PREPARING THE RADIAL ARTERY GRAFT

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RADIAL ARTERY

Radial artery (RA) is the second arterial graft that can be preferred for coronary artery bypass grafting (CABG) after the ITA. The RA excision is easy, and it provides a graft with a diameter compatible with coronary arteries, allowing for the creation of sequential bypasses and total arterial revascularization by forming T and Y grafts with ITA. It can be obtained in sufficient length (20 to 22 cm), is durable, and resistant to bending. It is considered a good option for patients of all ages, including the elderly. To effectively utilize RA, it should be anastomosed to a coronary artery with more than 70% stenosis. The competition of the high-flow RA with the native artery leads to vasospasm, which is angiographically manifested as the "string sign."

To prepare a successful RA graft, one must minimize complications during and after the extraction procedure. These complications include cosmetic issues and infections at the incision site, neurological damage (particularly sensory impairment), finger or hand ischemia, graft damage, and vasospasm. Therefore, it is crucial to be familiar with the anatomy of the forearm, RA morphology, and employ proper extraction techniques.

The use of RA has absolute contraindications such as dominance in the Allen test, a history of severe trauma, collagen vascular disease, Raynaud's phenomenon, arteriovenous fistula, severe calcification with a diameter less than 2 mm, and significant vasospasm with a surface and intraluminal vasodilator despite fasciotomy. Relative contraindications include cold climate, renal failure requiring arteriovenous fistula, carpal tunnel syndrome, interventions for arterial monitoring from RA, lymphedema in the arm, and tasks requiring significant manual dexterity.

TIPS & PITFALLS

- Anastomose RA to coronary arteries with over 70% stenosis.
- Conditions where RA usage is contraindicated include:
  - Negative Allen test
  - Damage to the radial or ulnar artery (UA) in the forearm due to trauma
  - Collagen vascular disease
  - Raynaud's phenomenon
  - Arteriovenous fistula in the RA
  - Severe calcification in RA (particularly in patients with chronic kidney disease)
  - Radial artery diameter less than 2 mm.

ANATOMY

The brachial artery, just below the bicipital aponeurosis in the cubital fossa, divides into the UA and RA. The latter is lateral and usually smaller in diameter than UA. The RA lies just beneath the deep fascia and is surrounded by collateral vessels. There is no major nerve accompanying RA during its course; however, the terminal sensory branch of the radial nerve is located just lateral to the proximal third of RA. The superficial branch of the radial nerve approaches RA in its middle segment and emerges from deep to superficial. The RA covers the proximal third by the brachioradialis muscle and is located below the pronator teres muscle. During RA dissection, to fully expose RA, the brachioradialis muscle must be laterally retracted. The RA traverses the forearm between flexor muscles for half its length, then becomes superficial, forming the superficial and deep arches of the hand immediately after the wrist. The pulse becomes palpable in the distal third of the forearm, about halfway down the radius. The RA gives off

its recurrent branch 1 cm after its origin, and this branch progresses laterally and proximally. The interosseous branch of RA departs immediately after the recurrent branch and travels deep. The RA gives off several branches in its proximal two-thirds during its course. In the distal third, particularly near the wrist, it gives off more numerous branches. The branching of RA to the surface is rare. If the entire length of RA is not needed, it is recommended to preserve the branches around the wrist (Figure 2.1).

The diameter of the RA is usually 3 to 3.5 mm proximally and 2 to 2.2 mm distally. The macroscopic muscle layer of RA is more distinct compared to ITA. It has a larger lumen and thicker vascular wall. The smooth muscle tissue is twice that of ITA. The intima and elastic lamina are well developed.

Various anomalies of RA have been described, with the most common being a high origin of RA in the upper extremity. It can originate just above the elbow, in the middle of the brachial artery, or from the axillary artery. The course in the forearm is constant in these cases. The most crucial anomaly is the presence of a functional major lateral branch that arises a few centimeters proximal to the wrist. A rudimentary RA is in its anatomically expected position. In this case, a false-negative Allen test occurs. During the modified Allen test, if the major lateral branch of RA is not compressed, the assessment of UA dominance and the ability to maintain circulation can be inaccurate.

The RA excision should be performed with caution to avoid damage to the lateral cutaneous nerve of the forearm, the superficial and deep branches of the radial nerve, and the pronator quadratus muscle. Damage to the radial nerve can cause problems with motor innervation of the forearm extensor muscles.

