Comparison of ultrasonically activated scalpel and traditional technique in radial artery harvesting; an electron microscopic evaluation

Radiyal arter hazırlanmasında ultrasonik koter ve geleneksel yöntemin karşılaştırılması; bir elektron mikroskopik değerlendirmesi

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ABSTRACT

Objective: Use of the radial artery (RA) as a conduit in coronary artery bypass grafting (CABG) has become increasingly popular in recent years. The aim of this prospective randomized study is to determine how the endothelial wall and blood flow of RA are differently affected with the usages of ultrasonic scalpel and conventional electrocautery in addition to effects of hypothermia and storage solutions. Histopathologic study was achieved by electron microscope to evaluate endothelium of the grafts.

Methods: Between 2008 and 2009, 182 patients with coronary artery diseases were operated for coronary artery revascularization. The radial arteries were harvested for 40 of these patients and divided into two groups depending on the use of the ultrasonic cautery (UC) (n=20) and the high-frequency electrocautery (EC) (n=20). Patients were divided into two subgroups according to the storage media of the graft. RA was preserved *in situ* at room temperature (Group 1) and normothermic organ bath (NOB) (Group 2). Harvesting time, use of hemostatic clips, frequency of spasm, *in situ* free flow, temperature and endothelial damage were compared between the two groups. Statistical analysis was performed using one-way ANOVA, Friedman and unpaired t tests.

Results: In all groups, blood flows were significantly decreased as parallel to the local temperatures. Second and third phase flows were similar in group EC_1 and UC_1 ($p>0.05$). Free flow was increased in group UC+NOB when comparing with only EC group (60.4±9.83 ml/min and 40.8±7.50 ml/min, $p<0.001$), whereas the graft preparing time "t2" was shorter in group EC than UC (10.9±2.42 min and 15.2±1.31 min, $p<0.01$). Nonetheless scoring of the groups in terms of endothelial cell structure and mitochondrial morphological changes did not show any significant difference.

Conclusion: If endothelial integrity of the RA can be preserved along with the application of systemic temperature (NOB), regardless of harvesting technique, it provides better flow rates. *(Anadolu Kardiyol Derg 2011; 11: 250-6)*

Key words: Radial artery, harmonic scalpel, harvesting, endothelium

ÖZET

Amaç: Koroner arter baypas cerrahisinde radiyal arterin kondüit olarak kullanılması son yıllarda artan popülarite kazanmıştır. Bu prospektif randomize çalışmada; radiyal arter hazırlanması sırasında konvansiyonel elektrokoter ile ultrasonik koter kullanımının damar endoteline ve kan akımına etkilerini karşılaştırmayı, buna ek olarak hipotermi ve bekleme solüsyonlarının etkilerini göstermeyi hedefledik. Ultrasonik koter veya düşük voltajlı elektrokoter kullanımının endotel hasarına yol açıp açmadığının, elektron mikroskopu ile saptanması araştırmamızın bir diğer amacını oluşturdu.

Yöntemler: Koroner arter hastalığı olan 182 hasta, 2008 ve 2009 yılları arasında, koroner revaskülarizasyon amaçlı ameliyat edildi. Radiyal arter 40 hastada kullanıldı ve bu hastalar ultrasonik koter (UK) (Grup 1; n=20) ve elektrokoter (EK) (Grup 2; n=20) grupları olarak iki gruba ayrıldı. Hastalar ayrıca greftin bekleme solüsyonuna görede iki alt gruba ayrıldı. Hazırlanan radiyal arterler oda sıcaklığında *in situ* ortamda (Grup 1) ve

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normotermik organ banyosunda (NOB) (Grup 2) korundu. Gruplar arasında; greft hazırlanma zamanı, hemoklip kullanımı, spazm oranları, serbest akımlar, sıcaklık ve endotel hasarı açısından karşılaştırma yapıldı. İstatistiksel analizler için tek yönlü ANOVA, Friedman ve eşleştirilmemiş t-testi yöntemleri kullanıldı.

