Perfusion Monitoring in Microvascular Flaps

Fluorescence Imaging Applied as a Method to Discover Vessel Thrombosis

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Tissue transfer in head and neck reconstruction has a high success rate. Nevertheless, in up to 10% of all cases serious complications occur. Skin flap monitoring with technical devices should help with the earlier detection of vascular problems so it is possible to intervene in time. In this study fluorescence imaging was tested on its suitability in measuring a perfusion-dependent parameter for discovering vessel thrombosis in free flaps. A prototype of the VisiSens system by PreSens was used to measure oxygen flux into the skin of 10 microvascular grafts before explantation, after successful anastomosis and 1 day after surgery. It was possible to clearly identify poorly perfused flaps 1 day after surgery with this method.

Microvascular free tissue transfer is often used to reconstruct defects in the oral maxillofacial region, and shows a success rate of 91 to 99%. Still, in some cases vessel occlusion can cause serious complications and result in flap failure. Often the gradual shutdown of the microcirculation is the main problem, a slow process that is hard to detect. Though monitoring methods for flap transplants are available, no reliable, accurate and easy to use procedure has been established yet. In this study free flap monitoring by measuring a perfusion-dependent parameter was tested on its suitability for discovering complications in anastomosed tissue. Tissue perfusion was determined applying fluorescence imaging performed with a prototype of the VisiSens system by PreSens. A handheld microscope was used to read out the response of a fluorescent sensor foil, which was put onto the skin surface.

Fluorescence Imaging on Skin Flaps

Fluorescence imaging of dermal tissue of the flaps was performed before explantation, after successful anastomosis and 1 day after surgery. The sensor foil was put with its sensing side directly onto the skin surface and its response read out non-invasively with a handheld fluorescence microscope. Every measurement was documented in pictures to optically judge flap perfusion. Tissue oxygenation depends on the oxygen supply provided by blood vessels and the oxygen consumption of the tissue cells. Oxygen partial pressure (pO$_2$) is an ideal parameter for monitoring tissue oxygenation as it is proportional to the concentration of physically dissolved oxygen. In the experiments the fluorescent sensor foil was loaded with oxygen from ambient air and put onto the skin surface. It released its reservoir of oxygen depending on the demand by the tissue. The reservoir was not reloaded during the measurements, because the transparent polyester support of the sensor is impermeable. The oxygen release, which is driven by the oxygen flux, could be recorded measuring the sensor response over time. The measurements were started right after the sensor was put onto the skin surface and only performed during equilibration time of the partial pressures of the sensor and the tissue, in a time series of 10 images every 10 seconds (100 sec. recording time). After determining a certain region of interest (ROI) on the images the sensor response to oxygen could be plotted over time. The perfusion-dependent parameter driven by the oxygen tension of the tissue could be calculated from the slope of these graphs.

Monitoring Results

Low perfusion rates led to low oxygen tensions in the tissue and therefore to high slopes, while high perfusion rates led to high oxygen tension and showed low slopes. The 10 grafts investigated showed a mean slope value of 0.14 [standard deviation ± 0.12] before explantation. After successful anastomosis the mean slope value was 0.25
Fig. 2: Slope graphs for oxygen tension inside hypo, normal and hyper perfused tissue (top graphs); mean slope values for hypo, normal and hyper perfused tissue (bottom graph).

[standard deviation ± 0.14]. One day after surgery well-perfused grafts (n=6) showed slope values between 0.07 - 0.27 (mean slope value 0.18 ± 0.07) which were almost equal to the preoperative values. Poorly perfused grafts (n=4) on the other hand had strongly altered perfusion-dependent slopes with values in a range of 0.35 - 0.75 (mean slope value 0.52 ± 0.19) and could therefore be clearly identified. It was possible to successfully revise three of the flaps by surgery. A threshold slope value of 0.3 could be determined in these tests, with values below 0.3 indicating good flap perfusion. The high standard deviation values resulted from the abnormally high slope values in sample 3 - a highly compromised flap which was lost at an early stage of the study.

Conclusion

Though measurements in this trial depended on the experience of the examiner and the pressure applied with the examination tool good results could be achieved. We suggest that measurements with the VisiSens system in future studies are made by the same examiner to obtain better data quality. Imaging with fluorescent sensor foil on microvascular grafts allowed two-dimensional and non-invasive assessment of tissue oxygenation.

Of course it needs to be tested and evaluated with a higher number of measured samples but it might be an objective measurement tool for monitoring free flaps. Moreover, the threshold value of 0.3 determined in this study has to be confirmed in a larger trial. The possibility to monitor an entire flap over time with oxygen imaging represents an important advantage, aiding the evaluating surgeon in flap examination and giving clear indication on the extent of flap perfusion.

Application note adapted from: