Perfusion examinations of hind limb ischemia (HLI)

with the TIVITA® Tissue HSI Camerasystem

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Many surgical disciplines are often confronted with pathophysiological phenomena in clinical practice, which originate in the area of microcirculation. The postischemic reperfusion injury, a clinical problem in the field of plastic surgery, is particularly evident in free flap plastics or after replanting's [1]. Also many chronic wound healing disorders are due to microcirculation disturbances, blocking the transport of important nutrients, which are essential for a successful healing process. A more prominent disease is peripheral arterial occlusive disease (PAD), which is becoming a large problem for the national health system by strongly increasing prevalence. In Germany alone, the number of all PAD-related hospital stays rose by around 21% between 2005 and 2009 [2]. An important part of the microcirculatory consideration of these problems is the processes of the formation and development of new blood vessels. These include, among others, angiogenesis (formation of new blood vessels from already existing blood vessels) and arteriogenesis (growth of collateral arteries after vessel closure). Therefore, research into the underlying patho-physiological mechanisms is of paramount importance for the development of innovative therapeutic procedures. A widely used animal model that is applied in these research questions is the hind-tracheal ischemia model. Here, an ischemic condition is artificially induced by the setting or severing of the thigh bats (e.g., rats). The model thus allows the investigation of the formation of new blood vessels during angiogenesis and arteriogenesis. This model is also used to develop new surgical methods and to train doctors for filigreed operations. It is particularly important after anastomoses to obtain a feedback on possible perfusion disorders caused by stenoses or thrombi.

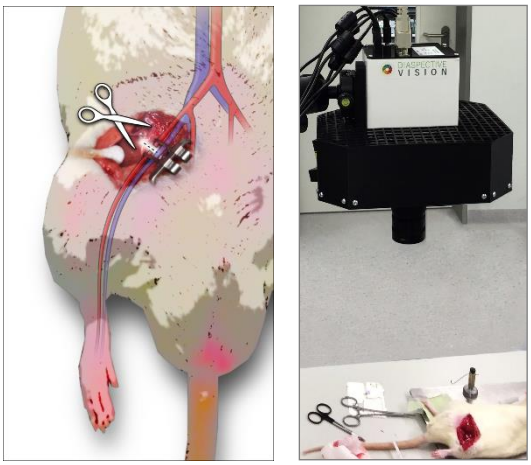

Fig. 1: Typical vascular intervention on the animal model and measurement with the hyperspectral camera

Furthermore, the HLI model is an essential component of the clinical testing of new therapeutic methods in this field. For this purpose, the objective measurement and monitoring of tissue perfusion is an important prerequisite. Until now, none of the available diagnostic methods had a sufficiently high reliability, which is why they could not establish themselves in clinical practice. The hyperspectral camera system TIVITA® Tissue by Diaspective Vision allows the non-invasive, hyperspectral analysis of perfusion after microvascular anastomoses and can thus make a significant contribution to the research and validation of new therapeutic procedures.

Perfusion monitoring in the hind limb ischemia model using the TIVITA® Tissue

Within the scope of a research project of the Department of Oral, Maxillofacial, Plastic and Facial Surgery, University of Rostock, headed by PD Dr. Dr. Peer W. Kämmerer and Dr. Dr. Michael Dau, the hyperspectral camera system TIVITA® Tissue has been tested for the intra- and postoperative assessment of anastomoses.

