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European Journal of Cardio-thoracic Surgery 28 (2005) 420–424

EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

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Does radial artery harvesting for coronary revascularization cause neurological injury in the forearm and hand?

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Received 25 April 2005; received in revised form 1 June 2005; accepted 2 June 2005

Abstract

Objective: Radial artery (RA) is now used widely as a conduit of choice in coronary artery bypass grafting. Although RA removal is considered safe in the presence of adequate collateral arterial supply, there is still a considerable suspicion on the functional status of the forearm and hand. However, a neurological dysfunction may occur owing to either surgical trauma or ischemic neuropathy. This study was aimed to investigate the functional outcome of the donor forearm nerves of the patients who underwent coronary artery bypass grafting surgery with RA conduits. **Methods**: A consecutive series of 50 patients who underwent coronary artery bypass graft surgery with one or two RA grafts were investigated in the study. Motor and sensory functions of donor forearm nerves were measured by ENMG studies, pre- and postoperatively at the third week and sixth month of the operation. The conduction velocities, distal latencies and amplitudes of action potentials for motor and sensorial conductions of radial, ulnar and median nerves were measured in each ENMG examination. Neurologic status of the donor forearm and hand was assessed by the same neurologist who performed a detailed neurologic physical examination and ENMG studies. Results were statistically compared using one-way ANOVA test. **Results**: The incidence of any neurologic symptoms was 32% in early postoperative period. All reported neurologic complaints were associated with sensory conduction deceleration in ENMG investigations of related nerves. In postoperative assessment, median nerve sensory-motor, and ulnar nerve motor conduction records were slightly lower than the preoperative values, but no statistical difference was observed. Pre- and postoperative radial nerve motor and sensory conduction records were statistically similar ($P>0.05$). **Conclusions**: We advocate that removal of RA does not lead to any major neurologic hand complications in the presence of adequate collateral arterial blood supply. ENMG studies confirmed minimal conduction alterations with no statistical significance, even if neurologic symptoms were stated.
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Keywords: Radial artery; Graft; Coronary revascularization; Neurological injury; Neurologic complication; Coronary artery bypass grafting; Forearm; Hand; Complication

1. Introduction

Radial artery (RA) has been increasingly used as a conduit of choice in coronary artery bypass grafts. Simpler technique of harvesting and good patency outcomes provided a more common use for RA grafts [1,2]. Although RA removal is safe depending on adequate collateral arterial supply, some surgeons are still concerned about it because of ischemia and poor neurologic outcome risks at donor forearm and hand. In the literature, few complications of RA harvesting such as severe ischemia of hand [3] and infections at harvesting site [4] are reported. Nevertheless, neurologic complications of RA harvesting are reported as a rare surgical complication resulting from direct radial nerve damage during surgery [5,6]. Denton and colleagues [7] also pointed out that median and radial nerve injuries may be a consequence of hypoperfusion of hand following to RA removal as well as direct surgical trauma to radial, median and ulnar nerves and their branches supply the motor and sensorial functions in the forearm. Potential responsible mechanisms for the neurologic complications at hand following RA removal are inadequacy of the blood flow at the hand and its adverse effects on the nerve conduction network. In the aim to investigate sensory and motor complications of the forearm nerves, we prospectively performed pre- and postoperative nerve conduction studies in donor forearms of the patients who underwent coronary artery bypass grafting surgery with RA conduits.

