3. Smeltzer DM, Stickler GB, Schirger A. Primary lymphedema in children and adolescents: A follow-up study and review. *Pediatrics* 1985;76:206–218.
4. Herman-Giddens ME, Slora EJ, Wasserman RC, et al. Secondary sexual characteristics and menses in young girls seen in office practice: A study from the pediatric research in office settings network. *Pediatrics* 1997;99:505–512.
5. Euling SY, Herman-Giddens ME, Lee PA, et al . Examination of US puberty-timing data from 1940 to 1994 for secular trends: Panel findings. *Pediatrics* 2008;121(Suppl 3):s172–s191.

Continued Observations in the Postoperative Monitoring of Free Flaps: Preliminary Experiences with Masimo Radical-7 Transcutaneous Plethysmography and Pulse Oximetry

Sir:

Reliable assessment of the postoperative perfusion of free tissue transfers has always been a challenge for reconstructive microsurgeons, with the complexities of flap microcirculation often difficult to assess despite all the subjective and objective examination techniques available today. A large number of techniques have been described in the literature, ranging from invasive techniques such as the injection of fluorescein dye and implantable Doppler probes, to simple noninvasive clinical assessment. We recently described our use of clinical monitoring alone,[1] and despite demonstrating that no adjunctive technique has significant advantages over clinical monitoring alone, many surgeons still use adjunctive techniques in an attempt to detect failing flaps early and improve salvage rates.

In our unit, we have used numerous adjunctive invasive and noninvasive monitoring methods, including the implantable Doppler probe, microdialysis, photoplethysmography, temperature probes, near-infrared spectroscopy, and others, and have reported our findings in the literature. In an attempt to find an adjunctive technique to complement clinical assessment, we have continued to test novel technologies for this role. Of particular interest to plastic surgeons are noninvasive devices that can accurately measure the blood flow to the skin, and regardless of outcome, we feel it is important to publish experiences so that other groups can build on our findings.

One noninvasive probe of particular interest was the Massimo Radical-7 pulse oximeter (Masimo Corp., Irvine, Calif.), which combines pulse oximetry with plethysmographic assessment to measures oxygen perfusion, heart rate, and a perfusion index. The perfusion index is the ratio of pulsatile versus nonpulsatile flow (arterial versus venous flow), with previous studies suggesting a perfusion index of over 0.7 as a measurement of effective oxygen perfusion and showing Masimo pulse oximetry to be the most accurate and reliable means of obtaining oxygen saturation readings during low-perfusion states, as proven in more than 100 peer-reviewed studies.[2–5]

Our initial trials encompassed the use of the device on glabrous (palmar) skin, where we found that it was highly sensitive for detecting occlusion of either the ulnar or radial arteries. We then began trials of the device on free flaps, using the Masimo monitors postoperatively on 20 flaps, including 12 fasciocutaneous flaps (anterolateral thigh flaps) and eight musculocutaneous flaps (vertical rectus abdominis, perineal artery, and latissimus dorsi flaps). We also used the monitors for assessment of intraoperative flap perfusion. Institutional ethical approval was obtained through Melbourne Health Human Research Ethics Committee no. 2006.231.

We used a range of settings in the course of these trials and, despite setting the sensitivity to maximum, securing the probe on the flap with tape, and using continuous monitoring while removing extraneous light, we found that the probe was able to uniformly record positive values for perfusion index and the other measures of perfusion. However, the probe did not seem to be able to reliably confirm flap viability. The perfusion index and the oxygen saturation were both extremely variable when applied to flaps with adequate perfusion. We postulate that this was attributable to the mechanism of perfusion assessment: initially licensed for use on the forehead, the probe technology is based on the presence of a deep layer providing a surface off of which to reflect. The forehead is an ideal area, as the periosteum is in close proximity to the skin and the depth of penetration is not an issue. In hindsight, our preliminary experiences assessing the perfusion of glabrous skin were probably relying on the presence of the palmar fascia and possibly the metacarpals. On the thicker flaps and extremities, the depth of penetration and lack of reflective layer were likely to have been factors in the failure of the probe to produce reliable results. The idea of inserting reflective layers under the flap was discussed, and this is an interesting area for future research.

Although our pilot study was not successful in proving a role for the Masimo Radical-7 probe for postoperative monitoring, we feel the benefits of the technique (i.e., it is noninvasive, cheap, and based on accurate measures of perfusion) could have an impact in this field if the limitations are addressed and with modifications to the application of the probe.

