

# StO<sub>2</sub> Sensor

A forum for trends and tissue oxygen monitoring in trauma and critical care

## Issue 2 – September 2005

**Welcome** to the second issue of *StO<sub>2</sub> Sensor*, a newsletter for the Trauma and Critical Care communities in the United States and Europe. Hutchinson Technology's BioMeasurement Division is very pleased to bring you this newsletter and the forum it provides.

## In this issue

- An Interview with Dr. Ari Leppäniemi
- Research Assistance
- StO<sub>2</sub> Science
- StO<sub>2</sub> Research Presentations
- StO<sub>2</sub> Research Publications

## Trauma Surgery Education and Delivery of Care in Finland: An Interview with Dr. Ari Leppäniemi

*Dr. Ari Leppäniemi, MD, shares his observations and views on trauma surgery education and trends in Finland. Dr. Leppäniemi is Chief of Emergency Surgery at the Helsinki University Hospital Meilahti in Finland.*

### **Would you please describe the educational preparation for trauma surgeons in Finland and other Scandinavian countries?**

Currently, no single educational system has been adopted by the European nations or within the Scandinavian countries. In Finland, a new general surgery specialty or program has been in place for several years. Like the other surgical main specialties, it begins with a three-year "common trunk" program in a central or district hospital during which every resident receives training in basic surgical techniques and emergency operations. This is followed

by three additional years of training at a university hospital in the respective main specialty. In the general surgery program at the Helsinki University this includes one year each of gastroenterological surgery, orthopedics and traumatology, and an elective year

in any surgical field. General surgery residents choosing the emergency surgery program receive training in emergency procedures of all key specialty areas, as well as some experience in surgical critical care.

One hundred hours of theoretical education and a national exam are part of all specialty programs.

### **Could you provide an update on the relatively new general surgery training program in the Helsinki University Hospital System?**

We created the program due to a Finnish legal change regarding surgical specialization that became effective in 1999. It is offered exclusively at the Helsinki University Medical School and offers residents flexibility so they can "tailor-make" their training. There are basically two "lines" from which to choose. In addition to the traditional "elective general surgery" line, another line of the new program focuses on emergency surgery and surgical critical care. The program includes rotations in almost all specialties and is designed to help residents gain experience in the life-and limb-saving surgery required in the first 24 hours of care. It also addresses pre-hospital emergency medicine and surgical critical care, which had been managed largely by anesthesiologists. Two major hospitals are participating: Meilahti Hospital (where I'm based) which provides training in visceral and vascular surgery and Töölö Hospital which provides musculoskeletal, plastic and neurosurgical training. Depending on the nature of the surgical emergency, ambulances will deliver the patient to



Dr. Ari Leppäniemi

## Dr. Ari Leppäniemi Interview cont.

one of these two hospitals. However, surgeons on night call from one hospital can be asked to go to other hospital to provide patient care. The two hospitals will be merging within five to seven years.

### ***Dr. Leppäniemi, what do you believe are the strengths and weaknesses of this approach for training trauma and emergency surgery specialists?***

The education program, overall, is in harmony with European Union requirements. It will guarantee a supply of well-trained surgeons for specialized elective surgery who will have increased acumen and experience with the procedures they

perform. However, the education system has weaknesses. It is expensive and leaves small hospitals unable to cover needed specialties for emergencies. Significant challenges also will be faced as improvements are made to the system.

One of these is the role of the general surgeon. Currently, only two of Finland's five university hospitals have a general surgery program, yet there is a marked need for surgical generalists, especially in day care surgery, emergency surgery and areas that do not have their own specialties, such as breast or endocrine surgery. The Finnish model needs to — and will — move towards a "hospitalist surgeon" who can handle 90 percent of emergency surgery cases and call upon specialists less frequently.

### ***What effects could increased specialization have on centralization of care?***

Because everyone is specializing in some area of medicine, we are heading towards the age of "one-organ surgery."