Bulgular: Lokal ısıdaki düşmeye paralel olarak tüm gruplardaki kan akımlarında anlamlı düşme saptandı. Serbest akımlar açısından ultrasonik koter+normotermik organ banyosu yönteminin sadece elektrokoter yönteminden daha etkili olduğu gözlemlenmiş (60.4±9.83 ml/dk ve 40.8±7.50 ml/dk, p<0.001) iken greft hazırlanma zamanı "t2" EK grubunda daha kısa olarak saptanmıştır (10.9±2.42 dk ve 15.2±1.31 dk, p<0.01). Bununla birlikte gruplarda endotelyal hücre yapısı ve mitokondrial morfolojik değişiklik skorlamasında anlamlı farklılık görülmemiştir.

Sonuç: Çalışmamız endotel bütünlüğü korunarak hazırlanan radiyal arter greftlerinde, normotermik organ banyosu ile sistemik sıcaklığa gelinmesi ile hazırlanma tekniğinden bağımsız olarak daha iyi kan akım oranlarının elde edilebileceğini göstermiştir.

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Anahtar kelimeler: Radiyal arter, harmonik skalpel, "harvesting" tekniği, endotel

Introduction

Despite the early abandonment of radial artery as a coronary artery bypass graft surgery (CABG) conduit by the mid-1970's, together with the introduction of minimally traumatic dissection techniques, new preservation methods and medical therapies to prevent postoperative spasm has revived the radial artery as a graft for CABG (1, 2). Several studies about the use of radial artery bypass grafts have documented excellent clinical results and satisfactory short and mid-term patency rates on restudy angiography (3-5). Being more prone to preoperative spasm compared to other grafts, radial artery has many important cases that care should be taken such as harvesting techniques; deal with solutions and hypothermia during operation.

The ultrasonic scalpel, which became available recently, can dissect perivascular tissues, coagulate and cut vascular branches owing to mechanical incision by vibrations, cavity fragmentation and protein coagulation, but there are still debate on the advantages and disadvantages of this technique. It has been reported on one hand that the ultrasonic scalpel least damages the vessel owing to a low temperature, whereas, on the other hand, it has also been reported that the damage reaches the depth of vascular walls (6-9).

In this study we aimed to investigate how the endothelial wall and blood flow of radial artery (RA) are affected differently with the usages of ultrasonic scalpel and conventional electrocautery. Hypothermia and storage media are investigated *in vivo* histologically, and clinically.

Methods

Patients

This prospective randomized study was approved by the Educational Planning Board of our hospital. A written informed consent was obtained from all the patients, who are chosen randomly during the study, and they agreed to participate in the study and accepted RA to be utilized as coronary bypass conduit. All of the techniques were explained to each of the patients before the operation. To determine the sufficiency of ulnar circulation to the hand, an Allen's test was performed on the nondominant hand of all patients. If the test results were negative, a modified Allen's test was done to confirm the result. During the same procedure, oxygen saturation of the thumb was measured by means of a pulse oximeter. Those patients with a positive Allen's or modified Allen's test were excluded from the study. Additionally, patients who had one of the following criteria were not included in the study: age over 70 years, previous upper limb trauma, presence arteriovenous fistula, peripheral arterial disease, chronic renal failure as suggested by a serum creatinine level greater than 2 g/100 mL, low cardiac ejection fraction, peroperative vasoactive agent utilization. Perioperative demographics and hemodynamics of the patients are shown at Table 1.

Between 2008 and 2009, 182 patients with coronary artery diseases were operated for coronary artery revascularization. The radial arteries were harvested for 40 of these patients and divided into two groups depending on the use of the ultrasonic cautery (UC) (n=20) and the high-frequency electrocautery (EC) (n=20). RA preserved *in situ* at room temperature (Group 1) and normothermic organ bath (NOB) (Group2).

Group EC_1 was, the group of patients whose RA was harvested with electrocautery. Group EC_2 was the group of patients with normothermic organ bath applied after RA harvesting with electrocautery.

Group UC_1 was the group of patients whose RA was harvested with ultrasonic cautery and group UC_2 was the group of patients with normothermic organ bath applied after RA harvesting with ultrasonic cautery.

Operative and harvesting techniques

In account to individual hemodynamic parameters such as cardiac output, heart rate, blood pressure and central venous pressure may have affected the blood flow of RA and all these values were measured prior to endotracheal intubation. RA was harvested as a pedicle by the same staff surgeons from the nondominant arm meanwhile an observer kept an account of measurements.

The period from the arrival of the patient to the anesthesia room and the initial flow measurement was defined as "t1", the graft preparing time was defined as "t2" and period between the second and third measurements was defined as "t3".