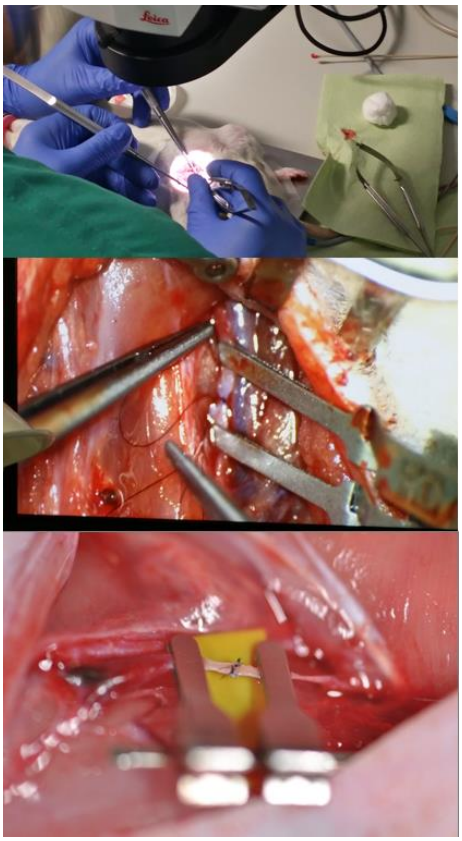

Fig. 2: Typical vascular intervention on the animal model in practice

For this purpose the A. femoralis was surgically severed on one side of a total of 21 male Wistar rats and subsequently re-anastomized by microsurgery. The tissue parameter Oxygenation (StO_2) as well as near infrared (NIR) perfusion, preoperatively and after reperfusion were measured several times intra- and postoperatively using the TIVITA® tissue camera system. The animals were then sacrificed and the vessel removed, including histological processing. Histology was used to assess the anastomoses independently. A typical recording sequence is shown in Fig. 3.

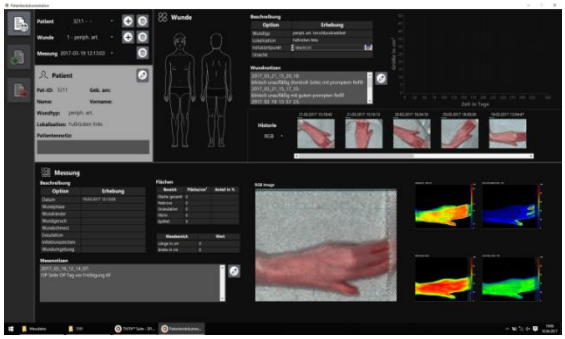

Fig. 3: Graphical user interface of the documentation tool showing the recording sequence

Figures 4-6 show different gradients of the surgical procedures.

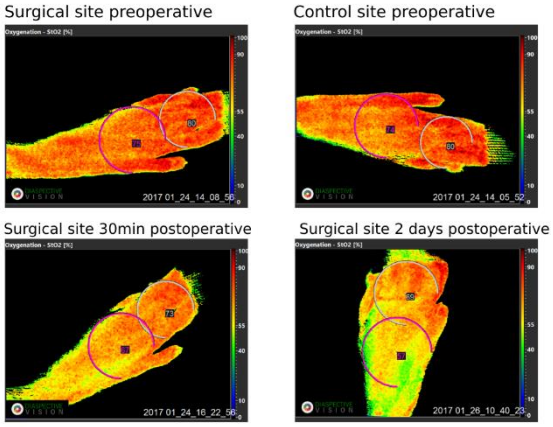

Fig. 4: Oxygen saturation StO_2 at different times with no complications; the reddish coloring indicates good oxygen saturation of the hind legs at all times. On the second postoperative day, a yellow-green color appears, which means a slight decrease of the values, but these remain in the positive range.

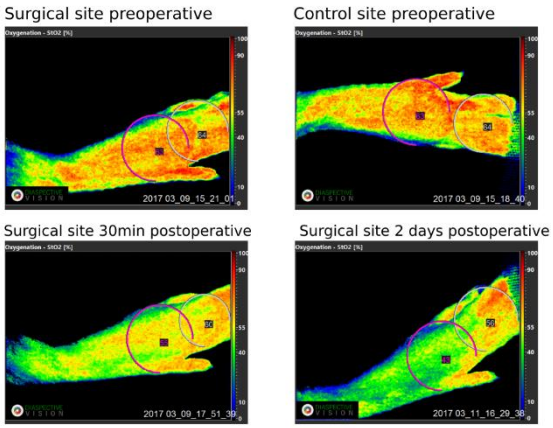

Fig. 5: StO_2 at different time points with reduced perfusion after 30 min and thrombosis 2 days postoperatively; before the operation the reddish color shows a good oxygen saturation of the hind legs, which after the surgery changes to yellow-green and means a decrease of the values. After two days, the values in the middle part of the hind legs in the green-blue areas drop, suggesting a critical change.