This leads to a challenge in organizing surgical emergency services. The more advanced emergency surgery must be centralized, which presents administrative and logistical concerns. These include incorporating adequate orthopedic, neurosurgical and interventional radiology services, as well as regionalization to three to seven centers and staffing them with sufficient hospitalists and specialists. Another issue would be transport of patients. Currently, depending on the severity of the trauma call, physicians are placed in helicopters and ambulances as needed. Ninety percent of these physicians are anesthesiologists who would handle cardiopulmonary emergencies. However, less resuscitation is being done in the field as "scoop and run" is gaining popularity. Instead, once the patient is at the hospital, a surgeon directs the resuscitation and patient management. We need to develop a good balance between centralizing care and keeping local hospitals active and close enough to the population in more remote areas. I think we need a basic network to take care of simpler surgical emergency services while more complex problems, and perhaps night surgery, would be done in bigger centers.

### ***What changes in the delivery of trauma and emergency care are you currently observing?***

Some of the changes we are observing were discussed by Miller and Richardson in their 1992 report and are also occurring in the United States. Approximately 90 percent of emergency surgery is performed for trauma cases. At the same time, trauma management has become largely non-operative. Essentially 100 percent of spleen and liver trauma used to be treated surgically but now perhaps

---

*Because everyone is specializing in some area of medicine, we are heading towards the age of "one-organ surgery."*

---

continued >

### **Dr. Ari Leppäniemi Interview cont.**

80 percent of cases are managed without operating. Knife wounds are now addressed using a defined protocol that favors non-operative management and only 50 percent of cases are treated surgically.

#### ***What types of trauma are still being treated surgically?***

Hip fractures from falls are being treated with surgery and the number of cases is increasing due to the aging population. Injuries sustained in high-speed motor vehicle accidents need surgical treatment in most cases. However, over the past 25 years, there has been a significant decline in the number of cases since cars are being built with better safety features and roadway design and speed control have improved.

#### ***What implications do these changes have for trauma surgeons who are currently in practice as well as those preparing to enter the field?***

Unlike the U.S. system in which trauma surgeons follow patients during post-surgical hospitalization, in Finland, surgeons involved in the initial treatment, while being on call, usually transfer hospital care of patients to other physicians. Surgeons are paid a fixed salary plus additional compensation based on active surgical in-house time and night calls. A new approach with emergency surgeon-lead multi-disciplinary teams managing the patient through the hospitalization period needs to be developed.

#### ***Dr. Leppäniemi, as you look to the future, what role do you see for general surgeons with expertise in both trauma and emergency surgery?***

A general surgeon with the ability to handle most life-and limb-saving procedures in the first 24 hours serves as a mentor and team leader who could synchronize the work of other specialists. That person could also be an ideal choice for developing and administering trauma and emergency surgical units in larger hospitals as well as being a planner for mass casualty situations.

---

## **Let Hutchinson Technology Assist Your Research**

*“Research is to see what everybody else has seen, and to think what nobody else has thought.” Albert Szent-Gyorgyi, Hungarian Biochemist, 1937 Nobel Prize for Medicine, 1893–1986.*

If you have thought of incorporating tissue oxygen saturation (StO<sub>2</sub>) into your research protocols, the Hutchinson Technology clinical research team would be happy to assist you. With more than 10 years of experience in near infrared spectroscopy (NIRS) and the study of tissue oxygen saturation, our clinical research team has a level of scientific understanding that researchers have come to rely upon.

Having received U.S. FDA 510(k) clearance in 2002, our system can be the focus of your clinical or laboratory investigations, or can provide critical data to amplify related studies.

#### **Free Trial Period**

HTI offers a free system trial. This enables you to test your protocol to ensure the metric provides the value you expect. HTI also offers rental and purchase options as well as on-site support.

#### **Please Contact Us**

To learn more, please call our Customer Service Representative at (800) 419-1007, or complete and return the business reply card in this newsletter. Additional product information is available at [www.htibiomeasurement.com](http://www.htibiomeasurement.com). We look forward to talking with you further.