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REFERENCES

1. Chubb D, Rozen WM, Whitaker IS, Acosta R, Grinsell D, Ashton MW. The efficacy of clinical assessment in the postoperative monitoring of free flaps: A review of 1140 consecutive cases. *Plast Reconstr Surg.* 2010;125:1157–1166.
2. Barker SJ, Curry J, Redford D, Morgan S. Measurement of carboxyhemoglobin and methemoglobin by pulse oximetry: A human volunteer study. *Anesthesiology* 2006;105:892–897.
3. Clack SL, Shah N, Hoang TD, Gupta B. A comparison of four major brands of pulse oximeters (PO) with Masimo SET PO during motion and low perfusion under normoxic and hypoxic conditions in human volunteers (Abstract). *Anesthesiology* 2001;95:A586.
4. Hager H, Dayakar R, Kurz A. Perfusion index: A valuable tool to assess chances in peripheral perfusion caused by sevoflurane? *Anesthesiology* 2003;99:A593.
5. Macknet MR, Kimball-Jones PL, Applegate RL, Martin RD, Allard MW. Non-invasive measurement of continuous hemoglobin concentration via pulse CO-oximetry. *Anesthesiology* 2007;107:A1545.

The Feeling of Healing

Sir:

During healing, wounds are painful or pruritic, and the resulting scar may be anesthetic or pruritic. Furthermore, tissues fail to heal normally if deprived of a nerve supply, leading to the observation that neuropeptides have dual purposes in wounds, both in sensory signaling and as mediators of healing. The sensory nervous system exerts a distally directed *antidromic* effect in addition to the conventional *orthodromic* response.

Wounds are initially hyperinnervated during healing. During scar maturation, nerve density normalizes[1] or becomes less than in controls. Although densities can be normal, the normal pattern of scar innervation is not reestablished (Fig. 1). Nerve end organs cannot regenerate, preventing restoration of normal sensation.

The neurotransmitters calcitonin gene-related peptide and substance P are expressed by C fibers and are implicated in pain signaling. Calcitonin gene-related peptide is also found in Aδ fibers mediating pruritus. Substance P and calcitonin gene-related peptide contribute to the cutaneous response to injury. Nerve growth factor (NGF) is important in healing and sensory nerve development.

Pruritic hypertrophic scars and experimental wounds contain more calcitonin gene-related peptide and substance P than normal skin. Although calcitonin gene-related peptide nerve fiber density returns to control levels in normotrophic scars, the increase in substance P–immunopositive fibers persists in mature scars.[1] Substance P immunoreactivity is increased in pruritic skin grafts despite an overall decrease in graft innervation. Substance P is also elevated in psoriatic lesions and hypertrophic scars, whereas substance P–deficient mice show reduced allodynia and hyperalgesia. Calcitonin gene-related peptide fibers identified within human peroneal nerves stimulated electrically or with histamine cause pruritus. We suggest that calcitonin gene-related peptide levels could explain pain and pruritus during wound healing, and substance P might mediate the symptoms of mature scars.

Neurotransmitters have multiple actions in mediating healing: substance P causes mast cell degranulation, inflammation, and keratinocyte proliferation. Substance P injection causes flare, wheal, and pruritus.

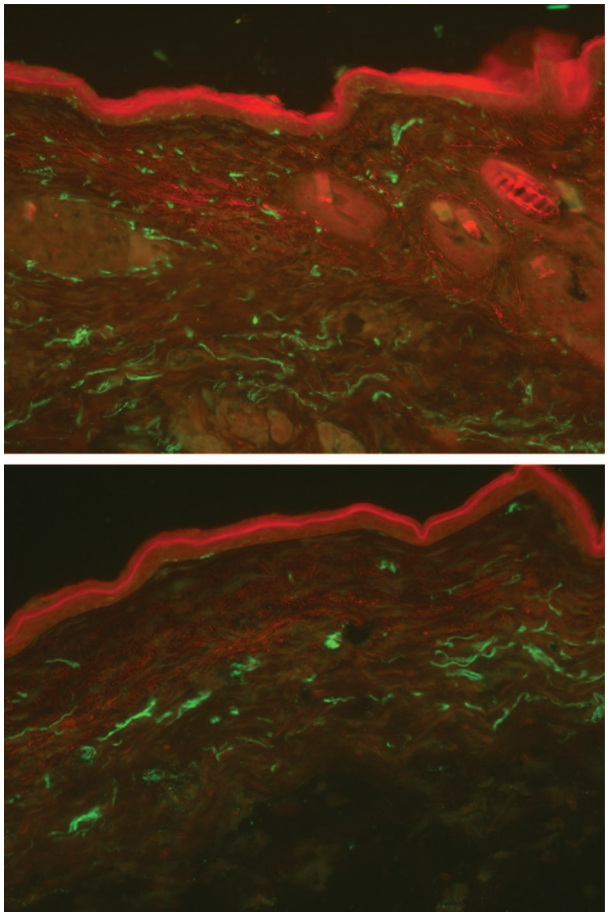

Fig. 1. Immunohistochemical staining of (*above*) normal (unwounded) murine skin and (*below*) 42-day-old murine excisional wound for the pan-neuronal marker PGP9.5 in green. Red counterstain shows epidermis and hair follicles. Note the absence of hair follicles in the scar. Sensory end organs also fail to regenerate. (From Henderson J, Terenghi G, McGrouther DA, Ferguson MW. The reinnervation pattern of wounds and scars may explain their sensory symptoms. *J Plast Reconstr Aesthet Surg.* 2006;59:942–950.)