Initial experience with an endoscopic radial artery harvesting technique

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Objective: The purpose of the study was to investigate the feasibility of an endoscopic radial artery harvesting technique to improve esthetic results and possibly reduce the incidence of neurologic complications observed with the open method.

Methods: Between July 1, 2002, and October 1, 2003, a total of 54 patients underwent endoscopic radial artery harvesting at our institution. Standard endoscopic equipment and a Harmonic Scalpel (Ethicon Endo-Surgery, Inc, Cincinnati, Ohio) were used. Mean age of the patients was 63 ± 8.1 years, and 16% were female. All patients underwent a preoperative Allen test and duplex ultrasonography to demonstrate adequate ulnar collateral flow. The nondominant arm was used for radial artery harvesting. Mean clinical follow-up was 13 ± 4.6 months.

Results: The artery was harvested through a 3-cm incision at the wrist and was divided at the elbow either through a small counterincision ($n = 16$) or endoscopically with the use of clips, Endoloop, and endoscopic scissors ($n = 38$). Mean harvest time was 42.2 ± 16.9 minutes but decreased from 85 minutes for the first cases to 25 minutes for the last 5 cases. Mean harvested length was 19.6 ± 1.7 cm. Harvesting complications included 1 conversion, 2 postoperative hematomas, 1 injury, 8 endoscopically controlled bleedings, and 15 cases of at least some superficial radial nerve paresthesia at 6 weeks (clinically relevant in 4 cases). Selective postoperative angiography revealed 1 occluded graft and 1 stenotic graft requiring percutaneous transluminal coronary angioplasty of the native vessel. Eighty-seven percent of the patients were enthusiastic about this new procedure.

Conclusions: Endoscopic radial artery harvesting is a feasible procedure that requires a definite learning curve. Although nerve paresthesias were not completely eliminated in our experience, the technique provided ample patient satisfaction. Further clinical follow-up is required to determine long-term patency rates.

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The radial artery (RA) is an increasingly popular arterial conduit for coronary artery revascularization.¹ In patients with triple-vessel disease or risk factors for sternal wound complications, use of the RA allows extension of the number of arterial anastomoses. However, open RA harvesting is associated with some neurologic complications, with an incidence around 30%.² In addition, the healing characteristics of the forearm wound are not always predictable. Some patients have hypertrophic scar healing, even in the presence of normal sternal wound healing. For these reasons, we have not been using the RA aggressively in our department. The success of the endoscopic vein harvesting technique,³ however, has stimulated various companies and surgical groups to consider endoscopic RA harvesting (ERA). In an attempt to reduce the skin incision substantially and possibly reduce the incidence of neurologic complications, we started ERA in our department in July 2002. This report describes our initial ERA experience and short-term clinical follow-up.

Methods

Between July 1, 2002 and October 1, 2003, 54 patients underwent ERA in our institution. Mean age of the patients was 63 ± 8.1 years (range 44-77 years), and 16% ($n = 9$) were female. All patients underwent elective primary ($n = 51$) or reoperative ($n = 3$) coronary revascularization. In 78% of the cases ($n = 42$) the procedure was isolated coronary revascularization. Nine patients underwent an associated valvular procedure, 1 underwent an atrial septal defect closure, 1 underwent a patent foramen ovale closure, and 1 underwent a left ventricular aneurysm resection. Diabetes mellitus was present in 32% of the patients ($n = 17$), and 17% ($n = 9$) were more than 20 kg overweight (number of kilograms exceeding number of centimeters above 1 meter). Peripheral vascular disease was present in 6% of patients ($n = 3$), and chronic obstructive pulmonary disease was present in 1.9% ($n = 1$). Left ventricular ejection fraction $<50\%$ occurred in 13% of the patient group ($n = 7$).

Preoperative evaluation included a clinical Allen test and Doppler ultrasonography to check the integrity of the palmar arch and detect atherosclerosis. Five seconds was chosen as upper limit for recoloration of the fingers after release of the compression of the ulnar artery. We always used the nondominant arm for ERA.