---

For more information on StO<sub>2</sub>, visit our website at  
[www.htibiomeasurement.com](http://www.htibiomeasurement.com)

---

## StO<sub>2</sub> Science

### Hutchinson Technology's "Wide Gap" Second Derivative Algorithm For Near Infrared Spectroscopy Is Published In Peer-Reviewed Journal

The May/June 2005 publication of the *Journal of Biomedical Optics* includes a manuscript describing the research and application of the **InSpectra™** Tissue Spectrometer near-infrared spectroscopy technology using a simple continuous wave algorithm. The paper describes the validation of a "wide gap" 40 nanometer (nm) wavelength used to calculate the second derivative attenuation. **The StO<sub>2</sub> calibration to hemoglobin oxygen saturation showed superiority over predicate models by evidence that it was insensitive to the common confounding factors of total hemoglobin, optical path length, and optical scattering.**

#### Near Infrared Spectroscopy (NIRS)

NIRS relies on the relative transparency of living tissue to light in the 650 nm to 1000 nm wavelength range. *In vivo* NIRS instruments use reflectance probes to measure scattered light remitted at a distance of 20 mm to 50 mm from where the light emits into tissue.<sup>1</sup> Probe spacing (source-detector distance) influences light

penetration depth and traversed distance (optical path length) within the tissue.<sup>2</sup> Tissue spectrometers must compensate for the scattering of light by tissue and the overlapping absorbance spectra of various chromophores.

#### Superiority of the Second Derivative Algorithm

Unlike previous second derivative methods which focused primarily on measuring deoxyhemoglobin concentration, a wide gap 40 nm wavelength used to calculate the second derivative attenuation significantly improves sensitivity to

oxyhemoglobin absorption. When light penetrates tissue, the attenuation or reduction in energy is due to absorption and optical scattering. Using longer wavelengths of light allows the technology to penetrate deeper into tissue to obtain values for tissue oxygen delivery and oxygen saturation.

However, multiple scattering events occur in tissue when light enters, resulting in optical path lengths that vary with both tissue and absorption properties. In order to relate light signals to a measurement of hemoglobin or other chromophores, NIRS tissue spectrometers have to compensate for how this indeterminate and variable optical path length affects the measured light attenuation signal.

- Continuous wave spectrometers measure changes in the attenuation of 2 to 6 wavelengths of light using estimates for the increase in optical path length beyond probe spacing, known as the differential path length factor. Using these differential path length factors enables algorithms based on the Beer-Lambert Law to provide good estimates of changes in tissue deoxyhemoglobin and oxyhemoglobin concentration.

**Predicate second derivative models use equations from diffusion theory to derive an estimate of tissue absorption coefficient. All these methods yield apparent values for tissue chromophore quantification. However the literature lacks sufficient reference to cross validate or compare these methods.** The inherent weaknesses of predecessor methods are evidenced by the fact that:

- The mean value of resting hemoglobin oxygen saturation in tissue can vary between methods.

*The InSpectra™ Tissue Spectrometer system, manufactured by Hutchinson Technology Inc., is designed to provide a non-invasive method for measuring local hemoglobin oxygen saturation in tissue. The device is intended for use on peripheral skeletal muscle. Percent saturated oxygen (StO<sub>2</sub>) is a measure of hemoglobin oxygen saturation of blood contained in the volume of tissue illuminated by the near infrared light. The InSpectra™ Tissue Spectrometer is designed to display real time changes of the quantitative measure of StO<sub>2</sub>.*

continued >

## StO<sub>2</sub> Science cont.

- Direct comparisons sometimes (not always) give similar readings.
- Optical path length influences the measurement signal.
- Measurement errors result from approximations inherent in applying diffusion theory equations to heterogeneous tissue, because there is no known *in vivo* derived calibration set for actual tissue hemoglobin oxygen saturation or total hemoglobin.

### A New Approach

In research sponsored by Hutchinson Technology, Myers proposed an alternate approach to NIRS tissue chromophore quantification with the application of second derivative spectroscopy to multi-wavelength data. Second derivative spectroscopy has the advantage of removing both baseline offset and linear slope from optical density attenuation spectra. The importance of this is apparent when noted that shorter wavelength light has a smaller mean path between scattering events, which attributes to a higher scattering attenuation. This wavelength dependent scattering attenuation gradually decreases with increasing wavelength and can be approximated as being linear within a 650 to 900 nm wavelength region.<sup>3,4,5,6,7</sup>

HTI's "wide gap" 40 nm interval used to calculate the second derivative provides maximum sensitivity to oxyhemoglobin concentration and

results in fewer required measurement wavelengths. Myers' research demonstrated that in addition to the 40 nm wide gap proving maximum sensitivity to oxyhemoglobin, it also provided better measurement reproducibility. Fewer required measurement wavelengths allowed simplification of spectrometer design.

