THE USE OF THE LASER-DOPPLER METHOD IN SURGERY

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The assessment of microcirculation has diagnostic value in many fields of medicine. Microcirculatory examinations may also play a role in monitoring the progression of disease and the effects of treatments following surgery (1). Circulation disturbances in micro-vessels may pose a problem as this vascular bed is responsible for gas and metabolic exchange, as well as for the process of thermoregulation. Thus, microvascular dysfunction may impair the healing process.

It should be emphasized that in vivo studies of microcirculation are difficult to perform due to the very small size of vessels differentiated blood flow, and heterogeneous morphology in regards to the to the site of examination (2). With regard to the above mentioned conditions, routine clinical practice generally uses the evaluation of large vessels which, however, do not give any insight into the pathological processes taking place in the microcirculation.

Amongst the relatively small range of methods enabling study of microcirculation, those that are widely used in diagnostics are: capillaroscopy, video-capillaroscopy, thermography, and percutaneous oxygen pressure measurement (3). Despite the numerous advantages and practical applications of the above listed methods, they focus primarily on the microcirculatory morphological investigations or the registration of blood flow at rest. Due to the fact that ischemia is the cause of many pathologies and complications, the understand-ing and monitoring of mechanisms regulating microcirculatory blood flow seems to be very important (4).

Microcirculation in humans can be assessed routinely by non-invasive, laser-doppler techniques. The method enables the local registration of real-time blood perfusion in response to different stimuli. Modern scanners enable the monitoring of changes in perfusion in a given area of affected tissue, even without contact (5, 6).

THE LASER-DOPPLER METHOD IN THE EVALUATION OF MICROCIRCULATION

The basis of the laser-doppler method the emission of a monochromatic laser light, from red to infrared (wavelength ranging between 780 and 810 nm), into the tissue. The laser beam emitted by the probe is conducted by means of an optical fiber, 0.7 mm in diameter, to the surface of the tissue, and then propagates within the examined field. Photons are deflected by moving blood cells changing their frequency accordingly to the Doppler phenomenon. The returning light passes through a pair of optical fibers, both 0.7 mm in diameter, and are registered and analyzed by means of the photo detection system. The above-mentioned generates a voltage, which is directly proportionate to the velocity and number of migrating cells in a given area (2, 6). The de-
The use of the laser-doppler method in surgery

vice registers blood flow in a given tissue area using arbitrary perfusion units (PU).

The first-generation device that uses the above-described method is known as Laser Doppler Flowmetry (LDF). An important advantage of this technique is the possibility to monitor microcirculation flow in real-time, which very effectively evaluates the rapid changes occurring in the vascular field. The depth of penetration depends on the type of tissue being examined, e.g. penetration ranges from 1 mm in case of skin perfusion up to 6 mm in case of the intestinal wall (fig. 1). However, an important limitation of LDF consists in “point measurements”, that allow the evaluation of only a small volume of tissue (1 to 3 mm), which often results in the small representations and repeatability of measurements, especially in regard to the physiological heterogeneity of microcirculation (6, 7) (fig. 2).

A technical solution which allowed the improvement of measurement repeatability and spatial resolution was the development of a Laser Doppler Imaging Scanner (LDI). LDI enables perfusion imaging of a large tissue area (fig. 3). Additionally, it is also important to note that this investigation can be used in a surgical environment as it is a non-contact examination (8). LDI allows the imaging of small and large tissue areas, relative to the distance of the scanner from the given object. The essence of LDI action is the detection of the laser beam using a mirror, whose movement is controlled by motor leaps. The scattered and reflected radiation is focused on the photodiode and converted into an electrical signal, which in turn is processed by the computer. This method is limited in that measurements are not performed in real-time since the processing time depends on the size of the area under investigation and can range between several seconds and several minutes.

Assessment of microcirculation by laser-doppler techniques are usually performed after one-hour adaptation period at a constant temperature of 23°C±1°C, with normal humidity ranging between 50-75%. Before the examination, the assessed areas should be immobilized in order to minimize moving artifacts associated. With LDF, the probes register perfusion in a small tissue area (1 to 3 mm). While in LDI, the laser head should be placed 20 cm above the investigated area, which provides good spatial resolution and allows obtaining a perfusion maps of microcirculation.
THE USE OF LDF AND LDI IN SURGERY

Laser-Doppler flowmetry is widely used in a variety of surgical fields such as general surgery, vascular surgery, plastic surgery, and transplantation surgery. In general surgery, microcirculation monitoring after videoscopic lumbar sympathectomy in patients with primary Raynaud’s syndrome and hyperhidrosis enables the assessment of the efficacy of the surgical procedure (9). For many years, LDF has also been positively verified during amputation operations. Amputations should be, as far as is possible, tissue sparing in order to ensure the highest quality of life and enable limb prosthetic use. Thanks to LDF, one can precisely determine the best level of amputation intraoperatively, ensuring proper stump healing (10).

