

From COVID-19 to critical care: monitoring microvascular health at the bedside

ICFO's Medical Optics group develops a new multimodal system to monitor tissue oxygenation and blood flow, pushing forward non-invasive optical tools in critical care.

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Critically ill patients often experience impaired microvascular oxygenation and perfusion, which means that their bodies struggle to deliver oxygen to the smallest blood vessels. Persistent alterations in the microcirculation are strong predictors of organ failure and increased mortality. However, unlike standard intensive care monitoring, which focuses on global parameters such as blood pressure or arterial oxygen saturation, microvascular dysfunction can go unnoticed despite apparently stable vital signs.

In modern intensive care units, clinicians are required to make frequent and critical decisions, such as adjusting respiratory support, managing fluid resuscitation, and regulating drugs that affect blood pressure or sedation, often in patients with rapidly evolving

conditions. These interventions rely largely on global circulation and respiratory parameters, which may not fully capture alterations occurring at the microvascular level. As a result, early signs of impaired tissue perfusion and oxygenation can remain undetected, even when standard vital signs appear stable, highlighting the need for bedside tools that provide clinically useful information on microvascular function in real-time.

In that context, and building on years of methodological work, the ICFO Medical Optics group designed a practical and robust platform, specifically tailored for critical patients. ICU clinical use was explored in close collaboration with Dr Jaume Mesquida, intensivist at Hospital Universitari Parc Tauli and clinical researcher at the I3PT, specialised in acut hemodynamic monitoring. The system is fully automated and self-contained, allowing IC personnel to perform measurements autonomously and supporting routine, standardised us across patients, operators, and clinical settings

Overcoming technological limitations

One way to assess the microvascular function is to evaluate how well the blood flow and oxygenation recover after inducing a short period of blood flow restriction, known as reactive hyperemia. Over the past few decades, researchers have evaluated reactive hyperemia using various methods, including ultrasound, plethysmography, and near-infrared spectroscopy (NIRS).

NIRS is a non-invasive optical technique that uses light in the range of 650 to 950 nm to monitor the local microvascular blood oxygenation and blood volume. Over time, continuous-wave NIRS devices have become commercially available and are used in clinical settings to assess tissue oxygenation and metabolism. While clinicians recognise the prognostic value of these devices, they lack depth sensitivity and rely on relative measurements, limiting their ability to provide quantitative and reproducible information. In addition, measurement protocols are often not standardised. ?

In a recent article published in the**Journal of Biomedical Optics**, the team presented a new multimodal device that overcomes these limitations by integrating **time-domain near-infrared NIRS**, which offers enhanced depth sensitivity and accuracy compared to conventional devices, **with diffuse correlation spectroscopy**, which measures microvascular blood flow. When the measurements are combined with arterial oxygen saturation obtained from a standard pulse oximeter, the system allows direct, bedside estimation of baseline tissue oxygen metabolism, without the need for a provocative test.

A thorough clinical validation

Developed in the frame of the European research project VASCOVID, the new platform was validated through seven-month clinical measurements under real-world ICU conditions, accumulating more than 200 hours of usage across 150 sessions. Beyond basic performance, the team also evaluated system replication and independent operation.

i¿½All the data collected in the clinical studies will be useful to get information abo
t confounding effects and report reference values, which is important due to the hi
h heterogeneity of the ICU populationi¿½says ICREA **Prof. at ICFO Turgut Durduran**, leader of the group. i¿½Alongside our clinical partners from Parc Tauli, we are now focusing
n understanding if the combined oxygenation and flow signals are interpretable a
d meaningful under a wide range of clinical conditions in the ICUi¿½
? Further beyond the ICU validation, researchers and clinicians have been using the n
w devices as well as some slightly improved replicas, for the past two years, applying **twelve clinical protocols across more than 400 patients.** The team has developed ten identical devices that will be deployed in hospitals worldwide, enabling new hypotheses and laying the foundations for future studies. ?

The study demonstrates the high precision, stable performance, and reduced variability o
the device, supporting reliable microvascular assessment in clinical and research settings
This multimodal platform represents a significant step towards making microvascula
monitoring a practical component of routine critical care, helping clinicians to mak
efficient, timely, and informed decisions.