TIPS & PITFALLS

- Important anatomical structures for RA:
  - Recurrent and interosseous branches of RA proximally
  - Superficial branch of the radial nerve
  - Lateral cutaneous nerve of the forearm
  - Brachioradialis muscle
  - Pronator quadratus muscle
  - Tendons of the flexor carpi radialis muscle.

Allen Test: In 5 to 10% of patients, RA may not be a suitable graft for CABG. The Allen test is a standard screening test to assess ulnar collateral

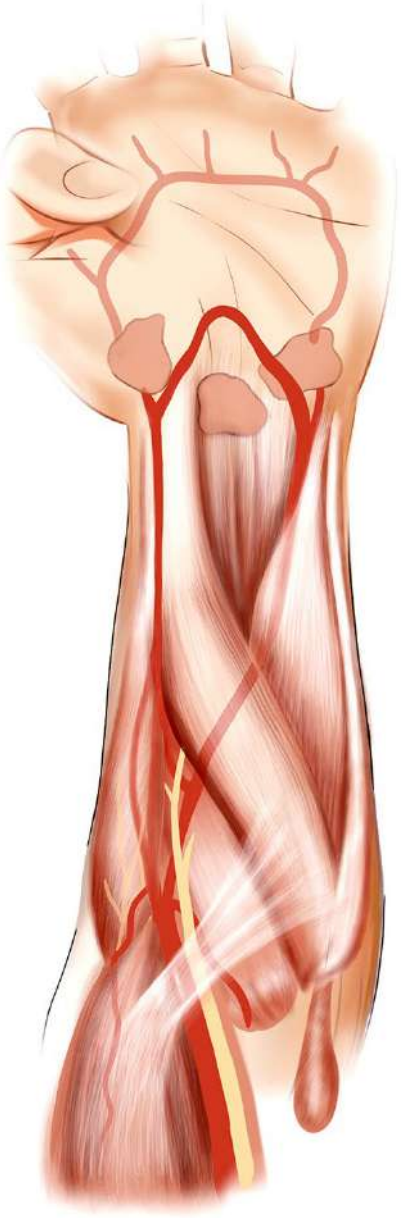

Figure 2.1. Anatomical structures to be observed during the preparation of the radial artery (RA) graft are depicted. It is important to pay attention to two muscles (brachioradialis muscle, pronator quadratus muscle), two nerves (superficial branch of the radial nerve, lateral cutaneous nerve of the forearm), and two arteries (recurrent RA, superficial palmar artery).

circulation in the hand before the removal of RA. In the Allen test, the examiner compresses both the RA and UA circulation to the patient's wrist with their thumbs (Figure 2.2). The patient is, then, asked to make a fist five times and slowly release it. Afterward, compression on the UA is released. If the thenar area and the index, middle, and ring fingers do not pale within 10 sec, it indicates that the ulnar collateral circulation is sufficient. If the blanching occurs in less than 5 sec, the specificity is over 97%.

In the operating room, oxygen plethysmography waveform can be used for the Allen test. The waveform of the pulse oximeter should also be monitored. However, in the operating room setting, factors such as cold or anesthesia-related hypotension can lead to false positives in the Allen test.

Currently, Doppler ultrasound is available in many modern operating rooms. Thus, preoperative evaluation of RA for calcification, diameter, and intimal irregularities is possible.

TIPS & PITFALLS

- Consider the major lateral branch of RA in a negative Allen test.

Spasm Prophylaxis: The muscular component of the RA wall is twice that of ITA, making it prone to spasm, and preventive measures are necessary. Many agents can be used topically or intraluminally. During RA extraction, efforts should be made to avoid trauma and manipulation to prevent vasospasm. Papaverine is a potent vasodilator used

