequently, the long saphenous vein is still the primary conduit of choice. The longest incision made in surgery is the incision from ankle to groin that is made for the harvesting of the long saphenous vein, and unfortunately, this incision, used for open (traditional) harvesting, causes serious leg pain and morbidity influencing postoperative recovery period. Postoperative leg wound recovery problems are seen in 1%-25% of cases and often patients complain more about their leg wounds than they do about their sternotomy [DeLaria 1981, Utley 1989]. Wound infections, hematomas, reccurent cellulitis, saphenous neuropathy, and neuralgia retard the recovery of the patient [Lavee 1989]. Additionally, the need for wound dressing and immobilization causes impairment in the quality of life of the patient [Farrington 1985, Wilson 1987].

To minimize the trauma and related complications of a standard long incision, a bridging technique was employed, interspersing a series of skin incisions with multiple bridges of intact skin and underlying subcutaneous tissue tunnels. Thus minimally invasive saphenous vein harvesting has been advocated and encouraged to lessen the leg-woundrelated problems [Alien 1997, Cable 1997, Davis 1998]. In a previous study, it has been shown that these techniques significantly reduce wound complications such as pain and infection, and also give superior cosmetic results [Davis 1998].

In this study, we investigated whether minimally invasive saphenous vein harvesting using a laryngoscope is better than the traditional single large incision which allows a full exposure of all tissues. Because the surgical techniques used can affect the functional properties and patency of venous grafts, we also evaluated the vascular function and the vascular morphology in saphenous veins harvested by the minimally invasive technique compared to veins harvested by the open technique.

METHODS

Study Design

A total of 30 patients who underwent elective coronary artery bypass surgery with use of the long saphenous vein at the Akdeniz University Hospital (Antalya, Turkey) between August 2003 and January 2004 were prospectively randomized into two groups. Fifteen patients, designated the minimally invasive group, had their saphenous vein harvested using a conventional laryngoscope with a no. 5 straight blade. The remaining fifteen patients were designated the open (standard) group and had their long saphenous vein harvested by the traditional open technique using a single long, continous incision.

Patients whose venous insufficiency was obtained by a venous doppler ultrasonography were excluded. The study protocol conformed to the Declaration of Helsinki and was approved by the institutional Ethics Committee, and written informed consent was given by each patient. Exclusion criteria included emergency surgery, low ventricular function (ejection fraction < 40%), conversion from laryngoscopic to open technique during the operation, need of harvesting from both legs, and the presence of leg decubitus ulcerations or an active dermal infection.

Surgical Techniques

Laryngoscopic (Minimally Invasive) Technique. This technique is a modified bridging technique using a conventional laryngoscope. We used a sterilized conventional laryngoscope, with a no. 5 straight blade attached for retraction, for illumination and for direct vision.

First, the saphenous vein is identified by a 2-3 cm longitudinal incision made 2 cm distal to the medial tibial condyle. Once the vein is identified and cleared from the surrounding subcutaneous fatty tissue and fascia, a subcutaneus vein tunnel is identified and progressed proximally with gentle digital blunt dissection. After the tunnel is again further progressed 2-3 cm proximally by using a longer blunt equipment, it is inflated with a 50 cc nasogastric irrigation syringe 2 to 3 times so that the surrounding fatty tissue is completely detached from the vein and the tunnel is cleared all through the trace. The straight blade of the laryngoscope is placed through this incision and progressed as far as possible. By holding the laryngoscope upwards to retract the tunnel, the vein is readily visualized. Then with a sharp dissection using ordinary Metzenbaum scissors, the saphenous vein is dissected from the surrounding tissue and the side branches are ligated using ordinary vascular clips before dividing them with the same ordinary scissors.

Once the vein is dissected free as far as possible, the next incision is made proximally as far away as possible along the trace and the dissection of the vein is continued through this new incision, which is nearly localized on the mid-thigh region in the same manner. As the last incision, which is smaller compared to the others, is made in the groin region, the proximal end of the vein is excised after being ligated with a silk tie. Then this free saphenous vein is withdrawn distally through the vein tunnels underlying the intact skin bridges. If needed, dissection can proceed in the same manner from the first incision distally and the excised saphenous vein length can be readily increased.

