



Palmar arch backflow following radial forearm free flap harvest

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SUMMARY. *Background:* Most surgeons advocate an Allen test (for occlusion of the radial or ulnar artery) and Doppler ultrasound examination before harvesting a forearm flap. In this study we attempted to correlate the results of these tests with intraoperative measurement of backflow pressure in the radial artery stump. *Method:* Stump pressures were measured in 30 patients after the flap had been harvested and were compared with preoperative assessment and intraoperative measurements of mean arterial pressure (MAP). *Results:* Mean arterial backflow pressure (MABP) in the arterial stump varied from 27 to 55 mmHg (mean 40.5). The ratio of this value to the mean arterial pressure ranged from 0.39 to 0.89 (mean 0.59) and exceeding 0.5 in 21 patients (70%). There was no correlation between this ratio and the preoperative assessment. *Conclusions:* These findings suggest that in the presence of a satisfactory Allen test and Doppler examination, there is adequate pressure in the palmar system to maintain vascular integrity of the donor hand after sacrifice of the radial artery. Despite the possibility of anatomical variants, the routine use of more invasive imaging is unnecessary.

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INTRODUCTION

Since its original description in 1981,¹ the radial forearm free flap has gained acceptance worldwide. Although it has been used more extensively and for more diverse reconstructive problems than any other free flap, its widest application remains the reconstruction of oral mucosal defects after ablative surgery of the head and neck. As harvesting the flap of necessity removes a segment of the radial artery, it is essential that the surgeon ensures that the ulnar arterial system is adequate preoperatively if survival of the donor hand is to be assured.

Traditionally preoperative assessment relies on the Allen test,² which is designed to show the relative contributions of the radial and ulnar arteries to the blood supply of the hand through the palmar arches. Although this is a simple bedside investigation, it is subject to error as the degree of arterial compression applied by the examiner is variable. In addition false positives may occur if the patient's hand is hyperextended.³ Most importantly, acute ischaemia of the hand has been reported after the flap has been harvested in the presence of a satisfactory preoperative Allen test.⁴

The existence of vascular abnormalities^{5–8} has prompted several clinicians to suggest a number of sup-

plementary tests to improve the vascular assessment of the donor hand. By its very nature arteriography is invasive and therefore rarely advocated in a normal limb. Colour flow duplex scanning of forearm vessels⁹ is a non-invasive option, which provides dynamic images. In common with arteriography it requires both specialised equipment and interpretation, which negates its use as a bedside investigation. Doppler ultrasound examination provides more accurate information than the Allen test alone and yet it is simple to do and requires minimal patient co-operation.^{5,10} Although segmental upper limb pressure recordings using Doppler ultrasound probes are now widely made, to date no correlation has been sought between these preoperative measurements and intraoperative arterial pressures. We therefore sought to investigate the correlation between Doppler ultrasound segmental upper limb pressures and radial artery stump pressures in the donor arm following forearm free flap harvest.

PATIENTS AND METHODS

Thirty consecutive patients who had radial forearm free flaps for the reconstruction of oral mucosal defects were included in the study. In all cases the non-dominant arm

was chosen for harvest. An Allen test was performed on the donor hand. The examiner applied simultaneous digital compression of the radial and ulnar arteries while the hand was alternately opened and closed to exsanguinate it. The hand was then opened to a relaxed, neutral position before release of the ulnar arterial compression. The hand colour should be restored within 20 seconds, delay beyond this being considered to be pathological. For the purposes of this study normal results were divided into accentuated (restoration of colour between 1 and 10 seconds) and reduced (restoration between 10 and 20 seconds).

Segmental arterial pressure measurements of the upper limb were obtained by combining Doppler ultrasound flow readings with sphygmomanometer cuff compression at the brachial, radial, and ulnar arteries in an attempt to quantify asymptomatic vascular disease. Measurements were repeated and mean values calculated.

After harvest of the flap, the radial artery stump was cannulated at the wrist with a 20-gauge needle immediately distal to the point of transection. The needle was connected through a lectrospiral catheter to the transducer of a Draeger PM 8040 anaesthetic machine, which recorded systolic, diastolic, and mean arterial backflow pressure (MABP) electronically. As all patients had hypotensive anaesthesia, simultaneous mean arterial blood pressure (MAP) measurements were recorded from an

arterial catheter introduced into the opposite radial artery. The latter was used as the denominator to derive a ratio between the mean arterial pressures in the donor and control arms (MABP:MAP).

RESULTS

The details of all 30 patients are summarised in Table 1. There were 21 men and 9 women with a mean age of 63 years (range 39–80). Twenty-four flaps (80%) were raised from the left forearm; 23 flaps were fasciocutaneous whereas 7 osseofascial flaps¹¹ were used to restore mandibular continuity. Thirteen patients (43%) had medical histories that included some degree of cardiovascular abnormality (essential hypertension, previous myocardial infarction, or angina). The Allen test was judged to be accentuated in 18 patients (60%). All flaps were successfully transferred and no patient developed ischaemia of the hand.

The MABP in the radial artery stump after harvest of the flap varied from 27 to 55 mmHg (mean 40.5). Comparative blood pressure readings from the opposite artery (MAP) ranged from 58 to 85 mmHg (mean 70.4). The ratio of radial stump MABP to MAP had a mean of 0.59 (range 0.35–0.89). The ratio exceeded 0.5 in all but nine cases.