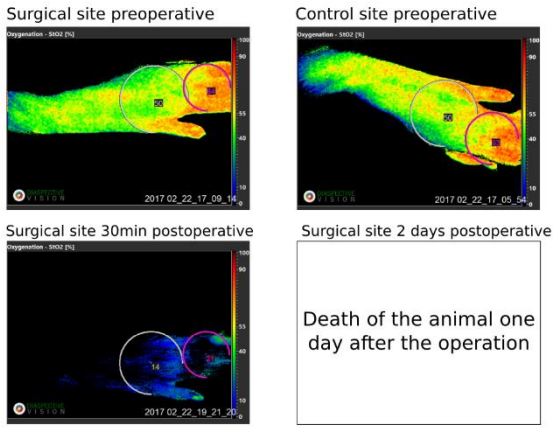

Fig.6: StO_2 at different times with very low oxygenation after 30 min and death of the animal on the following day of the operation; The blue saturation (black areas can not be evaluated due to the too low values) 30 minutes after the operation shows that the oxygen saturation falls completely and the animal has a critical state, which is subsequently confirmed by the death of the animal.

Of the animals operated, 5 animals died prematurely. In the remaining 16 animals 7 revision interventions were performed with 4 clinically detected thromboses and 3 stenoses. In all cases, this detection was confirmed by the camera.

The TIVITA® Tissue camera system is therefore a valid non-invasive system for the assessment of tissue oxygenation and perfusion after microvascular anastomosis. The technology shows perfusion problems reliably and at an early stage, enabling clinicians to intervene in time to avoid prolonged ischemic conditions.

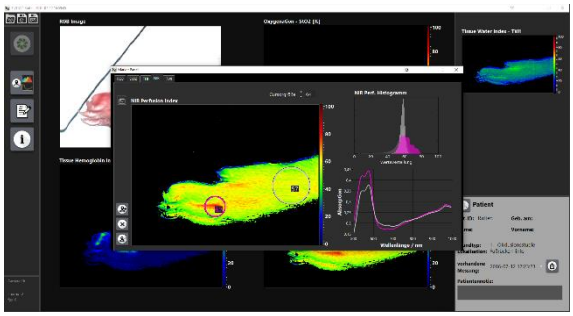

Fig. 7: Screenshot of the numerical evaluation function

How does the hyperspectral imaging technology of TIVITA® Tissue work?

The TIVITA® tissue is an imaging spectroscopic measurement system based on imaging reflectance absorption spectroscopy. To measure the tissue parameters, the desired area is illuminated with broadband white light. The emitted light penetrates deep into the tissue, depending on the corresponding wavelength, and is partly scattered, absorbed and remitted. The amount of light that is back-scattered is ecomposed into its spectral components (approx. 100 wavelengths in the range of 500-1000 nm) by the TIVITA® Tissue system and recorded with a two-dimensional camera sensor. A complete spectrum in the visual (VIS) and near-infrared (NIR) spectral range is recorded for each pixel during the measurement process. In doing so, the different absorption spectra of the skin components are utilized, whereby their existence and proportion in the affected tissue can be demonstrated. Since the output spectrum of the light source is known, the absorbed light component can thereby be evaluated. Subsequent to the analysis of the absorption spectra, different medical parameters such as the oxygen saturation of the tissue StO_2 (oxygenation of the superficial layer), the NIR index (oxygen saturation of the deeper tissue layers with a penetration depth of 4-6 mm), hemoglobin and the water index can be determined. The parameter StO_2 (tissue oxygen saturation) is shown in% and shows which fraction of hemoglobin molecules is saturated with oxygen. The technology is thus classified into the field of tissue oximeters. In conventional systems, however, the tissue oxygen measurement (NIRS / VLS technology) is carried out predominantly with multispectral optical sensors or spectrometer systems directly on the tissue (e.g., skin). Hyperspectral Imaging (HSI) technology with the TIVITA® Tissue camera provides these measurement parameters without contact to the skin. Investigations with the hyperspectral camera system are also carried out contactless, non-invasive (no contrast agent necessary) and radiation-free.

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