2. Materials and methods

2.1. Patients

This study was approved by The Osmangazi University Institutional local ethics committee on human research. From August 2002 to August 2003 a consecutive series of 50

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doi:10.1016/j.ejcts.2005.06.004

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Table 1
The demographic characteristics of patients are summarized

Characteristic	
Number of patients	50
Number of radial artery grafts	54
Age (y) (mean±SD)	59±5
Male sex (%)	68
Hypertension (%)	57.1
Diabetes (%)	26
Smoking (%)	62.8
Hypercholesterolemia (%)	48.5
Ejection fraction (%)	46.8
Creatinine (mg/dL)	1.2±0.4
Metabolic syndrome (%)	18

patients (34 men, 16 women) (mean age±SD; 59±5 years) who underwent coronary artery bypass graft surgery using 54 radial artery grafts were investigated in the study. Table 1 shows the characteristics of patients. Thirteen patients (26%) were diabetic, and nine (18%) had metabolic syndrome characteristics [8]. Patients with past forearm injury or rheumatic diseases were excluded for RA harvesting. Patients who had suspicious neurologic complaints in forearm, indicating peripheral neuropathy such as carpal tunnel syndrome were also excluded. Evaluation of adequate ulnar artery supply was initially checked by Allen's test [9] and patients with capillary refilling within 10 s were considered as a candidate for RA harvesting. In these patients, arterial blood supply at hand was also examined in operating theater by digital pulse oxymetry (Datex-Ohmeda Division Instrumentarium Corp, Helsinky, Finland) with its probe at the thumb. Modified Allen's test was repeated in this position, and RA removal was considered safe either the pulse wave of the thumbnail bed reappeared within 10 s or systemic S_{PO2} value was achieved with the radial artery compressed at wrist.

2.2. Surgical technique

The non-dominant forearm was operated on to remove RA in unilateral harvested patients. RA harvesting was performed by the same surgeon, and in bilateral harvesting cases two surgeons followed the same surgical technique. A curvilinear skin incision starting 2–3 cm distal to the elbow and ending 2–3 cm proximal of the wrist was performed to facilitate the RA harvesting. Electrocautery with low-voltage diathermy was used to open subcutaneous tissue and deep fascia in proximal third of the forearm where RA is far from the fascia. Distal part of the deep fascia where the RA becomes superficial was incised using scissors to avoid thermal injury. When visible, the superficial radial and antebrachial cutaneous nerves were protected. The muscles of brachioradialis and flexor carpi radialis were separated using a self-retaining retractor in the proximal part of forearm. After exposing the RA, a mixture of 1% papaverine and diltiazem cocktail was applied externally with a soaked sponge to prevent arterial spasm. The branches of RA were divided between small metallic clips using scissors. After mobilization of RA, an atraumatic vascular clamp was placed temporarily across to trunk of the artery to observe retrograde pulsation indicating adequate ulnar artery collateral flow. Then the artery was proximally clamped and transected first, and retrograde blood flow from ulnar collaterals was observed as a final test. After homeostasis was assured using electrocautery and small clips, the harvesting site was closed with 3–0 absorbable sutures.

2.3. Data collection

Nerve conduction velocities were measured by ENMG studies, pre- and postoperatively at the third week and sixth month of the operation. Neurologic status of the donor forearm and hand was assessed by the same neurologist who performed a detailed neurologic physical examination and ENMG studies.

Neurologic examination included assessing the finger strength and sensation to define abnormalities such as tingling, numbness or pain in either dorsal or palmar surface of the hand. Nerve conduction studies were performed using Saphire 4ME (Medelec, Surrey, England). Compound muscle action potential amplitudes, distal latencies, conduction velocities and amplitudes for both motor and sensory stimulations were calculated separately. The stimulation and recording points during ENMG for each forearm nerves are shown in Fig. 1.