After harvesting is completed, the ligaclips are replaced with silk ties as far as possible. The graft is then inflated with heparinized blood and checked for defects. All incisions are closed with 2-0 vicryl and 4-0 vicryl, subcutaneously and intracutaneously respectively. At the end of the operation, an elastic bandage is placed.

Traditional (Open) Technique. The saphenous vein is inspected and palpated proximal to medial malleolus. The skin is incised with a scalpel and the vein is dissected free using Metzenbaum scissors. Dissection is progressed through the medial tibial condyl to the saphenofemoral junction with a single incision according to the need of the graft length. Side branches are ligated using 4-0 silk. At the end of the operation, the wound is closed in layers and bandaged.

Organ Bath Studies

Human saphenous veins were obtained by either open surgery or laryngoscopic surgery. After the vein was removed, it was immediately placed in a cold Krebs buffer and transported to our lab. Briefly, the saphenous vein was cleaned of the connective tissue and cut into 3-4 mm width rings. The rings were carefully suspended by two stainless steel clips that passed through the vessel lumen in 20 ml organ baths filled with PSS (mM: NaCl 118, KCl 5, $NaHCO_3$ 25, KH_2PO_4 1.0, $MgSO_4$ 1.2, $CaCl_2$ 2.5, and glucose 11.2) maintained at 37°C gassed with 95% O_2 and 5% CO_2 to obtain a pH of 7.4. The rings were suspended under 2*g* of tension, and the preparation was allowed to equilibrate for 60 minutes. Isometric tension was continuously measured with an isometric force transducer (FDT10-A, Commat Ltd., Ankara, Turkey), connected to a computer-based data acquisition system (TDA 97, Commat Ltd., Ankara, Turkey). The buffer was changed every 20 minutes. After an equilibration period of 1 hour, all rings were precontracted with phenylephrine (Phe, 10^{-6} M). After stable contraction was achieved, a concentration-response curve to ACh (10^{-9} to 10^{-4} M) was constructed to check for the presence of functional endothelium. In another set of experiments, all rings were contracted with KCl (80 mM) to evaluate the contractile mechanism of venous preparations.

Histological Studies

At the end of the functional studies, SV samples from each group were routinely fixed in 4% formalin solution and subsequently embedded in paraffin. Paraffin-embedded vascular tissue sections (4 µm) were mounted on microscope slides, deparaffinized for 10 minutes in xylene at room temperature, and rehydrated through descending concentrations of ethanol. Sections were then stained with hematoxylin-eosin, and elastica van Gieson to define the intimal and medial layers. All sections were then examined using a light microscope.

Data Analysis

Data are expressed as the mean ± S.E.M. Responses to ACh are expressed as percentages of the reversal of the tension developed in response to phenylephrine. The concentration-

Table 1. Demographic and Risk Factor Profiles for the Two Groups*

Variable	Minimal Group (n = 15)	Open Group (n = 15)	*P* Value
Female sex	3 (20)	5 (33)	.68
Age, yr	67.17 ± 2.39	65 ± 1.7	.46
Diabetes	5 (33)	6 (40)	1
EF, %	56.67 ± 1.42	55.62 ± 1.94	.67
Hb, g/dL	12.39 ± 0.24	11.91 ± 0.21	.16
Albumin, g/dL	4.14 ± 0.07	4.12 ± 0.07	.88
Height, cm	169.7 ± 2.29	170.7 ± 2.49	.77
Weight, kg	75.92 ± 2.41	76.85 ± 3.32	.82

*Data are presented as absolute numbers with percentages in parentheses or as mean values ± the standard error. EF indicates ejection fraction.

response curves for the agonists were analyzed with a computer program (Graph Pad, Institue for Scientific Informatics, San Diego, CA). The concentrations of agents required to elicit 50% of their maximum responses (EC_{50}) were calculated for each ring in order to compare the sensitivities, and they were expressed as a negative log M (pD_2). The Student's two-tailed unpaired *t*-test was used to test the statistical significance of the differences between the two groups. The statistical significance of possible differences in quantifiable variables was calculated by analysis of variance (ANOVA). A *P* value lower than .05 was considered significant.

Drugs

Acetylcholine chloride, KCl, and L-phenylephrine were used. All drugs and the salts for the PSS were purchased from Sigma Chemical (St. Louis, MO) and prepared fresh daily during experiments.

