Optical sensing of mitochondrial NADH and microcirculatory function in critical care medicine

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Introduction

Intact mitochondrial function was identified as a critical factor in normal tissue activity. However, monitoring and evaluation of tissue cellular bioenergetics and microcirculatory function have not yet been integrated into monitoring systems of operating rooms and ICUs. Therefore we developed a unique biomedical device that provides real-time information on mitochondrial NADH redox state as well as microcirculatory blood flow and hemoglobin oxygenation. The mitochondrial redox state is measured by the fluorescence of NADH, microcirculatory blood flow by laser Doppler flowmetry and Hb oxygenation by the two wavelength reflectometry approach (1, 2). We hypothesized that during the development of cellular hypoxia blood flow redistribution mechanisms will protect the most vital organs (brain and heart) by increasing blood flow, while the less vital organs (GI tract, skin or urogenital system) will become hypoperfused and O_2 delivery will diminish. As a result of this mechanism the less vital organs will be the initial responders to O_2 imbalance and the last to recover after successful resuscitation..

Methods

In order to evaluate the viability of a less-vital organ we developed a three way Foley catheter that contains a fiberoptic probe in order to illuminate the internal side of the urethral wall. In order to perform small animal studies we developed a special probe inserted in a 3mm diameter PVC tube that was located in the small intestine. In few experiments we compared the responses of the brain to that of the intestine by IV injection of adrenaline. All data are collected and analyzed by a specifically developed software.

Results

In experimental animals (rats) a clear difference between brain and small intestine was found after sympathetic stimulation. In the brain a large increase in blood flow was recorded concomitantly with oxidation of NADH while a clear hypoperfusion and increase in NADH was found in the gut. The same difference between the brain and other less-vital organs (liver, kidney) under adrenaline injection was found as well (3). Preliminary large animal (pigs) studies and clinical studies suggest that our monitoring approach is practical in collecting data from the urethral wall.

Conclusions

Monitoring of mitochondrial NADH in combination with microcirculatory blood flow and Hb saturation may shed new light on body O_2 balance and the development of occult hypoperfusion state. In the near future we will conduct clinical testing of the device in critically ill patients.

References

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