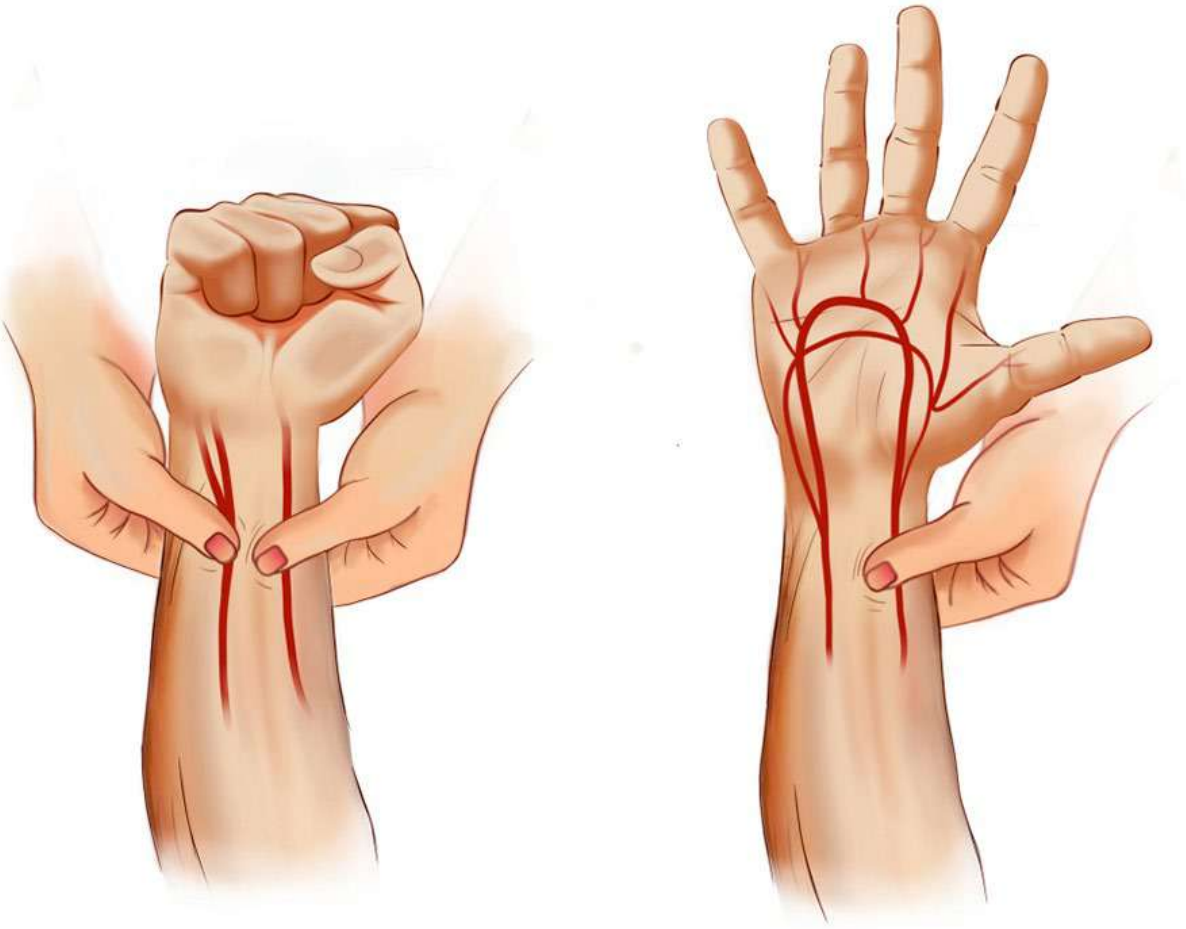

Figure 2.2. The Allen test demonstrates the perfusion capability of the hand through the ulnar artery (UA). Modified techniques (such as ultrasound or pulse oximetry measurement from the finger) are employed to determine whether the UA can provide sufficient circulation after the removal of the radial artery (RA).

topically, with an onset of action within minutes and lasting up to 8 hours. Nitroglycerin (NTG) is a fast and potent vasodilator, but has a short half-life. Among calcium channel blockers, verapamil is the most potent agent and is used topically. When used in conjunction with NTG, the rapid onset of action with NTG is extended up to 8 hours with verapamil. Milrinone is another potent vasodilator which can be used systemically. Commonly, clinics use papaverine alone or combinations of NTG/verapamil or diltiazem/nifedipine topically. The use of vasodilators in the perioperative period does not have a clear consensus; however, NTG, diltiazem, and milrinone can be used for up to 1 to 2 days. Postoperatively, attention should be paid to hypotension associated with the use of vasodilators.