No needles or angiography catheters were introduced into the nondominant hand that was to be operated upon; also, the intra-arterial cannula for monitoring the arterial blood pressure during operation was inserted into the other hand. Initially, a 3 cm long horizontal incision starting from 1 cm medial and proximal of the radial styloid was performed. With this limited incision

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Table 1. Clinical characteristics and hemodynamic data of the patients

Variables	Group EC-1 n=10	Group EC-2 n=10	Group UC-1 n=10	Group UC-2 n=10	*F	*p
Method	EC	EC+NOB	UC	UC+NOB		
Age, years	59.5±8.2	59.8±5.8	60.5±5.7	62.3±7.4	0.328	0.804
BSA, m^2	1.85±0.14	1.89±0.09	1.91±0.12	1.87±1.87	0.497	0.686
HR_1, rate/min	76.4±4.7	76.5±9.18	80.2±4.96	77.3±7.61	0.667	0.577
HR_2 , rate/min	75.6±55	78.4±7.41	80.9±3.95	75.8±4.84	1.999	0.131
HR_3, rate/min	75.8±4.4	78.6±6.32	79.5±3.44	76.3±6.03	1.173	0.333
MAP_1, mmHg	76.9±3.6	78.7±2.83	77.2±3.99	77.2±2.85	0.678	0.628
MAP_2, mmHg	77±2.49	77.5±2.55	77.3±2.49	76.2±3.01	0.460	0.707
MAP_3, mmHg	76.1±2.02	77.5±2.17	75.6±2.50	76.6±1.64	1.404	0.237
CVP_1, mmHg	3.6±1.07	3.3±1.16	3.4±1.17	4±1.05	0.604	0.569
CVP_2, mmHg	4±0.94	3.6±1.17	3.7±1.33	3.5±1.58	0.264	0.706
CVP_3, mmHg	3.9±0.73	3.6±1.6	4±1.49	3.6±1.07	0.218	0.916
t_1, min	36.7±4.57	39.9±4.17	36.2±2.93	35.1±4.55	2.51	0.575
t_2, min	10.9±2.42	10.1±1.44	15.2±1.31	15.3±1.88	22.983#	<0.001
t_3, min	12.6±1.71	12.9±1.19	11.6±1.71	12.5±0.97	1.52	0.352

Data were presented as mean±standard deviation

*One way ANOVA test

#Tukey - Kramer posthoc comparison tests: EC_1t_2 vs UC_1t_2 - p<0.0001, EC_1t_2 vs UC_2t_2 - p<0.0001, EC_2t_2 vs UC_1t_2 - p<0.0001, EC_2t_2 vs UC_2t_2 - p<0.0001

BSA - body surface area, CVP - central venous pressure, EC - electrocautery, HR - heart rate, MAP - mean arterial pressure, NOB - normothermic organ bath, t_1 - time period between the patient's entrance to the operating room and the first measurements. t_2 - time period between the first and second measurements. t_3 - time period between the second and third measurements, UC - ultrasonic cautery

the artery was mobilized with sharp dissection. The distal end was clamped proximal to the superficial palmar artery. Artery was divided proximally from the clamp. Then initial flow was determined by measuring the volume of blood expelled from the end of the bleeding artery in 30-seconds period (Fig. 1). After the bleeding end was clipped, the distal part of the clamp was tied with 2/0 silk.

In the execution of each method, a sharp incision was made; extending from a point lateral to the biceps tendon and 2 cm distal to the cubital crease, following curvilinearly the rounded belly of the brachioradial muscle down to a point about 1 to 2 cm above the wrist crease at the RA pulse. Dissection and coagulation achieved by low voltage electro cautery (EC) (VALLEYLAB FORCE FX monopolar 300W-300 Ohm, Bipolar 70W-100 Ohm, Tyco Healthcare, USA) in twenty patients (n=20) and with ultrasonic cautery (UC), (Ethicon Endo-Surgery, Cincinnati, OH) in the others (n=20). We divided the subcutaneous tissue and the fascia between the brachioradial and flexor carpal radial muscles, taking care to keep the lateral antebrachial cutaneous nerve in the lateral part of the division. Retracting the brachioradial muscle reveals the full course of the RA in the forearm. Low-current diathermy was used for the subcutaneous tissue and deep fascia in the proximal third of the forearm where the RA is well away from the fascia. A self-retaining retractor was used to separate the brachioradial and flexor carpal muscles, and a sili-