Table 1 Details of patients and results of vascular investigations

Case number	Sex	Age (years)	Allen test	MAP (mmHg)	MABP (mmHg)	MABP:MAP
1	M	80	++	71	28	0.39
2	F	63	+	76	41	0.54
3	M	47	++	83	42	0.51
4	M	58	+	62	38	0.61
5	M	68	++	75	36	0.48
6	M	72	++	70	27	0.39
7	F	63	+	68	54	0.79
8	F	58	+	78	45	0.58
9	M	55	++	62	51	0.82
10	M	71	++	58	52	0.89
11	M	39	+	51	35	0.69
12	M	67	++	85	32	0.38
13	F	71	++	72	30	0.42
14	M	70	++	70	44	0.63
15	M	72	++	69	49	0.71
16	F	63	+	56	31	0.55
17	F	51	+	78	43	0.55
18	M	70	++	69	39	0.57
19	M	68	++	82	55	0.67
20	M	64	+	59	42	0.72
21	F	53	+	66	53	0.82
22	M	68	++	62	37	0.60
23	M	72	+	64	45	0.70
24	M	78	++	77	35	0.45
25	M	67	+	67	29	0.43
26	F	47	++	73	40	0.55
27	M	55	++	81	28	0.35
28	M	62	+	70	45	0.64
29	F	52	++	86	36	0.42
30	M	73	++	71	52	0.73

Allen test: ++, accentuated; +, reduced; MAP, mean arterial pressure in control arm; MABP, mean arterial backflow pressure.

There was no correlation between this ratio and age, sex, underlying cardiovascular disease, side of harvest of the flap, Allen test, segmental upper limb pressures or MAP at the time of harvest.

DISCUSSION

The blood supply to the forearm and hand is derived from the brachial artery, which divides into the radial and ulnar arteries. In a study of cadaveric upper limbs, McCormack *et al.*¹² confirmed the presence of all three arteries in 750 cases. The radial artery terminates in the deep palmar arch and the ulnar artery in the superficial palmar arch. Harvest of the forearm free flap requires interruption of the radial artery, and total reliance on the ulnar system and palmar arches to maintain vascular integrity of the hand. It is abnormalities of the latter that preoperative assessment aims to identify.

The ulnar arterial supply to the hand is best considered as either “complete”, in the sense that it supplies branches to all five digits, or “incomplete”, in that the thumb and index finger rely on a vascular supply from the radial artery through the deep palmar arch. The ulnar supply to the third, fourth, and fifth fingers is rarely compromised. After harvest of the forearm free flap therefore it is the integrity of the thumb and index finger that is most at risk. For these two digits to become ischaemic, two vascular abnormalities must coexist. Firstly, the ulnar supply must be “incomplete”. Secondly, there must be no communication between the superficial and deep palmar arches. In a study of 650 cadaveric dissections, Coleman and Anson¹³ estimated that the combination of these two abnormalities occurred in 12% of specimens examined, whereas Little *et al.* reported an incidence of pathological Allen test of 3%.¹⁴

Anatomical abnormalities of the brachial,⁵ radial,^{7,15} and ulnar⁶ arteries and disruption within the palmar arches⁸ have been reported. Some may be innocuous while others are of relevance during harvest of a forearm flap and may not be suspected preoperatively unless all patients have extensive vascular investigations. Jones and O'Brien⁴ published a case of acute ischaemia after harvest of a forearm flap despite a normal preoperative Allen test. Reconstruction of the radial artery with a vein graft salvaged the donor hand. Heden and Gylbert¹⁶ reported a case in which an aberrant branch of the radial artery was found in the normal anatomical position during harvest, while the main vessel entered the hand superficial to the extensor tendons. Such an anomaly is thought to occur in 1% of people and will not be detected by the Allen test.

We might therefore anticipate that in a proportion of patients with a normal Allen test backflow through the radial artery stump would be reduced or even absent. We have, however, found good flow through the palmar arch

system in all patients with a normal Allen test. The MABP obtained at the radial artery stump was universally high given the anaesthetic-induced hypotension during measurement, and the MAPB:MAP ratio exceeded 0.5 in all but nine cases. No correlation was evident between the value of this ratio and age, gender, cardiovascular status, accentuation or attenuation of the Allen test, or segmental upper limb pressures. Presumably a MABP:MAP ratio exists below which critical ischaemia of the hand will occur. Although it is not possible to give this a value from our data, it presumably lies below 0.35, the lowest figure obtained.

These findings are perhaps not surprising in the light of the reliance on retrograde flow through the radial artery when the “reversed radial forearm flap” is transferred as a pedicled flap to the hand.^{17,18} The apparent contradiction between our findings and those of Coleman and Anson may simply reflect differences between cadaveric and in vivo assessment of patency. Alternatively it may reflect the presence of a third contributing blood supply to the hand. In up to 16% of cases¹³ the median artery persists from life to join the superficial palmar arch. This vessel may supply a circulation to the hand in patients at risk of ischaemia of the thumb and index finger after interruption of the radial artery, and in so doing ensure high radial artery stump pressures. More recently it has been shown that excision of the radial artery leads to compensatory changes in the ulnar, posterior interosseous, and anterior interosseous arteries that may in turn exert a protective effect and reduce the potential for ischaemia of the hand.¹⁹

The reliability of the Allen test as a screening investigation for patients with poor ulnar circulation is attested to by many series of successful forearm flap transfers that did not cause digital ischaemia.^{20–22} This study confirms the clinical impression that when the Allen test and Doppler ultrasound flow examinations are normal, digital perfusion is ensured after sacrifice of the radial artery. Importantly age, gender and the presence of co-existing cardiovascular disease did not have a deleterious effect on mean arterial stump pressure. Although some authors⁹ have suggested additional vascular imaging of forearm vessels in an attempt to rationalise selection of donor vessels and reduce the incidence of failure of forearm free flaps, the results of this study suggest that in most cases such imaging is unnecessary to ensure the viability of the donor hand after interruption of the radial artery.

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