Furthermore, in patients with low cardiac output in the postoperative period, caution should be exercised in the use of vasoconstrictor drugs, particularly in those who have undergone RA. Noradrenaline can cause vasospasm on RA. Therefore, its use is recommended in patients with low systemic vascular resistance. Amlodipine may be preferred for long-term prophylaxis up to six months.

TIPS & PITFALLS

- Be cautious about hypotension while prophylaxing for spasm in RA.
- Exercise caution in the use of vasoconstrictor drugs in the postoperative management of low cardiac output in patients using RA.

HARVESTING

Radial Artery harvesting can be performed through both open surgery and endoscopic procedures. Endoscopic RA harvesting may offer cosmetic benefits and a lower risk of infection, but it carries a higher risk of causing endothelial damage during the learning and equipment adaptation process compared to the open technique. Therefore, caution should be exercised. During RA extraction, manipulation should be minimized. Open harvesting causes less trauma and intimal damage compared to endoscopic procedures. Utilizing a "no-touch" technique and avoiding the use of electrocautery minimize RA damage. The use of clips, scissors, and a harmonic scalpel is recommended over electrocautery. Additionally, the harmonic scalpel, by ultrasonically stimulating nitric oxide release from the endothelium, contributes to vasodilation.

Preoperative evaluation of the RA course and intimal calcification through ultrasound is advisable. In the absence of ultrasound, marking the incision line from the wrist to the medial elbow by following the RA pulse facilitates the surgical procedure. The operated arm should be positioned perpendicularly on the table (Figure 2.3) (Photo 2.1).

The incision starts at the wrist with a 3-cm incision (Figure 2.4) (Photo 2.2). Evaluation of the RA diameter and calcification is performed. To avoid damaging the lateral cutaneous nerve, the incision is extended to the medial elbow in a curved line (Figure 2.5) (Photo 2.3). Using an elevator, the brachioradialis muscle is mobilized laterally. Low-power electrocautery is recommended for bleeding control and subcutaneous dissection. The fat and fascia over the RA are opened using scissors or electrocautery. The tissue around the distal part of the RA is more adherent, and leaving these tissues attached to the pedicle may be safer. To separate the RA completely, individual branches are clipped and cut with scissors or sealed with a harmonic scalpel. To prevent RA spasm, minimal touching is recommended, and flexible vascular tape can be used during mobilization (Figure 2.6) (Photo 2.4). Care should be taken not to damage the superficial branch of the radial nerve in the mid-forearm. Preservation of the recurrent and interosseous branches of the proximal RA is essential. Proximal venous structures are crucial for the venous drainage of the forearm and should be preserved as much as possible. After releasing the RA, two clips are placed distally and cut proximally. An intracatheter is inserted into the distal end for maximum dilation. Papaverine or diltiazem solution (2 to 3 cc) is slowly injected into the RA. Subsequently, the tip is clipped to reveal any untied side branches, if there is dilation in the RA.

Skeletonizing the RA is time-consuming and carries the risk of graft traumatization, but can increase the length by approximately 10%. Skeletonization reduces sympathetic stimulation and vasoconstriction. Often, the fascia surrounding the RA is longitudinally cut to allow the artery to expand. In this case, skeletonizing 2 to 3 cm from both proximal and distal ends facilitates maximum dilation at the anastomosis points.

Figure 2.3. Placing a sponge under the wrist facilitates the emergence of the radial artery from between the muscles to the surface.

Photo 2.1. As the surgical setup is completed, keeping the instruments ready in a small tray will facilitate the surgical team during simultaneous left internal thoracic artery harvesting. Placing a tourniquet under the wrist brings the radial artery slightly closer to the skin. At this stage, the first incision can be made with the help of ultrasound.