RESULTS

Patient Demographics

Population parameters influencing the wound healing (diabetes, Hb, albumin, weight, etc.) were well matched (Table 1). Both patient groups had peripheral venous diseases (varicosities, pigmentations), 20% in minimal group and 26% in open group. History of intermittent claudication was also present in 7% and 13% of the two groups, respectively.

Harvesting Variables

In all cases a sufficient graft was prepared for the anastomosis. Intraoperative data were collected and analyzed for both types of surgery (Table 2). A total graft of 15 cm consisting of 4.4 incisions was made for harvesting in the minimally invasive group compared to a single 50.3 cm continuous incision in open group. The length of the saphenous vein graft before distention was 47.8 cm in the minimally invasive group, whereas it was 50.3 cm in the open group. The mean harvesting time was 37.3 minutes versus 34.8 minutes, respectively. The calculated harvest rate (cm/min) was also similar in both groups. The rate of vein harvest (centimeters per minute) was 1.29 in the minimally invasive group and 1.45 in the open group. The harvest rate did not demonstrate improvement with experience. In the minimally invasive group 3.19 cm graft was prepared via 1 cm skin incision, whereas this proportion is 1/1 cm in the open group. In addition, pain and leg edema were significantly less in the minimally invasive group compared to those in the open group (data not shown).

Table 2. Surgical Outcomes for the Two Groups*

Variable	Minimal Group (n = 15)	Open Group (n = 15)	*P* Value
Harvest time, min	37.33 ± 2.73	34.85 ± 1.35	.42
Vein length, cm	47.83 ± 3.68	50.38 ± 2.13	.55
Rate, cm/min	1.29 ± 0.08	1.45 ± 0.05	.10
Incision length, cm	15.04 ± 0.96	50.38 ± 2.13	<.0001
No. of incisions	4.41 ± 0.22	1 ± 0	<.0001
Vein/incision, cm/cm	3.18 ± 0.12	1 ± 0	<.0001

*Data are presented as the mean values ± the standard error.

Effect of Surgical Technique on ACh-Induced Endothelium-Dependent Relaxation and KCl-Induced Contraction

As loss of endothelial function is an important indicator of vascular injury, endothelial cell function was assessed by the responses to ACh, an endothelial specific vasodilator. ACh (10^{-9}-10^{-5} M) evoked endothelium-dependent relaxation of isolated saphenous vein rings precontracted with phenylephrine (10^{-6} M). ACh caused vasorelaxations with similar sensitivities and maximal responses in vein segments that were harvested by the minimally invasive or the open technique (Figure 1, Table 3). Vascular contractions were preserved in the 2 groups and similar contractile responses to 80 mM KCl were observed in vessel segments harvested by both surgical techniques (Figure 2, Table 3).

Histological Results

The saphenous vein segments were stained with haemotoxylin-eosin and elastic van Gieson to examine the intima and media, and no morphologic difference was found in the vein

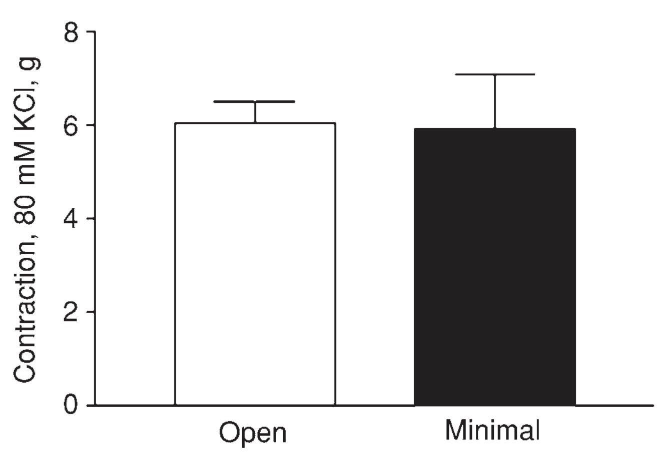

Figure 1. The effect of surgical technique on endothelium-dependent relaxation responses in human saphenous vein rings. All values are expressed as mean ± SEM of eight experiments.