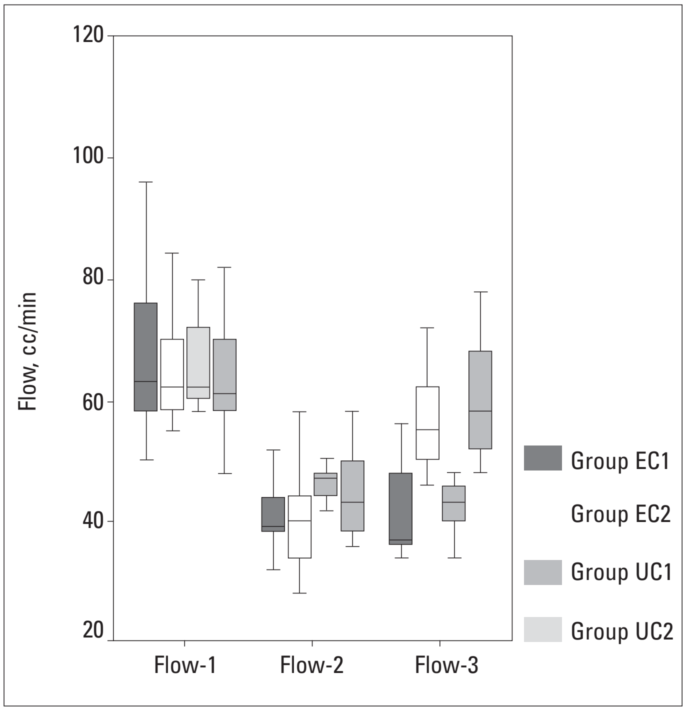

Figure 1. Blood flows of radial artery at each stage of operation

EC-1- radial artery harvested with electrocautery

EC-2- normothermic organ bath applied after radial artery harvesting with electrocautery

UC-1- radial artery harvested with ultrasonic cautery

UC-2- normothermic organ bath applied after radial artery harvesting with ultrasonic cautery cone elastomer vessel loop was placed around the RA pedicle to include the RA *vena communicantes* and fatty areolar tissue. From this point on, with emphasis on minimal touch of the artery by instruments, we carefully dissected with harmonic scalpel to the RA pedicle, including satellite veins, from the surrounding tissues; In both techniques, the tissue was dissected at least 1 cm away from the artery. Only greater arterial branches were occluded with one metal clip near the RA and divided by diathermy, while smaller branches were divided by diathermy alone. With this technique, we tried to keep diathermy at a minimum. After harvesting the RA, the proximal end was not cut, the pedicle was left *in situ*, and the post-harvesting flow was measured (Fig. 2). At both stages of flow measurement, we simultaneously recorded the patient's arterial blood pressure. Cardiopulmonary bypass was conducted at moderate hypothermia for all of the patients. After completion of CABG, we examined the harvest site again for proper hemostasis and closed the incision in two layers, in the usual manner.

Storage and flow measurement methods

Initially, the patients divided to two main groups in terms of which coagulation cautery was used during RA harvesting (Group EC and UC) and two subgroups according to the storage media of the graft. In control group RA preserved in situ at room temperature (EC_1, n=10 and UC_1, n=10) and in remaining at normothermic organ bath (EC_2, n=10 and UC_2, n=10). Tarhan et al. (10) called this rewarming procedure as normothermic organ bath (NOB) previously. According to this protocol; the grafts wrapped into gauze soaked with 0.9% NaCl solution in all groups. In every two minutes the gauze sprayed with %0.9NaCl at 20 °C in control group (Group EC_1 and UC_1) and with %0.9 NaCl at 36°C in normothermic group (Group EC_2 and UC_2). The flow was remeasured after 10 minutes duration of this preparation and recorded as flow 3.

Flow measuring time, flow volume, mean arterial pressure, heart rate, central venous pressure, esophageal and local temperatures were recorded. Local temperature was measured with myocardial probe (DeRoyal REF 81-030418) around the RA areolar tissue and esophageal with general purposeful probe (DeRoyal, REF 81-020709).

