White p aper

Endoscopic Vessel Harvesting: Using Advancement and Best Practices to Enhance Conduit Quality

Bershinsky, J Matt, PA-C; Bitondo, Jerene M, PA-C; Brennan, Teresa, PA-C, MPAS; Causey, Keith, PA-C; DeMara, David, PA-C; Dinwiddie, Greg, PA-C; Durbin, Harold Jr, PA-C; Eisenring, Christian, ACNP-c; Froelich, David, CRNFA; Ginn, Lonnie J, PA-C; Gottesfeld, Steven M, PA-C; Hahm, Edward, PA-C, MMSc; Hunnicutt, Carol, PA-C; Kollpainter, Robert, PA-C, FAPACVS, RDMS; Keuler, James P, PA-C; Lee, John, PA-C; McCarley, Christopher K, PA-C; Sullivan, Michael L, PA-C; Van Woerkom, Jon, PA-C; Vida, Kevin A, MS, PA-C; Vitali, Richard M, MPH, PA-C*

Benefits of the endoscopic approach to vessel harvesting

During the past decade, endoscopic vessel harvesting (eVh) has become the preferred technique over open harvesting procedures for patients undergoing coronary artery bypass grafting (Ca BG) surgery in the U.S. in 2014, 86.5% of the Ca BG cases used eVh in the United States and global adoption of the procedure has been increasing in recent years.[1] (Fig. 1)

Fig. 1 eVh

Table of Contents

* a uthors are listed alphabetically

in the open vein harvest (OVh) technique, the extensive incision along the medial aspect of the leg has been associated with postoperative complications, including dehiscence, hematoma, cellulitis, edema, and pain.[2,3] t hese complications delay wound healing, increase outpatient wound management resources and increase post-operative length of stay.[2] (Figs. 2 and 3)

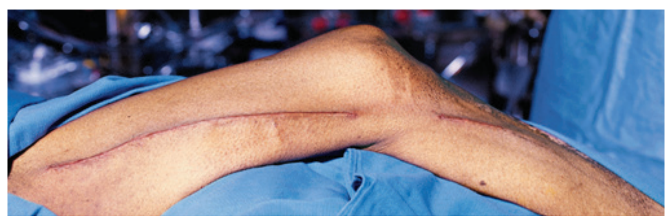

Fig. 2 Open vein harvest

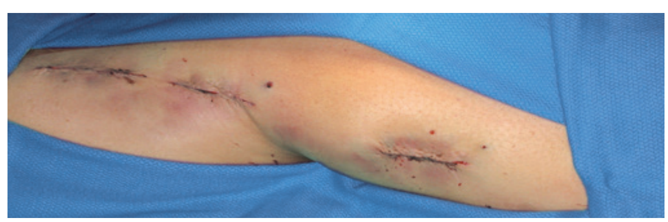

Fig. 3 Bridging vein harvest

t he body of evidence demonstrating clinical, economic and cosmetic benefits of eVh over OVh has steadily mounted, with benefits including:

- Reduced wound complications and infections[2-6]
- Reduced postoperative pain[5-8]
- Reduced length of stay and rate of readmission[9-11]
- Improved cosmesis and patient satisfaction[2,3]

in recent years, the endoscopic method has been increasingly used for harvesting the radial artery, and similar advantages to those seen with the greater saphenous vein have been demonstrated.

Assessing graft patency with EVH

While many studies have documented the “short-term” benefits of eVh such as reduced wound complications and postoperative pain, other studies have looked at the quality of the harvested vessel for the bypass procedure. t o date, a number of studies have shown equivalent graft patency whether the vessel graft was obtained endoscopically or with the open procedure.[2,12-14]

Graft patency and disease according to vein harvest method[12]

	EVH (n = 166)	OVH (n = 170)	p values
patent	113 (68%)	119 (70%)	ns
Significant disease	17 (10%)	21 (12%)	ns
Occlusion	36 (22%)	30 (18%)	ns

P = .584. eVh , endoscopic vein harvest; OVh , open vein harvest

in the largest randomized trial with the longest angiographic follow-up (six months postop), *Yun et al.* showed that occlusion and disease rates were comparable between endoscopic and OVh procedures.[12] t he authors concluded that overall patency rates depend on target and vein-related variables (e.g. vein size) and patient characteristics (e.g. congestive heart failure) rather than the method of vein harvesting.