Table 3. Maximum Responses (E_{max}) and Sensitivity (pD_2) Values for Responses to Acetylcholine (ACh) and 80 mM KCl in the Human Saphenous Vein Grafts*

	E_{max} (%)			pD_2		
	Open	Minimal	*P* Value	Open	Minimal	*P* Value
ACh	22.40 ± 2.04%	20.60 ± 1.93%	.53	7.85 ± .21	7.83 ± .29	.95
KCl	6.05 ± .45 g	5.91 ± 1.20 g	.91	ND	ND	ND

*Data are presented as the mean values ± the standard error (n = 6). The maximal dilation to ACh is expressed as percentage of the precontraction to Phe (10^{-6} M).

segments between both groups (Figure 3, Figure 4). No signs of damage were seen in any of the vein sections.

DISCUSSION

Saphenous vein harvesting for coronary bypass operation is still a routine operation despite the more frequent usage of arterial revascularization. Postoperative leg-wound complications are an underestimated source of patient morbidity [Düsterhöft 2001]. The traditional open technique is often associated with complications in wound healing, unsatisfactory cosmetic results, and delays in mobilization of the patients. Traditional harvesting techniques using a long groin-to-ankle incision over the vein, which involves this significant morbidity, may be challenged by less invasive procedures if these methods prove to be feasible in terms of technique, economics, and time [Fabricius 2000].

These less invasive techniques range from totally endoscopic techniques [Alien 1997, Cable 1997] to the use of nonspecialist and cheap equipment to aid the harvesting of the saphenous vein via smaller incisions [Cable 1997, Catinella 1982]. However, benefits for the patient can be expected only if postoperative discomfort is reduced and conduit quality is guaranteed [Fabricius 2000]. Minimally invasive techniques to harvest the saphenous vein have improved and evolved with the use of common instruments, such as a Richardson retractor (Aesculap, Tuttlingen, Germany) [Slaughter 1998] or a lighted retractor [Newmann 1999] in addition to commercially available, minimally invasive endoscopic instruments, [Cable 1997] especially with carbon dioxide insufflation [Morris 1998] and newly designed lighted retractors [Tevaearai 1997]. Clinical experiences have demonstrated the technical feasibility of these new techniques, and although always more time consuming [Davis 1998, Lumsden 1996, Pagni 1998], these have shown reduced postoperative morbidity, reduced pain [Davis 1998, Slaughter 1998, Newmann 1999, Allen 1998], and earlier ambulation [Tevaearai 1997].

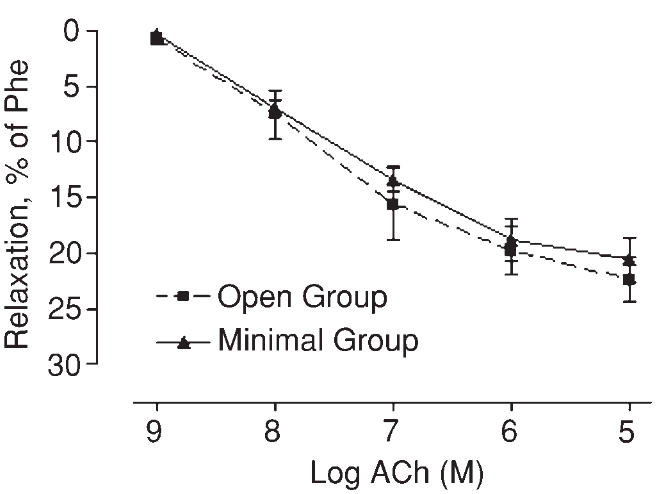

Figure 2. The effect of surgical technique on 80 mM KCl-induced contraction responses in human saphenous vein rings. All values are expressed as mean ± SEM of eight experiments.

