BLOOD FLOW MONITORING BY PULSE OXIMETRY DURING A FOREARM FLAP ELEVATION

TAKAHIKO SHIBAHARA, HIROYASU NOMA, TATSUYA ICHINOHE* and YUZURU KANEKO*

The First Department of Oral and Maxillofacial Surgery, Tokyo Dental College,
1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan
* Department of Dental Anesthesiology, Tokyo Dental College,
1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan

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Abstract

The Allen’s test for blood flow is performed before a forearm flap is elevated to examine vascularization through the ulnar artery. In this study, to ensure the survival of the donor site when a forearm flap was elevated, we monitored patients using a pulse oximeter. From oral cancer patients who were undergoing reconstructive surgery using the forearm flap, twenty patients were randomly selected to be served as subjects. A pulse oximeter probe was attached to the thumb on the side from which a skin flap was to be elevated. Oxygen saturation was measured when the tourniquet was released, and the radial artery was clamped and severed. The results showed that oxygen saturation temporarily decreased when the radial artery was ligated, but it recovered in one to two minutes.

Key words: Forearm flap—Morbidity—Pulse oximeter

INTRODUCTION

Various reconstructive techniques following ablative surgery of malignant tumors of the head and neck have been developed in the last two decades. Microsurgical techniques now play an essential role in modern reconstructive surgery, yielding cosmetically and functionally satisfactory outcomes in the treatment of a wide range of complex defects. The forearm flap has become a reliable tissue transfer for this purpose and is characterized by thinness, pliability, and contourability; it maintains consistent volume and surface area over time. The radial artery and the antebrachial vein are the feeding vessels of the forearm flap. Before elevating the radial artery and the forearm flap, it is necessary to confirm vascularization through the ulnar artery to the donor site, namely the palm and the back of the hand. Inadequate vascularization will lead to necrosis of the periphery of this site. One means of preventing necrosis is to perform the Allen’s test (radial artery compression test). This test is easy to perform and is now being routinely utilized by many surgeons. However, assessment is rather subjective because it is largely dependent on the visual sense of the tester. Hosokawa et al. reported that abnormalities were detected by
the Allen’s test in 3.6% of subjects and that the incidence of abnormalities increased with age. Therefore, a more accurate and safer test method is essential to confirm blood circulation through the ulnar artery when a skin flap is elevated. In this study, we assessed the effectiveness of a pulse oximeter in improving the safety of forearm flap elevation. The present paper explains the techniques used for this pulse oximeter monitoring.

METHODS AND MATERIALS

We performed reconstruction with forearm flaps in 120 patients between 1988 and 1998. From current patients who were undergoing reconstructive surgery using the forearm flap, 20 were randomly selected as subjects. The study was approved by the Ethics Committee, and each volunteer gave informed consent.

The measurements of vascularization in the hand after elevation of this flap involved pulse oximeter and a laser doppler blood flowmeter. Each probe was attached to the thumb on the side from which a skin flap was to be elevated. Oxygen saturation and vascularization were measured when the tourniquet was released (Fig. 1) and when the radial artery was clamped and severed (Figs. 2 and 3). Thumb blood flow was measured using a laser doppler flowmeter. The flow probe (NS-probe) was applied on the thumb skin. The results of pulse oximeter and laser doppler blood flowmeter measurements were compared to clarify the recovery process of microvascularization.

All data are expressed as mean ± SD. The results were analyzed using the Student’s t-test.

1. Pulse oximeter measurement

An oxygen saturation monitor (Pulsox-7, Minolta Co., Ltd., Tokyo, Japan) with a SP-7 probe was used. The probe was clipped to the thumb on the side from which the forearm flap was to be elevated. Since the thumb was within the surgical field, the probe and wires were sterilized in advance using ethylene oxide gas. Oxygen saturation was measured when the tourniquet was released (over five
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minutes) and from when the radial artery was clamped until three hours after surgery.