Based on a meta-analysis of studies comparing eVh to open harvesting, the international Society for Minimally invasive Cardiothoracic Surgery (iSMiCS) concluded in 2017 that endoscopic saphenous vein and radial artery harvesting should be the standard of care for patients who require these conduits for coronary revascularization and european a ssociation for Cardio-t horacic Surgery (ea Ct S) guidelines stating endoscopic vein harvest should be considered to reduce the incidence of leg wound complications.[2,3]

r ecently the issue of graft patency with eVh has come under scrutiny with the publication of a secondary analysis of patients who underwent Ca BG.[15] in light of this study, it is important to understand factors that can affect conduit quality. endothelial injury, which can diminish patency of the vessel, can be caused by surgical trauma, ischemia, storage conditions, and distension, among other factors.[16,17]

prompted by a better understanding of physiology and the surgical challenges that harvesters face, clinicians and manufacturers have worked to improve practice techniques and technology over the past several years in ways that promote optimal conduit quality. h arvester experience is a crucial element to consider; ensuring that all harvesters are trained and up to date on the latest clinical techniques is paramount to their success.

t his paper will look at eVh technique and technology improvements and share best practice tips from experienced harvesters.

Evolving technology and techniques

First introduced in the mid-1990s, endoscopic vessel harvesting technology has undergone many transformations as manufacturers have developed refinements to make the procedure easier, faster, and more protective of the harvested conduit.

t o address the learning curve for those new to the eVh procedure, ergonomic and operational improvements have been made. For example, certain models were designed with in-line instrumentation, in which the scope port and tool port are arranged parallel to the cannula. t his design helps reduce vessel manipulation and facilitates the instrumentation in the tunnel, enabling greater surgical control.

t o speed the procedure, features like built-in scope cleaning systems were added, so the harvester would not need to remove the tools from the tunnel when the scope became obscured. Some systems incorporated CO_2 insufflation to enhance visualization and maneuverability during dissection.[5] t his function has been refined with the addition of improved port and distal insufflation techniques in more recent technology generations.

Graft failure has been attributed to endothelial cell damage, which may be caused by electrocautery, generally referred to as “thermal spread.” t herefore, strategies to mitigate thermal spread have been pursued. r ecent generations of eVh technology enable harvesters to seal and cut in a single step, virtually eliminating thermal spread beyond the device.

While manufacturers honed technological and design innovations, harvesters developed better clinical techniques as they gained more experience with the eVh procedure and a deeper understanding of the physiological implications of it. For example, harvesters have developed and enhanced techniques for vessel ligation and removal at the end of the procedure.

a growing awareness of the need to protect the vessel has led to other changes in clinical practice. Distending the harvested vessel by flushing it with solutions has been a common practice prior to grafting to check for leaks. h owever, studies have shown that overdistension of the vessel can damage the endothelium and reduce long-term patency of the graft.[16,18] t herefore, keeping the pressure at controlled levels is now advised. (Fig. 4)

