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Free flap monitoring using simultaneous non-invasive laser Doppler flowmetry and tissue spectrophotometry

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SUMMARY. Background: **Early identification of flap failure is an indispensable prerequisite for flap salvage. Although many methods of free flap monitoring are available, there is still no single reliable non-invasive technique for early recognition of flap failure and for differentiation between arterial occlusion and venous congestion. The aim of this study was to investigate the benefits of the tissue oxygen analysis system O2C for monitoring patients undergoing maxillofacial reconstruction with fasciocutaneous radial forearm flaps.** Material and methods: **In a prospective clinical study the microcirculatory parameters of blood flow, flow velocity, haemoglobin concentration (AU, Arbitrary Units) and oxygen saturation (%) were assessed by clinical means, by laser Doppler flowmetry and tissue spectrophotometry in 61 patients intraoperatively. Measurements were carried out before flap harvest, in the separated radial forearm flap, immediately after anastomoses and up to 14 days after reconstruction.** Results: **Following anastomosis, blood flow and flow velocity exceeded the level before flap elevation and reached significant differences by the third postoperative day ($p < 0.05$). Oxygen saturation decreased significantly by the third postoperative day and haemoglobin oxygenation showed stable values after performing anastomosis.**

Simultaneous, non-invasive laser-Doppler flowmetry and tissue spectrophotometry detected vascular complications in all cases with no false positive or false negative results and prior to clinical assessment. Conclusion: **For the first time this new device allows reliable prediction of venous congestion by an increase of haemoglobin-concentration, and of arterial occlusion by a decrease in blood flow parameters and oxygen saturation. It can thus differentiate the mechanisms of flap failure before clinical assessment.** © **2005 European Association for Cranio-Maxillofacial Surgery**

Keywords: **microvascular tissue transplantation; laser-Doppler flowmetry; tissue spectrophotometry**

INTRODUCTION

Tissue oxygenation and maintenance of microvascular blood flow in grafted tissues are crucial for flap viability. Early identification of flap failure is a precondition of flap salvage and therefore important for flap prognosis (*Heller* et al., 2001; *Kamolz* et al., 2002). The time interval for re-establishing vascular patency is the limiting factor for a successful revision. With close postoperative monitoring and subsequent early detection of compromised flap perfusion, easy intervention can result in successful salvage rates of 70% and more (*Lineaweaver* and *Buncke*, 1986; *Hidalgo* et al., 1998; *Yuen* and *Feng*, 2000; *Brown* et al., 2003). Although many technical developments of free flap monitoring have now reached clinical application, there is still no reliable, non-invasive monitoring device for early recognition of flap failure and for differentiation between arterial occlusion and venous congestion (*Acland*, 1981; *Clinton* et al., 1991; *Hjortdal* et al., 1991; *Yuen* and *Feng*, 2000). Therefore, reliable monitoring of free microvascular tissue flaps would be a valuable new tool for clinicians (*Disa* et al., 1999; *Nabawi* et al., 1999; *Liss* and *Liss*, 2000).

The aim of this prospective study was to investigate the reliability of non-invasive simultaneous application of laser-Doppler flowmetry and tissue spectrophotometry to identify free flap failure early. Moreover, this probe has been tested for its potential to distinguish arterial from venous occlusion.

PATIENTS AND METHODS

In a standardized investigation, capillary perfusion and capillary oxygen saturation were assessed in 61 patients who were undergoing reconstruction with radial forearm flaps following ablative tumour surgery. Measurements were made intraoperatively before flap harvest, in the separated radial forearm flap, immediately after completion of anastomoses and at defined intervals up to 14 days following reconstruction.

For these investigations the tissue oxygen analysis system O2C (Oxygen-to-see, LEA-Medizintechnik GmbH, Gießen, Germany) was used which has been described earlier (*Holzle* et al., 2003). This diagnostic device has been developed to facilitate observation of organ and transplant vitality. In contrast to the