This wide gap 40 nm algorithm provides a scaled second derivative attenuation spectrum. The wide gap used contains spectral regions that are sensitive to both oxyhemoglobin and deoxyhemoglobin concentration and allows quantification of hemoglobin oxygen saturation with four wavelengths of 680, 720, 760 and 800 nm. The wide gap second derivative method also provides an empirical calibration relationship, which can be applied across a variety of tissues exhibiting different optical scattering properties. Using a measurement insensitive to optical scattering allows an *in vitro* calibration relationship to be utilized where the scattering properties of the simulated tissue could be dissimilar to *in vivo* tissue. At 720 nm, the scaled second derivative attenuation was correlated to *in vitro* hemoglobin oxygen saturation to generate a percent saturated oxygen (StO<sub>2</sub>) calibration curve. The StO<sub>2</sub> calibration curve was insensitive to the common confounding factors of total hemoglobin, optical path length and optical scattering.

- The wide gap second derivative technique does not require any solution to diffusion theory equations in order to derive its measurement. It merely requires a "one-time" empirical calibration, such as *in vitro* hemoglobin at known oxygen saturation levels. The result is an algorithm that is robust to heterogeneous tissue, as compared to algorithms that attempt calculated values of light scattering.

### Using The Wide Gap Second Derivative Algorithm in Medical Applications

This new approach to tissue chromophore quantification is incorporated in Hutchinson Technology's **InSpectra™** Tissue Spectrometer. The **InSpectra™** System is indicated for use in monitoring patients during circulatory or perfusion examinations of skeletal muscle, or when there is a suspicion of compromised circulation. The **InSpectra™** System is intended to non-invasively and continuously measure hemoglobin oxygen saturation in peripheral skeletal muscle. No contraindications are known. A non-invasive means of measuring oxygen in tissue will provide an important clinical tool in a variety of medical applications involving compromised perfusion.

- 
- 1 Delpy, D. T., and Cope, M. (1997). Quantification in tissue near-infrared spectroscopy. *Philos. Trans. R. Soc. London. Ser. B* 352, 647-648.
  - 2 Cui, W., Kumar, C., and Chance, B. (1991). Experimental study of migration depth for the photons measured at sample surface. *Proc SPIE*, 1431, 180-191.
  - 3 Franceschini, M. A., Gratton, E., Hueber, D., and Fantini, S. (1999). Near-infrared absorption and scattering spectra of tissues *in vivo*. *Proc. SPIE* 3597, 526-31.
  - 4 Anderson, R.R., and Parrish, J.A. (1981). The optics of human skin. *J. Invest. Dermatol.* 77(1), 13-19.
  - 5 Simpson, C. R., Kohl, M., Essenpreis, M., and Cope, M. (1998). Near-infrared optical properties of *ex vivo* human skin and subcutaneous tissues measured using the Monte Carlo inversion technique. *Phys. Med. Biol.* 43(9), 2465-2478.
  - 6 Matcher, S. J., Kirkpatrick, P., Nahid, K., Cope, M., and Delpy, D.T. (1995). Absolute quantification methods in tissue near infrared spectroscopy. *Proc. SPIE*, 2389, 486-495.
  - 7 Matcher, S. J. and Cooper, C. E. (1984). Absolute quantification of deoxyhaemoglobin concentration in tissue near infrared spectroscopy. *Phys Med Biol*, 39, 1295-1312.