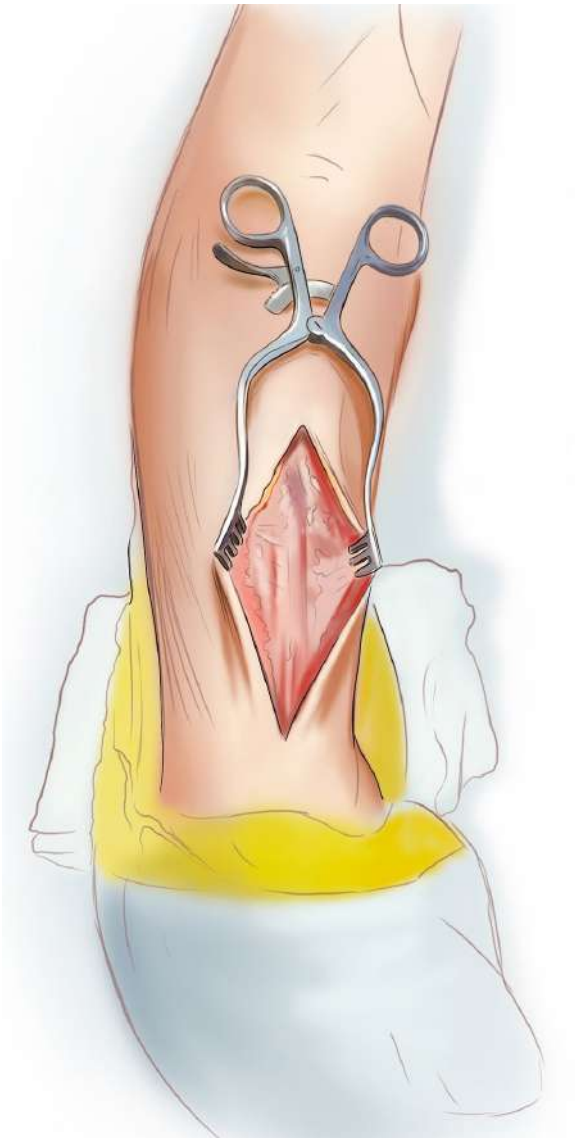

Figure 2.4. The pulse is palpated, and a short incision is made just above it to make the radial artery visible from its most superficial part. The fascia over it is gently opened to expose the side branches.

Photo 2.2. Since the fascia has not been opened yet, the side branches are not visible.

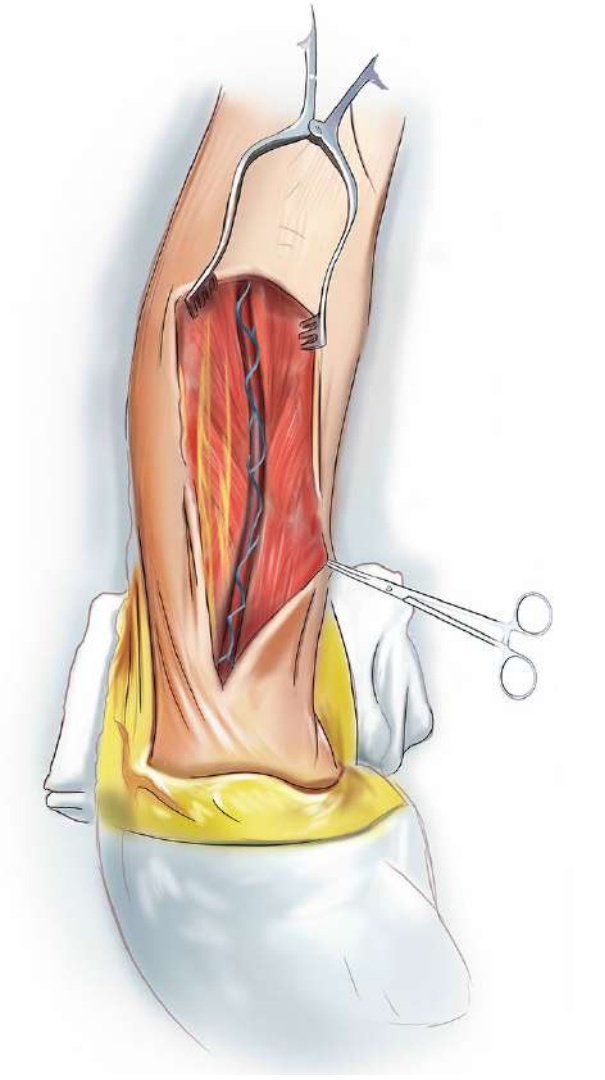

Figure 2.5. After opening the fascia, the artery and accompanying veins are clearly visible. At this stage, without touching the radial artery, the veins are held, and side branches are clamped with hemoclips before being cut.

Photo 2.3. Harvesting can be performed by a single operator with the assistance of an automatic retractor.