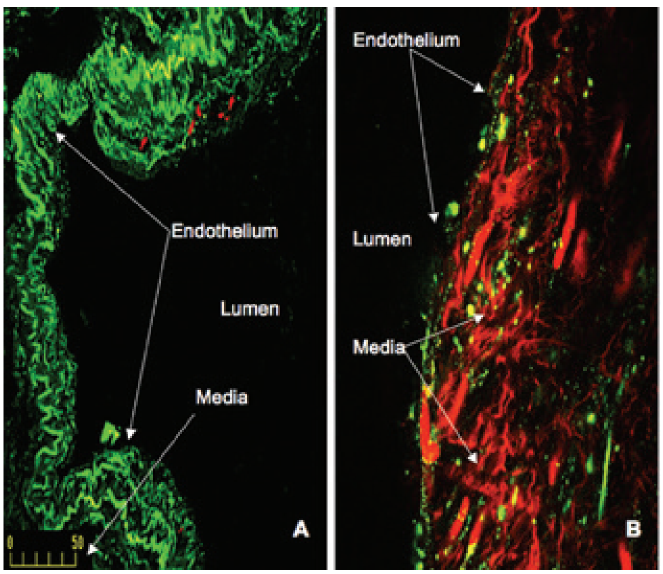

Fig. 4 Distension-dependent changes in vessel viability. Green cellular fluorescence indicates cell viability; red nuclear fluorescence shows compromised or dead cells.
a) Saphenous vein segment reveals living endothelium and media.
B) Distended saphenous vein segment shows denuded and damaged endothelium and media.
t hatte and Khuri.[16]

a nother clinical protocol change adopted by some institutions is the administration of heparin prior to eVh . it has been suggested that pre-heparinization lowers the incidence of fibrin strand formation within the lumen.[19]

r ecognizing that harvester experience and technique can play a vital role in graft quality and patient outcome, the aforementioned panel of proficient, experienced harvesters has established and endorsed the following set of "best practice" tips that serve as a gold standard for performing eVh .

EVH best practice tips

Many of the tips below are described specifically in terms of harvesting the greater saphenous vein; however, most of the concepts would also apply when performing eVh of the radial artery or lesser saphenous vein.

Preoperative preparation

Review the patient's History & Physicial for contraindications and pertinent anatomy preoperatively.
Look for potential contraindications or issues such as prior surgeries that may have stripped or injured the vessel. in this case, consider using an alternative conduit.

Whenever possible, perform vein mapping with ultrasound to locate and evaluate the vessel.
While harvesters should have a thorough knowledge of all anatomical landmarks, studies have shown that the use of ultrasound to perform vein mapping is beneficial in selecting the optimum site for the incision.[20,21] Ultrasound can help identify venous abnormalities and small vein segments, and pinpoint the vein location when dealing with challenging anatomies, such as in obese patients.

Think of the procedure as having three separate stages:

1. Choosing the incision site and making the incision
2. Dissecting the vessel and the vessel tributaries
3. Dividing the vessel branches

Incision

Decide on the best place to make the incision and mark the site.
h arvesters should choose whether to make the incision above or below the knee based on patient variables and preference, taking into account where their dominant hand will be positioned. While some new harvesters feel it is easier to guide the endoscope through subcutaneous tissue in the thigh as opposed to the tighter space in the lower leg, conditions can vary greatly from patient to patient so this should be an individual decision. For example, some harvesters have more difficulty manipulating the scope around an elderly arthritic knee than the lower leg.

Keep the length of the skin incision to a minimum.

When making the initial incision, clinicians must balance the need to protect the vessel during removal and achieve a good seal to prevent leaks, if a CO_2 insufflation system is used. t he blunt tip of the CO_2 insufflation port placed at the incision should have a good seal, but it should not be forced into the incision. in addition, keep inflation pressure of the balloon to a minimum; inflate it just enough to maintain the seal.

Consider making the incision to correspond with tension lines of the skin.

Making an incision that follows skin tension lines can enhance wound healing and cosmesis. t herefore, clinicians may choose to make the above-the-knee incisions transversely and below-the-knee incisions longitudinally over the vein. One advantage of a longitudinal incision is that it is in line with the vein, and if endoscopic harvesting needs to be converted to an open procedure, the incision can simply be extended. a n advantage of a transverse incision is that it may offer more leeway in locating the vein if the harvester is not confident in the landmarks or was unable to perform vein mapping with ultrasound prior to the eVh procedure.

CO_2 Insufflation

Use the lowest tunnel pressure possible to reduce the risk of CO_2 embolism.

CO_2 insufflation is commonly used with eVh and other endoscopic surgical procedures to improve visibility and control, but it does create the potential for CO_2 embolization to occur.[22] One way harvesters can help prevent this risk is by keeping the CO_2 pressure setting as low as possible. it is also helpful to minimize flow settings, so having a good seal at the port site is important.

Monitor central venous pressure (CVP) to keep the CVP/tunnel gradient in proper balance.

in a closed system, the CVp should be maintained slightly greater than the tunnel pressure to reduce the risk of CO_2 embolization/microembolization. peep (positive end expiratory pressure) can be adjusted to decrease the CVp/tunnel gradient, as tolerated by the patient.