To evaluate the feasibility of minimally invasive harvesting technique, firstly, we focused on both intra- and postoperative surgical outcomes of the harvested saphenous veins and cosmetic results of surgical techniques. As expected, the minimally invasive harvest significantly reduced the total length of incision. The mean length of vein harvested was not different in the minimally invasive harvesting technique using a laryngoscope. The time required for harvesting was also almost identical in veins harvested by both techniques. So, the intra-operative results of our study have clearly indicated that minimally invasive harvesting using a laryngoscope could be technically feasible in saphenous vein harvesting. As in previously published studies, all the minimally invasive techniques yielded superior cosmetic results and reduced wound complications, [Davis 1998, Puskas 1999] compared to those of the conventional technique; [Lavee 1989] only one trial showed substantially lower wound complications in the conventional group [Puskas 1999]. Clinically, all minimally invasive treated patients had an improved postoperative wound healing due to the short incision length and earlier ambulation due to the absence of the incision at the medial knee region. Although the most common problem in the minimally invasive groups was ecchymosis or mild hematoma, [Horvath 1998, Carrizo 1992] we did not face this problem in our patients. In the follow-up, no significant complications regarding wound dehiscence, infection, cellulitis, or major hematoma occurred in either group. Pain and leg edema were significantly less in the minimally invasive group compared to those in the open group. None of the patients required repeated hospitalization or reoperation for wound complications. Therefore, minimally invasive harvesting using a laryngoscope may serve as a great advantage if accepted and will help in early wound healing and earlier mobilization.

Although postoperative results, such as wound healing and mobilization time, were better in the minimally invasive group than those in the traditional open group, it is important to remember that the most important variable is the effect of the harvesting technique on graft patency and qual-

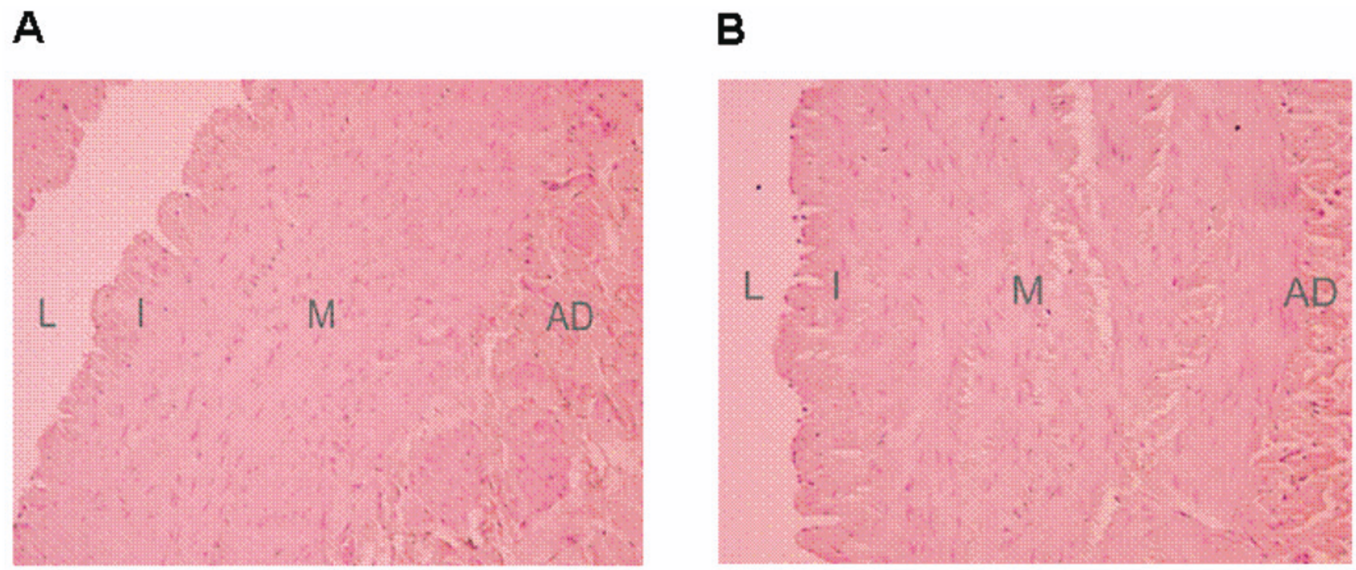

Figure 3. Morphology of saphenous vein rings harvested using open (A) and minimally invasive (B) harvest techniques. Tissues were stained with hematoxylin-eosin (orginal magnification ×100). L indicates lumen; I, intimal layer; M, medial layer; AD, adventitia.