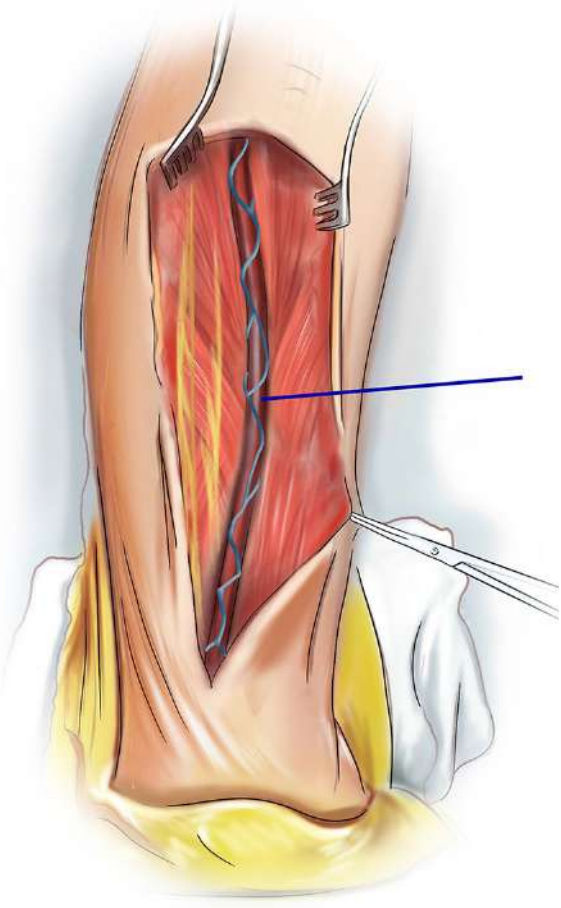

Figure 2.6. Due to the tendency of the radial artery to spasm, it is recommended to harvest it using the "no-touch" method, solely with aseptic vascular tapes.

Photo 2.4. A flexible vascular tape can be used gently for the purpose of atraumatic dissection.

It is recommended to use the RA before other grafts during the operation. If completely removed, it is advised to keep it in a solution of 1% papaverine or verapamil and NTG in the blood or, if left *in situ*, to preserve it surrounded by a gas-soaked with vasodilator (Figure 2.7) (Photos 5 and 6).

Before closure, ensure hemostasis. A Hemovac® drain is placed by extending it from the distal forearm under the brachiocephalic muscle toward the wrist. It is beneficial to keep this drain for 24 hours. Subcutaneous and skin absorbable sutures are used for closure. The area is, then, sterilized and bandaged. Postoperatively, hand circulation is evaluated using a finger pulse oximeter, and this assessment continues during the intensive care.

After RA removal, numbness in the thenar area and thumb may occur, mainly due to damage to the superficial branch of the radial nerve or lateral antebrachial cutaneous nerve. These symptoms generally improve within 12 months. Motor function impairment is rare, since there are no motor nerves close to the RA. Hematomas and seromas may occur and are treated with local drainage.

TIPS & PITFALLS

- Evaluate RA anatomy with preoperative ultrasound.
- Use clips, scissors, and harmonic scalpel instead of electrocautery during RA harvesting.

Figure 2.7. If the graft is to be kept *in situ*, placing warm compresses soaked in papaverine over the graft will reduce its susceptibility to spasm during the time leading up to the anastomosis.

Photo 2.5. After harvesting, the graft is inspected for possible hematomas and bleeding. At this stage, the graft can be separated from the proximal and distal ends and immersed in a solution or kept in circulation until the time of anastomosis.

Photo 2.6. The radial artery graft kept *in situ* till the anastomosis. During this time, papaverine soaked sponges are placed over the graft.

- Harmonic scalpel stimulates nitric oxide release, contributing to vasodilation.
- Leaving the pedicle at the distal end of RA may be safer.
- Preservation of recurrent and interosseous branches is crucial for forearm circulation.

TROUBLESHOOTING

- Leakage-type bleeding in RA:
  - Check if there are unclipped or unsealed side branches in the pedicled RA.
- Inadequate flow in RA:
  - Check spasm in the RA.
  - Assess calcification in the RA.
  - Look for hematomas in the RA wall.
  - Check hemoclips placed too close to the wall causing deformity.
  - Evaluate for thermal damage due to electrocautery and damage due to the harmonic scalpel on the RA.