Use appropriate monitoring to be alerted to CO_2-related events.

During CO_2 insufflation, exhaled carbon dioxide levels tend to be elevated. end-tidal carbon dioxide (et CO_2) monitoring is the gold standard used by anesthesiologists to assess ventilation.[23] t ransesophageal echocardiography (t ee) is also valuable for revealing evidence of gas bubbles in the patient's right atrium, suggesting an increased risk of embolism.

Dissection of the Vessel

Establish a regular sequence for dissection.

a pproaching the vessel the same way each time helps develop confidence and enhance harvester skill during the procedure. a sequence recommended by the authors for performing the overall procedure is: dissect thigh, dissect lower leg, divide lower leg, divide thigh. t his approach may potentially reduce blood stasis and, therefore, fibrin strand formation. a recommended sequence specifically for dissection is: dissect anteriorly along the vessel, dissect posteriorly along the vessel, followed by lateral dissection, one side then the other side.

During the initial dissection, use short, gentle motions.

a void any sudden or forceful motion while dissecting along the main body and branches of the vessel. Use small motions, advancing the dissection cannula from side to side along the vessel and around branches. a llow CO_2 to promote dissection along the tunnel by periodically moving the endoscope back a few centimeters. a fter confirming the orientation, continue with short, gentle advancements.

Ensure that side branches are thoroughly dissected to allow adequate length during branch division.

t he side branches should be long enough to apply suture ties and/or ligatures during vessel preparation. t o support CO_2 insufflation and open up more space around the branch, many harvesters use the "window" technique on the side dissections. t he "window" technique involves creating fenestrations into the surrounding fascial layers to allow access to the vessel branches.

Apply appropriate pressure with the opposite hand to promote ease of dissection along the vessel.

a pplying countertraction on the patient's thigh can be helpful for increasing the length of branches.

Division of branches

Establish a regular sequence for dividing the branches.
a s with dissection, establishing a regular sequence for the branch division improves confidence and efficiency. Most clinicians start the dissection of the vein in the thigh, ending with the lower leg, and therefore start dividing the branches in the lower leg at the distal end of the tunnel, working back toward the incision (in retrograde fashion). Some harvesters may divide branches as they navigate the tunnel if branches are at risk for damage.

Consider making a fasciotomy along the tunnel if the space is very tight.
if harvesters encounter a very tight tunnel during branch division, they should consider performing a fasciotomy along the length of the tunnel to increase the size of the tunnel and therefore to decrease the risk of injury to the vessel or the vessel branches. t he fasciotomy may not be necessary along the entire length, but enough to get through a very confined area.

Before dividing the branch, consider whether it is of adequate length to clip or tie.
Branches should be long enough to ensure an adequate margin to prevent thermal injury, allow for effective ligation, and moreover, to avoid compromising the vessel lumen in order to deliver a good conduit to the surgeon. Larger branches may need to be somewhat longer. if branch length is inadequate, dissect it farther out to obtain enough length.

Keep energy settings as low as possible during branch division.
While dividing with bipolar electrocautery, keep energy settings on the lowest possible setting. t his will allow the branches to adequately seal before division and minimize bleeding in the tunnel. t o prevent thermal injury, do not cauterize longer than necessary; usually 1 to 1 ½ second bursts of cauterization are adequate.

Vessel removal and preparation

Make sure all branches and connective tissue are free from the vessel before removing it.
Before dividing and ligating the ends of the vessel, make a final circumferential pass along the length of the vessel to ensure that all branches and connective tissue have been removed. t his final pass also allows the harvester to visually inspect the tunnel to assess hemostasis.

Use an appropriate technique for distal ligation of the vessel.
Clamping and ligating the distal end of the vessel can be challenging, and harvesters have developed a number of techniques to accomplish it. t he decision of which technique to employ may depend on the eVh technology being used, how the harvester was trained, and other variables. One of the most common techniques is "stab and grab" in which a small, stab incision is made at the distal end of the tunnel using a #11 blade, and the vessel is pulled through the stab wound incision with a hemostatic clamp, and divided and ligated externally under direct vision. (Fig. 5) a nother option is to use a knot pusher to create a ligation loop.