Surgical Technique

At the start of surgery, an intravenous infusion of Nitroglycerine was started at 0.25 - to $0.5\text{-}\mu\text{g}/(\text{kg} \cdot \text{min})$ as an antispasmodic agent⁴ and continued for 24 hours unless the patient remained longer in the intensive care unit.

Equipment. In all cases we used the ERA kit provided by Cardioventions (a division of Johnson & Johnson, Somerville, NJ). The kit consists of a tissue dissector (ultraretractor), a vessel dissector, and a pair of curved endoscopic scissors. Within the ultraretractor, a 5-mm 30° endoscope can be introduced. The endoscope faces downward and is connected to a light source and a camera that allows the surgeon to follow the dissection on a monitor. Carbon dioxide at 5- to 6-L/min was used to flush the working channel to optimize visibility. The tissues were divided with the Harmonic Scalpel (Ethicon Endo-Surgery, Inc, Cincinnati, Ohio), of which details of the clinical ease and safety have been published previously.⁵⁻⁹

Harvesting technique. A 3- to 4-cm longitudinal skin incision was made starting approximately 1 cm cephalad of the radial styloid. The subcutaneous tissues were divided, and the fascia overlying the RA was divided longitudinally. This division was extended a few centimeters below the skin incision in the cephalad direction. At the same time, some space was created in the subcutaneous tissue to allow subsequent introduction of the ultraretractor. The distal part of the RA was isolated under direct vision, and side branches were clipped. Care was taken to separate the RA from the superficial radial nerve (SRN) at this level.

Next, the ultraretractor (tissue dissector) was introduced and placed anteriorly to the RA fascia, heading toward the elbow crease. The retractor was then gently pushed forward into the subcutaneous tissues, just anteriorly to the fascia overlying the RA. Once a few centimeters of exposure was achieved, the longitudinal incision in the fascia (which was started at the level of the skin incision) was prolonged toward the elbow crease. This maneuver exposed the RA for a few centimeters. Once enough working space

was created, the ultrasonic Harmonic Scalpel was used to divide the side branches. The two satellite veins were included in the harvested pedicle. When this segment of the RA was completely free, the ultraretractor was advanced further, and the whole sequence was repeated.

In the middle third of the forearm, at the junction of the brachioradial and flexor carpi radialis muscles, the ultraretractor remained positioned anteriorly to the RA, thus "diving" underneath these muscles. Although the working space is reduced in this muscular part of the forearm—rendering this the more difficult part of the dissection—the previously mentioned sequence of endoscopic dissection remained unchanged.

The proximal part, the antecubital space, was recognized endoscopically by the abundance of fat. Care was taken here to visualize side branches adequately before dividing them. This of course was intended to avoid injury to the ulnar artery. We usually respected the laterally located recurrent branch, unless we needed maximum length of the RA conduit.

Once the conduit was completely dissected, the Harmonic Scalpel was removed, and the vessel dissector was introduced to verify that all side branches have been divided. We then clipped the proximal RA endoscopically and divided it with the long curved endoscopic scissors. Alternatively, we first divided the RA distally and slid an Endoloop (Ethicon Endo-Surgery) over the RA. The Endoloop was then advanced around the RA until the proximal end and tightened. Transection was achieved with the curved endoscopic scissors.

In the beginning of the experience, we routinely made a 2-cm counterincision in the antecubital space. This was done to increase vascular control in the antecubital space. However, with increased experience, the counterincision ceased being applied unless exposure or anatomic landmarks were uncertain.

Once the conduit was removed, the RA was flushed with a heparinized solution and checked for hemostasis. Only rarely have we needed to apply an extra clip to a side branch. The conduit was then stored in a papaverine solution. Hemostasis of the working channel was ensured, and the wound was closed in layers. Systemic heparinization was never given before the arm wound was closed and the arm had a circumferential compressive bandage placed.