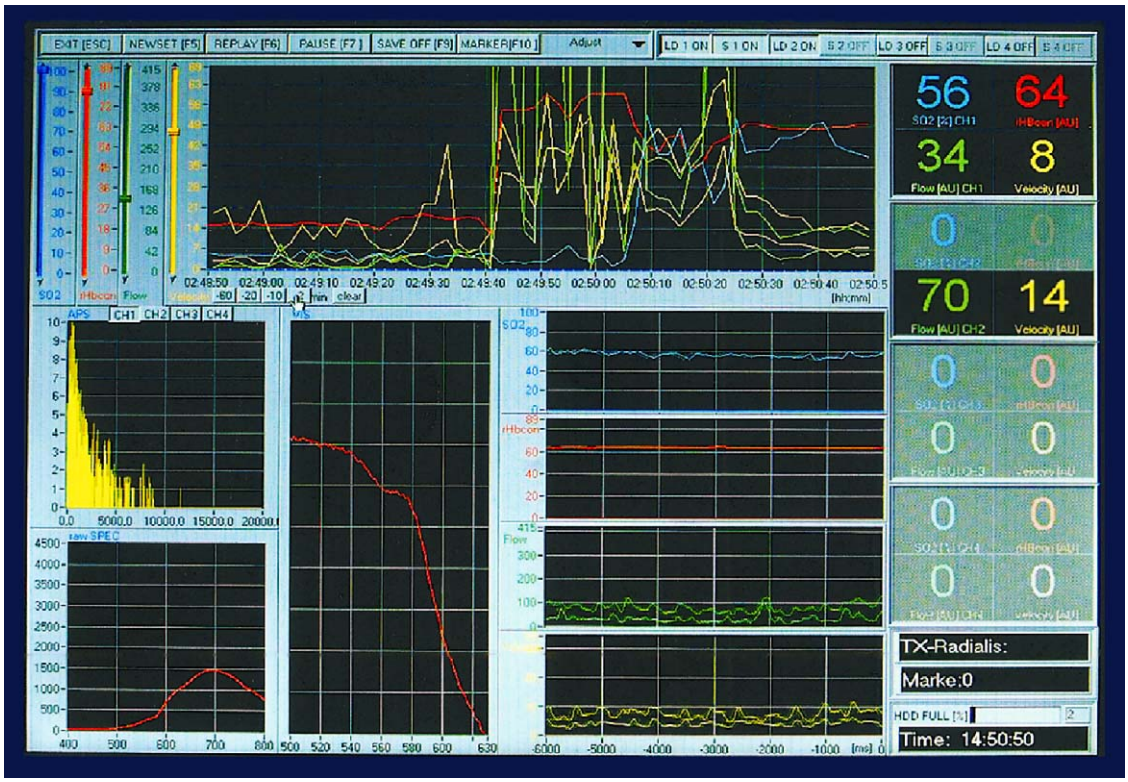

Fig. 1 – O2C monitor presenting microvascular parameters online.

current non-invasive assessment probes, it permits simultaneous non-invasive measurement of blood flow (AU, Arbitrary Units), flow velocity (AU), haemoglobin concentration (Hb_{conc} in AU), and oxygen saturation (SO_2 in %). The monitor provides online measurement of the microvascular parameters (Fig. 1) and is connected to the probe in a sterile cover sheath.

Patient data

From February 2002 to April 2004, 61 fasciocutaneous radial forearm flaps were harvested for microsurgical reconstruction of the head and neck region. Measurements were performed in all 61 patients (26 women and 35 men) with a mean age of 59.1 years (minimum 17, maximum 81).

Patients with negative Allen's manoeuvre, Sudeck's disease, earlier operations in the flap region or potentially vascularly compromised upper extremity and those with poor general health were excluded from transplantation. Out of these 61 patients, 53 (87%) were smokers at the time of operation or had smoked before. Indications for surgery are listed in Table 1.

Operative technique

In 42 patients the fasciocutaneous forearm flap was raised with tourniquet ischaemia and in 19 patients without. The flap was pedicled on the radial artery in all cases. The cephalic vein was included in 28 (46%) cases but used for anastomosis in only 18 (29.5%) cases. In five (8%) of these together with one vena comitans. In 36 (59%) flaps, only one of the venae comitantes was used for anastomosis. In seven (11.5%) cases anastomosis was performed using also the second vena comitans, to improve venous, drainage (Table 1). Operations were carried out by two surgeons only.

The patients were kept for 1 day in the surgical intensive care unit and then returned to the ward.

Measuring blood flow with the laser Doppler

Blood flow was measured using the O2C laser-Doppler flowmetry-Unit, that works using the Doppler principle. Tissue is illuminated with coherent laser light of 820 nm wavelength and 30 mW power through a fibre-optic cable. Backscattered light is collected by the same probe and frequency shifted light extracted by heterodyne light beating technique. The power-spectral density of shifted light is a linear function of the average velocity of moving cells within the tissue. Probe geometry allows detection of blood flow and flow velocity up to 8 mm depth. Recording speed was 40 measurements per second and thus allowed for pulsed synchronous measurements.