2. Laser doppler blood flowmeter measurement

A laser doppler blood flowmeter (ALF21, Advanced Technology Laboratories, Inc., Tokyo, Japan) with a type-C probe was used. This flowmeter can continuously measure tissue blood flow in a non-invasive manner. Since a quartz optical fiber is used, there is no electromagnetic noise. In addition, without being directly affected by the outside air temperature with a high degree of responsiveness, this flowmeter clearly assess blood flow, synchronized with the pulse. The probe was attached to the thumb on the side from which the forearm flap was to be elevated using adhesive tape, and micro-vascularization was continuously monitored.

RESULTS

Pre-operation measurements of pulse oximeter were similar in all subjects when the tourniquet was released (98.7 ± 0.65%). Mean oxygen saturation decreased significantly after clamping and reached a minimum in 0.5 min (96.5 ± 1.09%, p < 0.01) in all subjects. Mean oxygen saturation recovered in all subjects three minutes after clamping (Fig. 4).

The reading of a laser doppler blood flowmeter at pre-operation measurements in each patient served as the control when the tourniquet was released (100%, Fig. 5). Thumb blood flow decreased immediately after clamping, reaching the nadir (94.3 ± 3%, p < 0.01) in 0.5–1 minute in all subjects. It then gradually recovered. The complete recovery of thumb blood flow after clamping required approximately two minutes (Fig. 5). The degree of fluctuation in blood flow among the patients was small; the blood flow fluctuated in a comparable fashion in all patients.

DISCUSSION

When the forearm flap is elevated along with the radial artery, it is very important that a sufficient amount of blood is supplied to the palm through the ulnar artery. The Allen’s test is being routinely used to evaluate blood
circulation before the surgery\(^7\). However, there are some problems with the reliability of this test; since it checks for color changes of the palm, the skin color of individual patients must be taken into account, making it difficult to assess accurate vascularization in a consistent manner. In addition, assessments are very subjective in that the visual sense of the tester plays a large role. Hosokawa et al.\(^4\) conducted the Allen's test on 2,940 arms under strict conditions and reported that abnormalities were seen in 3.6% of subjects and that the incidence of abnormalities increased with age. We have used the forearm flap in 120 patients, but none of the patients had a vascularization disorder at the donor site\(^7,8\). Since vascularization disorder in the palm must be avoided at all costs, a safer and more accurate testing method is needed\(^3\).

A pulse oximeter is a medical instrument that is routinely used for general anesthesia, so no special preparation is required\(^3,9\). In addition, since the probe is attached to the thumb, surgery is not hindered. Furthermore, oxygen saturation can be measured simply regardless of blood flow\(^9\). The results of the present study showed that oxygen saturation temporarily decreased immediately after clamping the radial artery, but it never dropped by more than 5%. It was also found that oxygen saturation recovered in one to two minutes. In patients who are positive in the Allen’s test, perfusion of the ulnar artery may not be secured, so it will be necessary to examine the recovery process of oxygen saturation using a pulse oximeter by temporarily clamping the radial artery. Therefore, the radial artery should be severed and the forearm flap elevated after post-clamping oxygen saturation is assessed. The causes of the temporary decreases in oxygen saturation were investigated by simultaneously measuring blood flow. The blood flowmeter used in the present study is highly responsive and can capture clear waveforms synchronized with the pulse\(^5,6\). Immediately after the radial artery is clamped, blood flow decreased slightly and then recovered in approximately two minutes. Oxygen saturation should not have been influenced directly by the blood flow, but changes in the volume of hemoglobin may have caused the changes in oxygen saturation. The volume of reduced hemoglobin decreased, while the volume of oxidated hemoglobin remained constant. As far as the temporal decreases in blood flow were concerned, it was suggested that clamping the radial artery, a large artery carrying a large volume of blood, altered vascularization in the thumb.

The pulse oximeter was able to measure oxygen saturation in real-time in non-invasive

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*Fig. 5* Changes in thumb blood flow. The term “pre-op” implies release of the tourniquet, and the term “clamp” represents clamping of the radial artery. *: p<0.01 (vs pre-op)
manner when the forearm flap was elevated, thus proving to be a very effective assessment method. When the forearm flap is harvested, vascularization in the palm of the donor side must not be impaired. Therefore, the present test method incorporating a pulse oximeter should be routinely utilized when the forearm flap is elevated.

REFERENCES


Reprint requests to:
Dr. Takahiko Shibahara
The First Department of Oral and Maxillofacial Surgery, Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan