Effects of Diode Laser Therapy on Blood Flow in Axial Pattern Flaps in the Rat Model

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Abstract. Axial pattern skin flaps are a very important reparative tool for the plastic and reconstructive surgeon in the reconstruction of tissue defects. From whatever unfortunate reason, part or all of such flaps occasionally suffer from irreversible ischaemia with loss of the flap. Infrared diode laser therapy has been shown to improve local and systemic circulation. The present study was designed to assess the effect of an 830 nm diode laser (power density, 18.5 W/cm², energy density 185 J/cm²) on the blood flow of axial pattern flaps in the rat model and their survival, compared with unirradiated controls. The flaps were raised in all animals (n=40), and blood flow assessed with laser speckle flowmetry (LSF). In the experimental groups (3 groups, n=10 per group), the flaps were irradiated either directly over the dominant feeder vessel (iliolumbar artery), at the proximal end or at the distal end of the flap itself and blood flow assessed during irradiation. Flowmetry was performed again in all animals at 5 and 10 min postirradiation, and the flaps sutured back in position. The unirradiated controls were handled in exactly the same way, but the laser was not activated. The survival rate of the flaps was assessed on the fifth postoperative day. LSF demonstrated significant increased blood flow in the flaps at 5 and 10 min postirradiation in all experimental groups compared with the control animals. At five days postirradiation, there was significantly better survival of the flaps in all the experimental groups compared with the controls (p<0.01), but no significant difference was seen between any of the experimental groups. We conclude that laser therapy increases the blood flow and perfusion of transferred flaps, and that this has significant effects on the survival of the flaps. One possible mechanism of modulation of the autonomic nervous system is discussed.

Keywords: Autonomic nervous system; Diode laser; Failing skin flaps; Low level laser therapy; Photobioactivation; Tissue ischaemia

INTRODUCTION

In the field of plastic and reconstructive surgery, a variety of flaps have been developed to repair tissue defects, and failure of flaps is a major problem for the plastic and reconstructive surgeon. Despite good intraoperative care, for whatever reason, irreversible ischaemia sometimes occurs in the distal portion of random pattern skin flaps or in random portions of axial pattern skin flaps. If the peripheral blood flow is sufficient in the distal portion of the skin flap then flap necrosis would become much less of a problem. Low incident levels of laser irradiation have been shown to improve circulation [1,2]. If, for example, application of a diode laser can improve the circulation in the distal portion of the flap, then this should, in theory, help to ensure a greater survival area.

Since 1989, the author and others have been reporting on enhanced blood flow following the application of low incident levels of laser energy, often referred to as laser therapy, in research with animal models [3-5]. Of particular interest have been the reports on the effects of 830 nm GaAlAs diode laser irradiation on random pattern skin flap survival in the rat model. It has been demonstrated that GaAlAs diode laser therapy produced (1) higher vascular perfusion, (2) greater fluorescent areas under fluorescein angiography and (3) significantly larger flap survival areas than either non-coherent LED-irradiated or un-irradiated control flaps. Laser therapy has been used in humans with significant success...
However, despite our past studies on the effect of laser therapy on blood flow, the mechanisms and pathways are still mostly unclear.

Among skin flaps, the axial pattern skin flap has a dominant feeding vessel giving a stable blood flow, therefore clear results can be obtained. The present study examines the mechanisms of the effects of diode laser irradiation on peripheral blood flow on the axial pattern skin flap in the rat model, compared with unirradiated controls.

**MATERIALS AND METHODS**

**Laser System**

The diode laser system used in this study was a gallium aluminium arsenide (GaAlAs) system (prototype system from NIIC, Japan, Fig. 1), delivering 100 mW in continuous wave at 830 nm in the near infrared. The laser probe was set up at a constant distance from the target tissue, and held in a clamp (Fig. 2). The spot size at the tissue was 0.0054 cm², thus giving an incident power density or irradiance of approximately 18.5 W/cm², and the irradiation time was 10 s, delivering an energy density or radiant flux of approximately 185 J/cm².

**Laser Speckle Flowgraphy**

Figure 3 shows the laser speckle flowgraphy system (L-MAP 10, M&M Japan). This system uses a 20 mW 780 nm laser beam. The blood flow rate is measured by assessing the degree of wavelength Doppler shift in the laser speckles, which is created by the combination of the reflected light from the laser beam and the rate of blood flow in the irradiated tissue. The system displays increases in blood flow in real time on a CRT monitor, very similar in appearance to a thermogram. A polyurethane sheet was placed under the flap and dominant feeder to ensure the flowmeter measured the blood flow in only the flap and iliolumbar feeder artery, and not the body of the animal (Fig. 4), and to limit laser radiation to the flap-related target tissue. The material of the sheet, including the pigment giving it its colour, was specifically chosen for its poor absorption of 830 nm to minimise photothermal vasodilatory artefacts. Figure 2 shows a Group C rat covered with the polyurethane sheet, positioned