Electron microscopic evaluation

Specimens were prospectively collected representing both the proximal and distal region of the RA graft rather than the center, which was used as the bypass conduit. Segments 5-6 mm in length of the RA were sent to the histopathological laboratory after gentle hydrostatic dilatation and were subsequently fixed in 2.5% of glutaral aldehyde solutions. The specimens were fixed in glutaral aldehyde for 24 hours, at room temperature. Then the specimens were washed in phosphate buffers, dehydrated with increasing concentrations of alcohol, postfixed in 1% of osmium tetroxide (OsO_4) and dehydrated in increasing concentrations of alcohol (30%, 50%, 70%, 90% and pure alcohol). The tissues were then washed with propylene oxide and embedded in epoxy-resin embedding media. Semithin sections about 2 µm in thickness and ultrathin sections about 50 nm in thickness were cut with a glass knife on an LKB-Nova (Nova, Bromma, Sweden) ultramicrotome. A single pathologist, who was blinded to all the clinical information, examined the specimens. Ultrathin sections (600 ^{0}A) were collected on copper grids, stained with uranyl acetate and lead citrate and examined with a Transmission Electron Microscope (Joel JEM 1011 EX, Joel, Tokyo, Japan).

A novel scoring method which was recently described by Emir et al. (11) was applied for all RA tissue specimens to evaluate histopathological changes. In this article; three individual morphologic changes of this semi quantitative method: (1) structure of endothelial cells; (2) degree of tissue edema and (3) morphologic changes of mitochondria in endothelial cells were evaluated. Samples were assigned a score of 0 to 3, depending on the severity of damage to the integrity of the endothelium, according to which "0" is normal endothelium, "1" mild damage, "2" moderate damage, and "3" severe damage and endothelial necrosis. Four average scores, which were endothelial score, edema score, mitochondrial score, and the sum of these three scores, were achieved for every sample.

Statistical analysis

Data were analyzed with using Graphpad InStat 3.06 (San Diego, CA, USA) statistical software program. All continuous variables are presented as mean±standard deviation. Gaussian distributions were tested by using Kolmogorov and Smirnov assumption test. The comparison of variables between 4 study groups was performed using one-way ANOVA test and Tukey Kramer's multiple comparison tests. The comparison of variables within groups (repeated measurements according to temperature and flow levels) was done using Friedman test and Dunn's posttest. Unpaired t test was used for comparison of electron microscopic findings between EC and UC groups. The $p<0.05$ was accepted as significance value.

Results

Patient characteristics, hemodynamic variables and measurement times

When the patient's characteristics and hemodynamic variables were compared within and between the groups, there was no significant difference. The period between the arrival of the patient to the anesthesia room and the initial flow measurement "t1" and "t3" were similar (p=0.1010 and p=0.352, respectively), whereas the graft preparing time "t2" was shorter in group EC than in UC group ($p<0.001$).

Temperature measurements

Both esophageal and pedicle temperature measurements were presented in Table 2. First phase pedicle temperatures (T1)

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were; EC_1-T1=32.8°C, EC_2-T1=32.7°C, UC_1-T1=32.6°C, UC_2-T1=32.7°C. The first and the third phase temperature measurements were significantly different in control groups (EC_1, $p<0.01$; UC_1, $p<0.05$). During phase 3, the temperature continued to decrease in control groups (EC_1-UC_1). However in NOB group (EC_2-UC_2) it was significantly increased comparing to phase 2 (Group EC_2-T2 vs EC_2-T3 $p<0.001$, Group UC_2-T2 vs UC_2-T3 $p<0.001$) (Table 2). There was not any significant difference between the temperature measurements of phase 1 and 3 in NOB group.

Flow measurements

Flow measurement variance for all four groups during three stages were homogenous (Fig. 1). In all groups, as parallel to the local temperatures, the second phase blood flows were significantly decreased. Second and third phase flows were similar in groups EC_1 and UC_1 ($p>0.05$). Third phase flows were significantly decreased when compared with the first phase flows in all groups. The third phase flows were significantly increased in the groups with use of NOB (group EC_2 and UC_2). The flows in groups EC_1 and UC_1 were not significantly different ($p>0.05$). Free flow was increased in group UC+NOB comparing to only EC group (60.4±9.83 vs 40.8±7.50) (Table 3). The flows of EC+NOB were similar when comparing with UC+NOB ($p>0.05$) and it was significantly increased for only UC group (Fig. 1).