ity. Graft patency and quality are dependent on the structural and functional integrity of the vessel used to bypass. Excess traction and increased manipulation of the vein, especially in minimally invasive harvesting techniques, may compromise conduit quality and patency due to vascular injury. Shear stress may be severe with the blunt dissection of strong perivascular tissue as compared to the sharp preparation using conventional scissors under direct vision in applying the conventional no-touch technique. Impairment of endothelial cell function can lead to graft stenosis, [Motwani 1998] and thus to vein graft vascular dysfunction, [O'Neil 1994, Ku 1991, Cross 1994] and graft failure. Because the minimally invasive harvesting technique using a conventional laryngoscope can lead to vascular trauma, in a separate group of experiments we investigated the morphological properties of the vein harvested to assess endothelial and smooth muscle integrity. Surprisingly, histology via light microscopy revealed no morphologic differences when using the laryngoscopic technique compared to the traditional procedure. On the other hand, the biological properties of harvested veins were assessed by exposure to a receptor-independent vasoconstrictor, such as KCl, and an endothelial specific vasodilator, such as ACh. In the present study, no significant difference was seen in the response to ACh and 80 mM KCl between veins

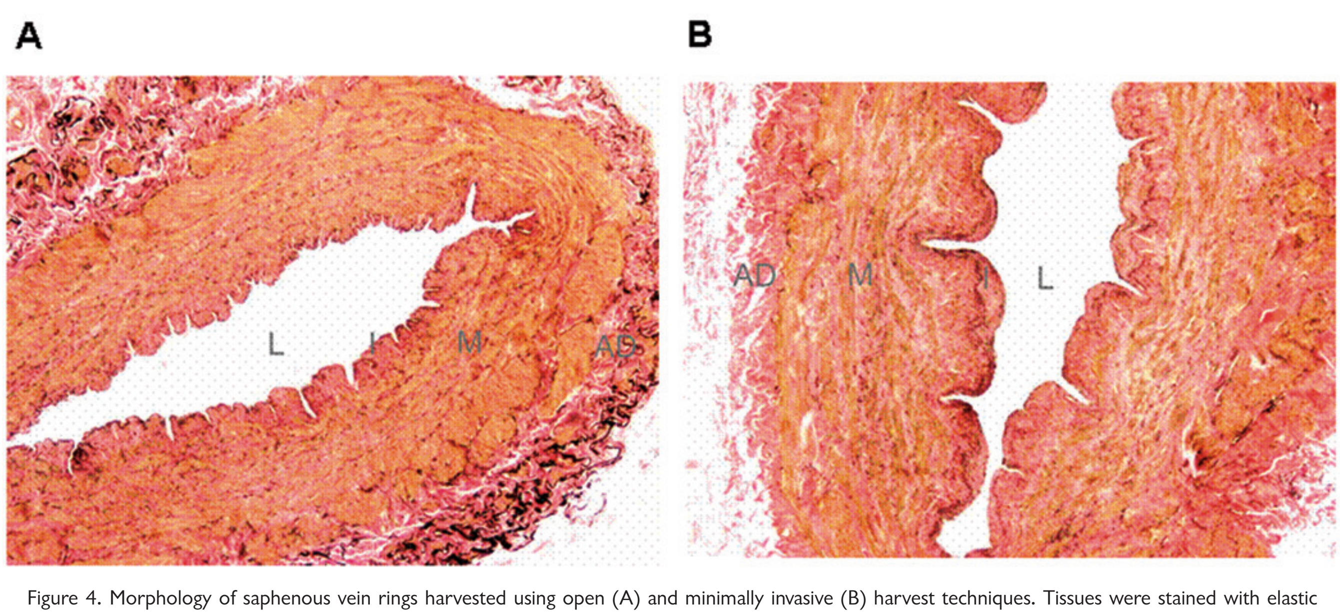

Figure 4. Morphology of saphenous vein rings harvested using open (A) and minimally invasive (B) harvest techniques. Tissues were stained with elastic van Gieson (orginal magnification ×100). L indicates lumen; I, intimal layer; M, medial layer; AD, adventitia.

taken with the laryngoscope and those with the traditional open technique. This suggests that minimally invasive saphenous vein harvesting using a laryngoscope preserves both endothelial cell and smooth muscle cell function as much as the traditional open harvest does, and it can be applied safely.

In conclusion, we have demonstrated that the minimally invasive saphenous vein harvesting technique using a laryngoscope is technically feasible, and it is associated with better cosmetic results and fewer wound complications than the traditional open technique. Furthermore, the laryngoscopic procedure is safe, as we confirmed by the preservation of the saphenous vein endothelium and smooth muscle.

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