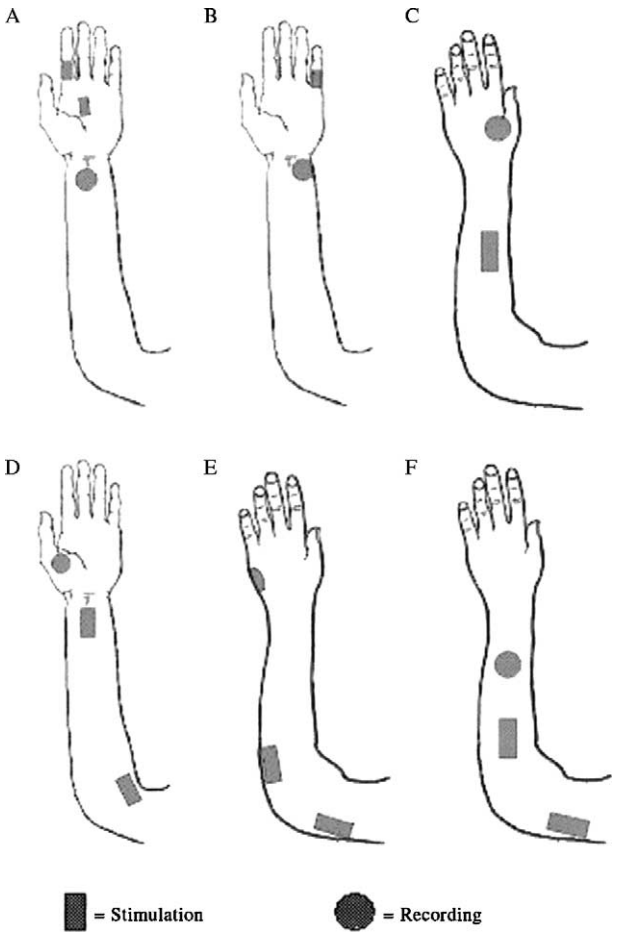


Fig. 1. The stimulation and recording points during ENMG for each forearm nerves are presented. (A) Median nerve sensorial conduction, (B) ulnar nerve sensorial conduction, (C) radial nerve sensorial conduction, (D) median nerve motor conduction, (E) ulnar nerve motor conduction, (F) radial nerve motor conduction.

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Briefly, median motor nerve conduction was recorded over the center of the abductor pollicis brevis muscle on the thenar eminence that was stimulated supramaximally at two different points; the first one is distally, 2 cm proximal to the cease on the volar surface of the wrist, between the flexor carpi radialis and palmaris longus tendons, at least 6 cm away from the active electrode, and the second one proximally, on the anterior surface of the upper arm between the biceps tendon and the medial epicondyle, over brachial artery. Sensory median nerve conduction was recorded over the wrist, which was stimulated from two different points; at the palm and at the proximal and distal interphalangeal joints of the index. Ulnar nerve motor conduction was recorded over the abductor pollicis brevis muscle that was stimulated consecutively, the first one, 2 cm proximal to the crease on the volar surface of the wrist, just medial to the flexor carpi ulnaris tendon, approximately 6 cm away from the recording electrode; the second one, 5 cm distal to the medial epicondyle over the ulnar nerve pathway, and the third one, 5 cm proximal to the medial epicondyle over the ulnar nerve pathway. Ulnar nerve sensory nerve conduction was recorded on the volar surface of the wrist next to the medial side that was stimulated at the proximal and distal interphalangeal joints of index. Radial nerve motor conduction was measured over the extensor indicis proprius muscle that was consecutively stimulated at 4 cm proximal to the muscle and at 6 cm proximal to the lateral epicondyle between the brachialis and brachioradialis muscles. Radial nerve sensory conduction was recorded at the area on the dorsum of the hand proximal to the web between the thumb and index finger that was stimulated on the mid-forearm lateral to the radial artery pathway.

2.4. Statistical analysis

Results were expressed as means $\pm$ SEM. Statistical analysis was performed using ANOVA (variance analysis for multiple comparisons). The post hoc Tukey multiple range test was used after ANOVA and $P<0.05$ considered as statistically significant.

3. Results

All surgeries were successful and no major complications ensued. None of the patients had hematoma requiring drainage. Improvement of subjective symptoms and physical findings followed an uneventful course.