Electron microscopic findings

In all segments, the morphologic characteristics of the endothelial cells were similar and the endothelial integrity was not affected by the two different techniques. According to our results, only degree of tissue edema was increased in UC group (EC vs UC; 1.7±0.2, 2.1±0.3, $p<0.0001$, respectively) (Table 4). A lesser degree of edema was observed in endothelium and tunica media in-group UC, but less significant when it was compared in-group EC. Subintimal edema and cytoplasmic mitochondrial swelling was also detected in UC group. Electron microscopic screenings are shown at Figure 2 and 3 for both groups.

Discussion

Although vast majority of the knowledge regarding the use of RA as a conduit in CABG have been came into the last 15 years, there are still unanswered questions and dilemmas such as preparing and perioperative medical treatment strategies. The major feature of this type of arteries is the higher tendency for spasm when compared with other types related to mechanical trauma or thermal injury especially during preparing the graft. Furthermore, long vasospastic period may lead to neointimal hyperplasia and premature occlusions. Anesthetic agents related to thermoregulatory control disability, cold operation room and open surgical techniques lead to appear hypothermia (12). In most of the studies which investigate the RA harvesting techniques, it seems that hypothermic effects on the graft has been overlooked. However, in addition to the major factor trauma, our study indicates that hypothermia plays an active role in RA spasm and blood flow as well.

This study determined that the RA flow also decreased significantly regardless of harvesting techniques as concurrent with the decreasing temperatures. Significant increase was

Table 2. Temperatures of the esophagus and radial artery pedicles

Method	Group EC-1	Group EC-2	Group UC-1	Group UC-2	*F	*p
	EC	EC+NOB	UC	UC+NOB		
ET1,°C	35.4±0.11	35.4±0.10	35.4±0.09	35.4±0.06	1.222	0.747
ET2,°C	35.3±0.08	35.3±0.96	35.3±0.11	35.3±0.09	1.022	0.795
ET3,°C	35.2±0.08	35.3±0.09	35.2±0.12	35.2±0.16	0.706	0.871
F	14.000	16.222	10.056	8.471		
$^{\alpha}$p	0.0009	0.0003	0.0066	0.0145		
RpT1,°C	32.8±0.21	32.7±0.17	32.6±0.17	32.7±0.22	0.940	0.431
RpT2,°C	30.6±0.41	30.7±0.25	30.3±0.29	30.5±0.21	2.794	0.054
RpT3,°C	28.9±0.32	32.9±0.23	28.3±0.40	32.5±0.18	629.58	<0.0001$^{\lambda}$
F	361.30	302.69	498.38	338.38		
$^{\beta}$p	<0.0001	<0.0001	<0.0001	<0.0001		

Data were presented as mean±standard deviation

*One way ANOVA test

$^{\alpha}$Friedman test for ET within groups, posthoc test for ET - Dunn multiple comparison test: EC_1-$_1$ vs EC_1-$_3$- p<0.01, EC $_2$-$_1$ vs EC $_2$-$_3$ - p<0.001, UC $_1$-$_1$ vs UC $_1$-$_3$- p<0.05, UC $_2$-$_1$ vs UC $_2$-$_3$- p<0.05

$^{\beta}$Tukey test for RpT between groups: EC_1-$_1$ vs EC_1-$_2$- p<0.001, EC_1-$_1$vs EC_1-$_3$- p<0.001, EC_1-$_2$ vs EC_1-$_3$- p<0.001, EC_2-$_1$ vs EC_2-$_2$- p<0.001, EC_2-$_2$ vs EC $_2$-$_3$- p<0.001, UC_1-$_1$ vs UC_1-$_2$- p<0.001, UC_1-$_1$ vs UC_1-$_3$- p<0.001, UC_1-$_2$ vs UC_1-$_3$- p<0.001, UC_2-$_1$ vs UC_2-$_2$- p<0.001, UC_2-$_2$ vs UC $_2$-$_3$- p<0.001

Posthoc test for RpT3: $^{\lambda}$Tukey-Kramer multiple comparisons test: EC_1-$_3$ vs EC_2-$_3$- p<0.001, EC_1-$_3$ vs UC_1-$_3$- p<0.01, EC_1-$_3$ vs UC_2-$_3$- p<0.001, EC_2-$_3$ vs UC_1-$_3$- p<0.001, UC_1-$_3$ vs UC_2-$_3$- p=0.001