During ERA harvesting, the sternotomy and harvesting of the left internal thoracic artery and saphenous vein could be done simultaneously.

Statistical Methods

All routine preoperative, intraoperative, and postoperative variables were extracted from our database. An ERA-specific follow-up chart registered all variables related to the ERA procedure and ERA follow-up data, including a patient satisfaction inquiry. The first author (F.P.C.) examined all patients postoperatively by light touch, and any sensation abnormalities were rigorously registered. Another clinical examination occurred at 6 weeks (100% complete). Longer follow-up was achieved by telephone interview during the first half of January 2004 (100% complete). In this way, the shortest follow-up obtained reached 3 months, with a mean of 13 ± 4.6 months (range 3.8-18.8 months). In case of clinical events, the cardiologist was contacted to determine the nature of the event.

Results

ERA Technique

All but two conduits were harvested successfully. In 1 case the harvest time was excessively long, and the procedure was converted. One injury to the RA occurred at the level of the antecubital space. The brachial artery was compressed, and the injury was sealed with the Harmonic Scalpel. A counterincision was made to ensure vascular hemostasis. The affected zone of the RA conduit was resected, and the remainder was used as bypass conduit.

In 8 cases, some bleeding occurred from a side branch during dissection. All of these episodes could be managed endoscopically.

Mean harvest time was 42.2 ± 16.9 minutes (range 20-90 minutes). The harvest time decreased from 85 minutes for the first cases to 30 minutes or less for the last 15 cases. Mean harvested length of the conduit was 19.6 ± 1.7 cm (range 16-24 cm). This was dependent more on arm length than the harvesting technique.

Division of the conduit at the elbow crease was done through a 2-cm counterincision in 16 cases and endoscopically in the remainder. All harvested RAs were used as a bypass conduits.

Of all isolated coronary artery bypass grafting procedures ($n = 42$), 30 were performed off pump (71%). A total of 175 anastomoses were performed (mean 3.2 ± 0.9 per patient), of which 151 were arterial and 64 were with RA.

Postoperative Follow-up

One patient had sternitis develop after the operation. Two ERA tunnel hematomas occurred, one of which required drainage through the wrist incision. No ischemic complications of the hand occurred. None of the patients had either cellulitis or infection.

Twenty-one patients reported some sensation alteration in the distribution of the SRN at discharge. None of the patients had alterations in the distribution of the lateral antebrachial cutaneous nerve (LABCN). At 6 weeks, some alterations were still present in 15 patients (27.8%). However, this was clinically relevant in only 4 patients (7.4%). This figure has remained unchanged at the latest follow-up.

Overall patient satisfaction rate with the ERA technique was very high: 87% both at 6 weeks and at follow-up.

Conduit Quality and Short-term Patency

Histologic analysis of 6 biopsy specimens revealed no intimal damage to any of the conduits. PredischARGE imaging of the bypass conduits was performed with angiographic computed tomography (CT) in 5 patients and coronary angiography in 4 patients. All the bypass conduits were revealed to be open.

One patient had recurrence of angina 5 months after the operation. He underwent repeated coronary angiography,

which revealed an occluded RA bypass graft to a small posterior descending branch of an occluded right coronary artery. Because all other bypass conduits were open, the patient was treated conservatively.

Another 2 patients underwent 6-month follow-up angiography. The first RA was patent, but in the second patient the sequential RA to a first diagonal branch and an obtuse marginal branch showed a proximal stenosis and an occlusion beyond the first distal anastomosis. This patient underwent percutaneous transluminal coronary angioplasty of the native branches.

Another patient had vague chest discomfort at exertion 9 months after the operation, but all conduits were patent according to coronary angiography. No other cardiac follow-up events occurred.