Fig. 5 "Stab and grab" technique for distal ligation of vessel

Take care to not stretch the vessel when removing it from the EVH tunnel.
t o preserve the quality and longevity of the vessel, the authors of this paper believe it is critical to minimize vessel trauma during removal and preparation. a void dimpling the vessel during branch ligation of the harvested conduit, and be especially mindful to not overdistend the vessel. irrigate the removed vessel with solution according to hospital protocol (e.g. heparinized saline/blood) to flush out any potential clot or fibrin strands—avoiding overdistension during this process.

Once the vessel is extracted and prepared, place it in the specified solution until ready for use in the surgery.

place the harvested vessel in the storage solution specified by hospital protocol until the surgeon is ready to use it. Note that studies have shown that endothelium and smooth muscle cells are affected by the storage solution used,[16] and the type of solution may therefore play a role in long-term graft patency.

Conclusion

Because of the numerous benefits demonstrated by endoscopic vessel harvesting versus the open approach, eVh has become more than a technique—it has become a standard of care. t he procedure, as well as the technology, has undergone continual refinements. By adopting best practices, harvesters promote optimal conduit quality, which contributes to a successful outcome for patients undergoing Ca BG surgery. Surgeons can support these practices by allowing ample time for them to be accomplished.

Key takeaways

Preoperative preparation

- r eview the patient's h &p for contraindications and pertinent anatomy preoperatively.
- Whenever possible, perform vein mapping with ultrasound to locate and evaluate the vessel.
- t hink of the procedure as having three separate stages: choosing the incision site and making the incision, dissecting the vessel and vessel tributaries, and dividing the vessel branches.

Incision

- Decide on the best place to make the incision and mark the site.
- Keep the length of the skin incision to a minimum.
- Consider making the incision to correspond with tension lines of the skin.

CO_2 insufflation

- Use the lowest tunnel pressure possible to reduce the risk of CO_2 embolism.
- Monitor central venous pressure (CVp) to keep the CVp/tunnel gradient in proper balance.
- Use appropriate monitoring to be alerted to CO_2-related events.

Dissection of the vessel

- establish a regular sequence for dissection.
- During the initial dissection, use short, gentle motions.
- ensure that side branches are thoroughly dissected to allow adequate length during branch division.
- a pply appropriate pressure with the opposite hand to promote ease of dissection along the vessel.

Division of branches

- establish a regular sequence for dividing the branches.
- Consider making a fasciotomy along the tunnel if the space is very tight.
- Before dividing the branch, consider whether it is of adequate length to clip or tie.
- Keep energy settings as low as possible during branch division.

Vessel removal and preparation

- Make sure all branches and connective tissue are free from the vein before removing it.
- Use an appropriate technique for distal ligation of the vessel.
- t ake care to not stretch the vessel when removing it from the eVh tunnel.
- Once the vessel is extracted and prepared, place it in the specified solution until ready for use in the surgery.

References

1. Data analyses of the Society of t horacic Surgeons National a dult Cardiac Surgery Database 2015. t he Society of t horacic Surgeons p. 116.

2. Ferdinand FD, MacDonald JK, Balkhy h h , et al. endoscopic Conduit h arvesting in Coronary a rtery Bypass Grafting Surgery: a n iSMiCS Systematic r eview and Consensus Conference Statements. *Innovations*. 2017; 12(5): 301-319.

3. 2014 eSC/ea Ct S Guidelines on myocardial revascularization. *European Journal of Cardio-Thoracic Surgery*. 46 (2014) 517–592 doi:10.1093/ejcts/ezu366.

4. r eed JF. Leg wound infections following greater saphenous vein harvesting: minimally invasive vein harvesting versus conventional vein harvesting. *Int J Low Extrem Wounds*. 2008;7:210-219.

5. Lee J. Vein h arvesting: t he Second Generation (chapter 14). in: Cohen r , Mack M, Landreneau r , Fonger J (eds): *Minimally Invasive Cardiac Surgery*, St. Louis, MO: Quality Medical publishing, inc.; 1999:155-164.