EC - electrocautery, ET - esophagus temperature, NOB - normothermic organ bath, RpT - radial artery pedicle temperature, t_1 - time period between the patient's entrance to the operating room and the first measurements. t_2 - time period between the first and second measurements. t_3 - time period between the second and third measurements, UC - ultrasonic cautery

Table 3. Free flow data of the groups

Variables	Group EC-1 Electrocautery	Group EC-2 Electrocautery+ NOB	Group UC-1 Ultrasonic cautery	Group UC-2 Ultrasonic cautery+NOB	F	*p
Flow1, ml/min	68.2±14.4	66.2±11.34	65.1±7.67	63.2±9.89	0.357	0.784
Flow2, ml/min	41.4±8.22	40.8±8.16	46.3±3.04	44.6±7.36	1.641	0.197
Flow3, ml/min	40.8±7.50	56.8±8.28	42.8±4.54	60.4±9.83	15.46	0.0001^{α}
F	87.787	85.683	77.391	59.187		
p	0.0001^{β}	0.0001^{ϕ}	0.0001^{λ}	0.0001^{δ}		

*One way ANOVA test

$^{\alpha}$Tukey -Kramer multiple comparisons test for flow3 between groups: EC_1-$_3$ vs EC_2-$_3$ - p<0.001, EC_1-$_3$ vs UC_2-$_3$ - p<0.001, EC_2-$_3$ vs UC_1-$_3$- p<0.01, UC_1-$_3$ vs UC_2-$_3$ - p<0.001

$^{\beta}$Tukey -Kramer multiple comparisons test for flow EC-$_1$ within groups: EC_1-$_1$ vs EC_1-$_2$- p<0.001, EC_1-$_1$ vs EC_1-$_3$- p<0.001

$^{\phi}$Tukey- Kramer multiple comparisons test for flow EC-$_2$ within groups: EC_2-$_1$ vs EC_2-$_2$- p<0.001, EC_2-$_1$ vs EC_2-$_3$ - p<0.001, EC_2-$_2$ vs EC_2-$_3$- p<0.001

$^{\lambda}$Tukey -Kramer multiple comparisons test for flow UC-$_1$ within groups: UC_1-$_1$ vs UC_1-$_2$- p<0.001, UC_1-$_1$ vs UC_1-$_3$- p<0.001

$^{\delta}$Tukey Kramer multiple comparisons test for flow UC-$_2$ within groups: UC_2-$_1$ vs UC2-$_2$- p<0.001, UC_2-$_2$ vs UC_2-$_3$- p<0.001

EC-1 - radial artery harvested with electrocautery

EC-2 - normothermic organ bath applied after radial artery harvesting with electrocautery

UC-1 - radial artery harvested with ultrasonic cautery

UC-2 - normothermic organ bath applied after radial artery harvesting with ultrasonic cautery

Table 4. Electron microscopic scores of the groups

	Endothelial cell structure	Degree of tissue edema	Morphologic changes of mitochondria of endothelial cells	Total score
Group EC	0.8±0.2	1.7±0.2	1.5±0.3	4.0±0.3
Group UC	0.9±0.1	2.1±0.3	1.7±0.1	4.7±0.2
*p	0.0527	0.0001	0.074	0.0001

Data were presented as mean±standard deviation

*Unpaired t test

EC - electrocautery, UC - ultrasonic cautery

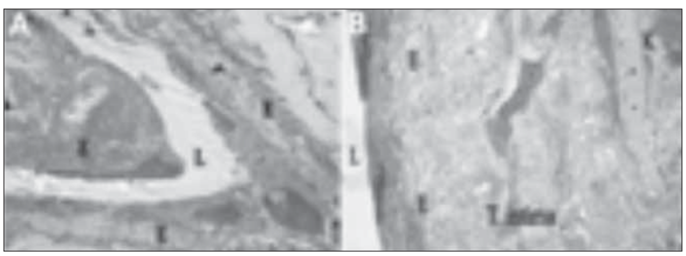

Figure 2. Electron microscopic screenings of radial artery grafts prepared with low voltage electrocautery