Discussion

Since the revival of use of the RA, many groups are reporting encouraging results.¹⁰⁻¹⁴ Midterm patency rates (6 months to 3 years) reportedly range around 90%.¹ However, open RA harvesting is not free of complications. In addition to the mostly unreported but unpredictable and esthetically disturbing hypertrophic scar healing, the most frequently occurring complications are neurologic. Indeed, two sensory nerves may be encountered during open RA harvesting.¹⁵ The LABCN provides sensation to the lateral volar aspect of the forearm and runs on top of the brachioradialis muscle. This nerve may be encountered during the midarm dissection. The SRN runs laterally of the RA in the distal forearm and provides sensation to the volar and dorsal part of the first two fingers. This nerve may be encountered during distal forearm dissection. The reported incidences of neurologic complications vary widely in the literature, from 2.4%¹⁶ to 6.5%,¹⁷ 30%,² and as high as 67%.¹⁸ Other than one reference,¹⁶ most articles have not distinguished between LABCN and SRN complications and stress the temporary, self-limiting, and clinically insignificant aspect of this complication.

The ERA harvesting technique avoids the LABCN because the dissection is performed underneath the brachioradialis muscle. We have therefore not encountered LABCN nerve injury in this series, confirming a previous report.¹⁹ However, the occurrence of SRN related paresthesia unfortunately has not been eliminated. The totally encountered incidence in this series was 27.7%, but clinical relevance was limited to 4 patients (7.8%), again comparable to other series.¹⁹ The clinically insignificant aspect of these paresthesias in most cases is also evidenced by the high patient satisfaction rate (87%).

During the study period, we did adapt a few technical aspects to decrease the incidence of paresthesia. We now always separate and visualize the RA and the SRN at the level of the wrist. At this level, we also divide the side

branches under direct vision, and once we start the endoscopic dissection, we stay as close as possible to the RA. Adopting these small modifications reduced but unfortunately did not eliminate the occurrence of paresthesia.

The integrity of the conduit has not been altered, as demonstrated by the histologic findings of the conduit. This has also been demonstrated previously with light and electronic microscopy, indicating that one could dissect with the Harmonic Scalpel as close as 1 mm to the main trunk of the conduit without damaging the endothelium.^{6,8} Preservation of both satellite veins provides a safety barrier exceeding this critical distance.

This procedure certainly has a learning curve, as demonstrated by our initial harvesting times. Although we had experience with endoscopic vein harvesting and the use of the Harmonic Scalpel in open RA harvesting, we still needed about 15 cases before becoming comfortable with ERA and harvesting the conduit in an acceptable time interval. We therefore strongly recommend adequate experience with endoscopic vein harvesting and the Harmonic Scalpel before attempting ERA. In addition, the company recently has introduced a training model, which should also reduce the required harvesting time in vivo.

Cost may of course be an issue, because the procedure requires a video tower, an ultrasonic generator, a Harmonic Scalpel, and a dissector kit. Because our department performs a lot of video-assisted procedures, the video tower was available. The same applies for the generator, because our abdominal surgeons use this exclusively for all their laparoscopic procedures. The cost per patient of the Harmonic Scalpel and the kit may remain an issue, but we hope that increased experience will further diminish the paresthesia rate and therefore justify the use of this technique.

Although the technique is appealing, nothing is known about the long-term patency rates of endoscopically harvested RA. This is why we recently started to control predischARGE patency rates with angiographic CT to establish a "baseline patency rate." Although the initial images and results are encouraging, numbers are still insufficient to draw any conclusions. However, angiographic CT allows us to control bypass conduit patency rates in a less invasive manner than coronary angiography, and we plan to repeat these at various intervals. This should allow a time-related comparison with literature data concerning patency rates of traditionally harvested RA.

Conclusions

Experience with endoscopic vein harvesting facilitates the learning curve associated with ERA. Once the technique has been mastered, ERA takes about 25 to 30 minutes. In our experience the technique provided ample patient satisfaction but did not totally eliminate the occurrence of SRN

paresthesia. Future trials need to elucidate longer-term patency rates of conduits obtained by ERA.

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