3.1. Hand function

We did not notice any serious hand complications in our patients such as severe hand ischemia. The incidence of any neurologic symptoms was 32% in early postoperative period. Sensation abnormalities were described in 28% of patients and most commonly reported complaints were paresthesia and numbness. Paresthesia on the ulnar nerve region of hand occurred in 12% of patients, and on the median nerve region in 16%. Thumb weakness was seen in 6%. After 6 months of follow-up, neurologic complications remained as numbness only in two patients (4%), and others reported that their symptoms improved in 3–6 months. Evaluation of 16 patients with any neurologic symptoms revealed that, 11 patients (68.75%) were diabetic, and 7 (43.75%) patients had metabolic syndrome characteristics. The rates of neurologic abnormalities are presented in Table 2.

Table 2
Incidence of neurologic abnormalities

Symptom	*n*/total	Proportion (%)
Any neurologic symptoms	16/50	32
Sensation abnormalities	14/50	28
Ulnar nerve region	6/50	12
Median nerve region	8/50	16
Thumb weakness	3/50	6

3.2. Nerve conduction studies

Preoperative data were similar in all cases. In postoperative assessment, median nerve sensory-motor, and ulnar nerve motor conduction records were slightly lower than the preoperative values, but no statistical difference was observed ($P>0.05$). Pre- and postoperative radial nerve motor and sensory conduction records were statistically similar ($P>0.05$). All reported neurologic complaints were associated with sensory conduction deceleration in ENMG investigations of related nerves. This impairment was more evident especially in diabetics. However, no statistically significant difference was observed between diabetics and non-diabetics ($P>0.05$). Likewise, metabolic syndrome did not cause any statistically significant difference in each parameter among three consecutive measurements despite a high incidence of neurologic complaints ($P>0.05$).

The mean values and standard deviations of distal latencies, amplitudes, velocities of motor and sensory conductions in the preoperative, the first month and the sixth month of operation are shown in Table 3.

4. Discussion

After re-suggested by Acar and colleagues [10] with modified harvesting technique and use of pharmacological dilatation agents, RA is now used widely as a conduit of choice in coronary artery bypass grafts. Despite removal of radial artery is considered safe in the presence of adequate blood supply of ulnar artery, there is still a considerable suspicion on the functional status of the forearm and hand because of the risk of decreased tissue perfusion. In this regard, the effects of radial artery harvesting on tissue perfusion and function of the hand have been studied by many investigators [11,12]. Denton and colleagues [7] have pointed out the neurological dysfunction, occurred owing to either surgical trauma or ischemic neuropathy, as the underlying potential mechanism of functional hand complications after RA harvest. They performed a written interview with patients who underwent coronary artery bypass surgery with a RA conduit, to reveal symptoms related to nerve damage. This elaborated report prompted us to

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Table 3
The means and standard deviations of distal latencies, amplitudes, velocities of motor and sensorial conductions are presented

		Before surgery ($n=50$)	After surgery	
			3 weeks ($n=50$)	6 months ($n=50$)
Median nerve motor	Distal latency (ms)	3.5±0.5	3.6±0.7	3.3±0.5
	Distal amplitude (mV)	9.7±3.9	9.3±2.4	9.0±3.1
	Proximal amplitude (mV)	9.2±3.6	8.9±3.9	9.0±4.1
	Velocity (m/s)	54.6±8.2	53.2±4.9	56.1±11.0
Ulnar nerve motor	Distal latency (ms)	2.6±0.4	2.6±0.3	2.5±0.4
	Distal amplitude (mV)	8.7±2.7	7.6±2.3	7.8±3.6
	Proximal amplitude (mV)[a]	8.1±3.4	7.1±3.1	7.5±4.4
	Proximal amplitude (mV)[b]	7.6±3.0	7.0±3.4	7.1±3.6
	Velocity (m/s)[a]	66.7±12.1	63.8±10.3	68.8±9.6
	Velocity (m/s)[b]	52.2±9.1	49.6±8.8	47.2±4.0
Radial nerve motor	Distal latency (ms)	2.2±0.4	2.2±0.4	2.3±0.6
	Distal amplitude (mV)	3.6±1.1	3.3±1.2	3.5±1.3
	Proximal amplitude (mV)	3.5±1.4	3.4±1.6	3.6±1.7
	Velocity (m/s)	57.4±9.9	54.5±8.5	57.8±7.1
Median nerve sensory	Distal amplitude (μV)	42.7±17.7	37.3±16.6	37.7±22.3
	Proximal amplitude (μV)	52.6±23.4	50.2±19.8	49.8±21.4
	Index digit velocity (m/s)	43.2±6.7	40.4±7.4	40.6±9.1
	Palmar velocity (m/s)	44.3±9.5	45.6±8.3	44.4±11.2
Ulnar nerve sensory	Amplitude (μV)	24.9±9.8	25.9±5.4	24.3±6.9
	Velocity (m/s)	46.1±10.5	43.2±5.9	45.1±4.3
Radial nerve sensory	Amplitude (μV)	23.1±4.5	21.1±4.6	21.5±4.2
	Velocity (m/s)	46.8±9.7	45.0±7.9	49.6±11.0