E - endothelium, L - lumen

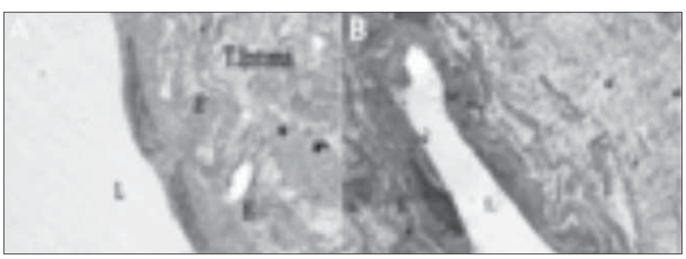

Figure 3. Electron microscopic screenings of radial artery grafts prepared with ultrasonic cautery

E - endothelium, L - lumen

found when the third flow of the groups EC_2 and UC_2 (NOB), was compared with their second flow. Our study suggest that re-warming of the pedicle, which is called normothermic organ bath after harvesting the graft, is an effective spasmolytic method as re-warming successfully increased RA flow.

This flow measurement studies were correlated with electron microscopic evaluation. During electron microscopic evaluation, we did observe less significant difference in terms of endothelial damage and morphological mitochondrial change between the groups but score of the tissue edema was increased in UC group. However, these results are in contrast to many previous histological or electron microscopic studies (11, 13). It may be related with both techniques, which are highly dependent on operator and technical skills such as frequency and duration of coagulation, coagulation distance to graft and intensity of mode.

The ultrasonic cautery, which became available recently, can dissect peri-vascular tissues, coagulate and cut vascular branches owing to mechanical incision by vibrations, cavity fragmentation and protein coagulation. Regarding the problems associated with use close to a blood vessel, it has been reported on one hand that the ultrasonic scalpel least damages the vessel owing to a low temperature, whereas it has also been reported that the damage reaches the depth of vascular walls (6-8). These opposing opinions on influences on vascular walls are thought to result from deficient information on differing influences on vascular walls depending upon the method of an ultrasonic scalpel use in the vicinity of a blood vessel. Recent reports have suggested that using the harmonic scalpel during the RA harvesting may be less traumatic when compared with conventional techniques, thereby decreasing spasm of this delicate conduit (13-15). Although in some of the studies, it has been shown that free blood flow was significantly greater with ultrasonically harvested conduits comparing with electrocautery, in our study we did not observe significant difference between these two groups. Electrocautery generates more heat than with ultrasonic cautery, if it is used minimally with low voltage during the entire dissection and when its use near the RA is avoided then both methods have similar effects on blood flow.

In as much as the RA is prone to spasm, successful use of it as a graft is dependent on techniques involving the management of vasospasm during surgery. During the past decade, after surgeons had begun using the RA as a graft, investigations focused on the contractile properties of this artery. Considering the influence of harvesting technique on the vasoreactivity and the endothelial integrity of RA, the results of the present study show that radial arteries harvested either by the harmonic scalpel or by electrocautery do not differ in their response to various vasoconstrictor and vasodilator agonists. Many vasodilator agents such as papaverine, Ca antagonists, phosphodiesterase inhibitor- milrinone, phenoxybenzamine and verapamil-nitroglycerine, verapamil-papaverine solutions are used overcome the spasm. However, there is still a debate on the ideal vasodilator agent. In our study, any kind of these agents was not used because these agents might interfere the flow rates of the study. In fact, the blood flow of RA was similar when compared with those studies (3, 16-18).

Study limitations

RA flow may be influenced by many factors, including vessel size, target vessel run-off, systemic blood pressure, and the presence of vasoactive medications. It was not possible to rigorously control and normalize all of these variables in comparisons made, and this represents a limitation of this study.

The small sample size probably did not have sufficient statistical power with compare to the influence of harvesting technique on the vasoreactivity and the endothelial integrity of RA between both groups of treatment.

Conclusion

As a conclusion, if endothelial integrity of the RA can be preserved along with the application of systemic temperature regardless of harvesting technique whether with electrocautery or ultrasonic cautery, it will provide better flow rates of the RA grafts. Additionally, our study suggested that harvesting by electrocautery, which yields similar blood flows comparing to ultrasonic cautery is an easy, fast and economic technique in the experienced hands of a careful surgeon. As the present findings regarding the two harvesting techniques resulted from in vitro organ bath experiments, further studies will be necessary to demonstrate whether they have any effect on the clinical condition, such as long-term patency, of patients undergoing bypass surgery.

Conflict of interest: None declared.

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