Monitoring of the gastrointestinal tract microcirculation may play a significant role, especially during small bowel resection procedures caused by ischemia. The evaluation of microcirculation enables the operator to precisely determine the level of incision and thus, helps spare the longest viable fragment of the small bowel possible, which aides preventing the development of short bowel syndrome (11). In the case of esophageal carcinoma resection, the above-mentioned monitoring allows for safe gastroesophageal anastomosis as well.

In investigations covering experimental surgery, LDF was used in case of acute pancreatitis in rats while determining microcirculation in the pancreas, liver, stomach, and kidneys. In diseases with multiorgan failure LDF was successfully used to monitor the progression of disturbances caused by SIRS (12).

The laser-doppler technique is also used in transplantation surgery cases (13). During organ transplantation graft reperfusion is subjectively evaluated by the surgeon. LDF enables more accurate and precise evaluation of vascular flow. The above-mentioned technique seems to be useful aide when undertaking difficult decisions, such as the need for early organ transplantation (14).

In plastic and reconstructive surgery, laser-doppler imaging scanners also show their utility by enabling early evaluation of microcirculatory disturbances, thus avoiding significant post-operative complications (15). Due to the procedure being noninvasive and a non-contact form of measurement, LDI may also be used to assess the degree of burn wounds (16, 17).

Laser perfusion scanners make it possible to evaluate the efficacy of vascular reconstructive procedures by means of tissue microperfusion imaging. In angiology, the laser-doppler technique can be used to monitor the effects of pharmacological treatment in case of chronic limb ischemia (18). LDI has also been successfully used in the evaluation of cerebral perfusion during vascular neurosurgery procedures (19).

DISCUSSION

The laser-doppler method has created new possibilities for non-invasive and relatively reproducible assessment of microcirculatory perfusion changes (20). Skin microcirculation is primarily used as a research model. This model allows the determination of the local microcirculation and blood flow changes in response to reactivity tests such as: PORH (post-occlusive reactive hyperemia), LTH (local thermal hyperemia), and acetylocholine and nitroprusside sodium iontophoresis. Microcirculatory investigations, aside from the possibility to study new mechanisms of physiological regulation, are regularly used in clinical practice (4, 8).

Despite the availability of many other methods, the assessment of microcirculation has recognized clinical value, such as capillaroscopy, video-capillaroscopy, and thermography, while the laser-doppler technique has found wide practical use, even in surgery. This is reflected by the number of new publications gathered in the PubMed system. In case of the laser-doppler techniques, the number of scientific publications from 1982 to date has increased nearly one hundred times (1982 – 4 publications, while in 2013 – 397). This trend however, is not observed in case of the remaining methods.

These non-invasive skin microcirculation examination techniques are usually performed under controlled conditions and results are based on qualitative assessment. The in vivo microcirculation assessment (provided by LD) enables the assessment of vascular function in the natural environment where one may observe the complex relationship between the nervous system, endothelium, and vascular smooth muscles. Such information has a direct impact on decision-making during surgery and
monitoring following the procedure. Therefore, this technique is widely recognized, in the fields of general, vascular, plastic, and transplantation surgery.

A major advantage of the LDF method is the fact that measurements are carried out in realtime. The device is used during organ transplantation procedures, intestinal resections, amputations, and vascular surgery. The disadvantage of laser doppler flowmetry was the spatial variability of microcirculation (flow differs depending on the area of investigation) (21, 22, 23).

Moreover, it is not always possible to maintain strict guidelines for the use of LDF when considering the operating room, which may affect the quality of measurements. Therefore, in the case of intraoperative investigations, special needle probes were introduced with laser scanners being most commonly used. The above-mentioned did not require contact during measurements. LDI enables the visualization of vasculature of a much wider area, being particularly used by plastic surgeons for the precise determination of the depth of the burn wound and monitoring of graft viability and process of wound healing.

The quality and reproducibility of results are influenced by such factors as surrounding temperature, accidental artifacts caused by patient or physician movement, gender, the position of the physician, and physical activity. Therefore, to obtain reliable results, it is necessary to use complicated and precise procedures.

Furthermore, the lack of methodology standardization and high device costs significantly limit the use of the laser-doppler method in everyday clinical practice (diagnostic purposes). The direct comparison of results is difficult due to the fact that the device is constructed differently by manufacturers.

CONCLUSIONS

Surgical interest in the laser-doppler method is continuously increasing. The non-invasive nature and reproducibility of the method allows the precise qualification of patients for surgery, the monitoring of their course, and evaluation of the effectiveness of treatment during the postoperative period. Despite this, it should be mentioned that due to high costs and lack of standardization of results interpretation, LDF and LDI are not routinely used during clinical practice.

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