None of the obtained data were statistically significant according to ANOVA ($P>0.05$).
[a] Below elbow to wrist.
[b] Upper arm to below elbow.

perform a detailed physical examination and investigate nerve conduction abnormalities using ENMG studies in donor arms of the RA harvested patients.

In a recent study, where a similar harvesting technique was performed, hand complications due to RA harvesting was reported as 9.0% in both cold and harmonic scalpel use [12]. In the present study, any neurologic symptoms were reported 32%. Although taking a special care, either surgical incision or thermal damage of electrocautery can be responsible for the direct nerve injury during RA harvesting. These effects may be attributed to sensory symptoms because of anatomic proximity of the superficial radial and antebrachial cutaneous nerves to the harvesting site. But, it is difficult to explain thumb weakness with these reasons, because median nerve lies far from RA, where it could not be affected easily from surgical manipulations. Sadaba and colleagues [13] suggested that removal of RA reduces the tissue perfusion of the hand and forearm. Median nerve receives blood supply from both radial and ulnar arteries. In this respect, thumb weakness is deemed as a result of temporary median nerve ischemia after removal of RA in early postoperative period even if preoperative tests indicated adequate collateral blood supply. One possible explanation to this phenomenon is the dominance of the artery, which provides most of collaterals to the median nerve. Dominance of radial artery determines the patients who are exposed to median nerve neuropathy after operation.

In the present study, both median and ulnar nerves sensory and motor conduction records were slightly lower compared to preoperative values, especially in the patients with neurologic complaints. Despite no statistical difference was observed, it is clear that, neurologic complications of the hand after RA harvest is consistent with a modest deceleration in neurologic conduction of the related nerves. The incidence of diabetes in the patients with any neurologic complaints was 68.75%. Metabolic syndrome was also found in a high rate in these patients. In this regard, it is possible to speculate that diabetes mellitus and metabolic syndrome are predisposing factors to neurologic complications in the RA harvested patients. According to presented results, only a modest deceleration can be achieved on conduction velocities of forearm nerves after radial artery harvest, even in diabetics. However, statistical analysis did not show any significant difference between the preoperative and postoperative records.

In summary, RA grafts, sometimes even bilaterally, are used in large series, in the aim of achieving total arterial revascularization [14]. Despite acceptable minor hand complications are reported in many studies [15,16]; none of them could eliminate controversy about the suspicions on this conduit. The current study highlights that removal of RA does not lead to any major neurologic hand complications in the presence of adequate collateral arterial blood supply. ENMG studies confirmed minimal conduction alterations with no statistical significance, even if neurologic symptoms were stated. We advocate RA as a safe conduit of choice in coronary artery bypass grafts to increase the number of arterial anastomoses. In order to avoid serious hand complications due to RA removal, Allen's test should be performed carefully in all patients before surgery.

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