6. Lee J, Dye K, Wilson S. endoscopic vein harvesting: multicenter outcomes. *Surgical Physician Assistant*. 1999;5(6):14-24.

7. a ndreasen JJ, Nekrasas V, Dethlefsen C, et al. endoscopic vs open saphenous vein harvest for coronary artery bypass grafting: a prospective randomized trial. *Eur J Thorac Cardiovasc Surg*. 2008;34:384-389.

8. r ao C, a ziz O, Deeba S, et al. is minimally invasive harvesting of the great saphenous vein for coronary artery bypass surgery a cost-effective technique? *J Thorac Cardiovasc Surg*. 2008;135:809-815.

9. a llen KB, Griffith GL, h eimansohn Da , et al. endoscopic versus traditional saphenous vein harvesting: a prospective, randomized trial. *Ann Thorac Surg*. 1998;66:26-32.

10. patel a N, h ebeler r F, h amman BL, et al. prospective analysis of endoscopic vein harvesting. *Am J Surg*. 2001;182:716-719.

11. illig Ka , r hodes JM, Sternback Y, Green r M, et al. Financial impact of endoscopic vein harvest for infrainguinal bypass. *J Vasc Surg*. 2003;37:323-330.

12. Yun KL, Wu Y, a haronian V, et al. r andomized trial of endoscopic versus open vein harvest for coronary artery bypass grafting: six-month patency rates. *J Thorac Cardiovasc Surg*. 2005;129:496-503.

13. perrault Lp, Bilodeauh L, Jeanmart h , et al. a prospective randomized angiographic study of open versus endoscopic saphenectomy for Ca BG. *Heart Surgery Forum*. 2003;6 Supp 1:S48.

14. Davis Z, Clark S, Bufalino V, Garber D, Budoff M, et al. Graft patency following endoscopic saphenous vein harvesting is equivalent to or better than traditional harvest. *Heart Surgery Forum*. 2003;6 Supp 1:S15.

15. Lopes r D, h afley Ge, a llen KB, et al. endoscopic versus open vein-graft harvesting in coronary-artery bypass surgery. *N Engl J Med*. 2009;361:235-244.

16. t hatte h S, Khuri SF. t he coronary artery bypass conduit: i. intraoperative endothelial injury and its implication on graft patency. *Ann Thorac Surg*. 2001;72:S2245-2252.

17. Manchio JV, Gu J, r omar L, et al. Disruption of graft endothelium correlates with early failure after off-pump coronary artery bypass surgery. *Ann Thorac Surg*. 2005;79:1991-1998.

18. a ngelini GD, Breckenridge iM, Williams h M, Newby a C, et al. a surgical preparative technique for coronary bypass grafts of human saphenous vein which preserves medial and endothelial functional integrity. *J Thorac Cardiovasc Surg*. 1987;94:393-398.

19. Brown eN, Kon ZN, t ran r , et al. Strategies to reduce intraluminal clot formation in endoscopically harvested saphenous veins. *J Thorac Cardiovasc Surg*. 2007;134:1259-1265.

20. Cohn JD, Korver KF. Optimizing saphenous vein site selection using intraoperative venous duplex ultrasound scanning. *Ann Thorac Surg*. 2005;79:2013-2017.

21. Luckraz h , Lowe J, pugh N, a zzu a a . pre-operative long saphenous vein mapping predicts vein anatomy and quality leading to improved post-operative leg morbidity. *Interact CardioVasc Thorac Surg*. 2008;7:188-191; discussion 191.

22. Lin t Y, Chiu KM, Wang MJ, et al. Carbon dioxide embolism during endoscopic saphenous vein harvesting in coronary artery bypass surgery. *J Thorac Cardiovasc Surg*. 2003;126:2011-2015.

23. Standards for Basic a nesthetic Monitoring. a merican Society of a nesthesiologists, 2005.

Getinge · 1300 Maca rthur Blvd · Mahwah, NJ 07430 · USa · +1 201 995-8700
90 Matheson Blvd. W. Suite 300 · Mississauga, ON L5R 3R3 · Canada · +1 800-387-3341

www.getinge.com/en-ca