## StO<sub>2</sub> Research Presentations

### Near-Infrared Spectroscopy in Patients with Severe Sepsis Correlates with Invasive Hemodynamic Measurements

Skarda DE, Taylor JH, Mulier KE, Myers DE, Beilman GJ. University of Minnesota.  
*Presented at the 2005 Surgical Infection Society Annual Meeting in Miami, FL*

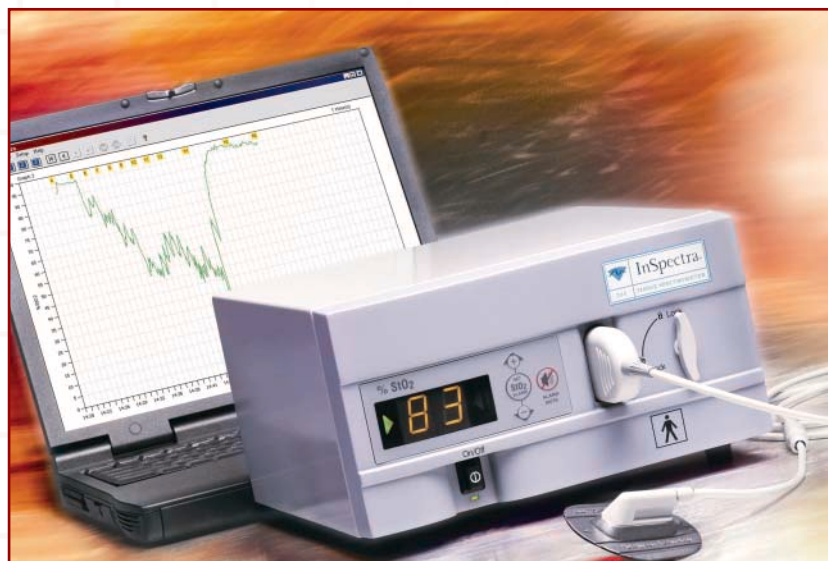
Clinicians are beginning to use near-infrared spectroscopy (NIRS) to monitor tissue perfusion in hemorrhagic shock. NIRS allows continuous non-invasive monitoring of tissue hemoglobin oxygen saturation (StO<sub>2</sub>), and total hemoglobin index (THI). The study hypothesized that StO<sub>2</sub> measurements in patients with severe sepsis would be associated with severity of illness and correlate with invasive hemodynamic measurements.

**Methods:** Measurements included mean arterial pressure (MAP), serum lactate, plasma hemoglobin, StO<sub>2</sub>, and THI in healthy volunteers (n = 9) and patients with severe sepsis in surgical

ICU (n = 10). NIRS data was collected using the **InSpectra™** system (Hutchinson Technology Inc.) probe placed on the thenar eminence with the patient in supine position. Septic patients were selected for the study who met criteria for severe sepsis, had a pulmonary artery catheter, and had family able to give written consent. Invasive hemodynamic parameters were collected three times daily simultaneous to NIR measurements, and once daily metabolic cart measurements were performed for three consecutive days. A poor outcome was defined by multi-organ dysfunction seven days after the development of severe sepsis, death within 28 days of severe sepsis, or both.

**Results:** Healthy volunteers and septic patients were similar with respect to age and sex. In septic patients, StO<sub>2</sub> correlated with mixed venous oxygen saturations (p<0.05). Of these patients, 4/10 developed poor outcome. Patients with poor outcomes had significant elevations of both oxygen delivery and StO<sub>2</sub> compared to patients who did not develop poor outcomes (p<0.05).

**Conclusions:** NIRS measurements of StO<sub>2</sub> correlated with invasively measured hemodynamic values in patients with severe sepsis. This suggests a role for StO<sub>2</sub> as a possible endpoint for resuscitation in severe sepsis.



The **InSpectra™** Tissue Spectrometer System measures tissue oxygenation (StO<sub>2</sub>) directly in muscle tissue at various depths using a contact probe that rests on or adheres to the skin.

### Comparisons Of Single And Multi-Probe NIRS Signals During Progressive Treadmill Exercise

Zheng J, Bacharach DW. St. Cloud State University, St. Cloud, MN.  
*Presented at the 2005 ACSM Annual Meeting in Indianapolis, IN*

Near infrared spectroscopy (NIRS) has become a popular technique for the non-invasive determination of local oxygen saturation and blood flow in

human skeletal muscle. NIRS light (700–1000 nm) penetrates superficial layers (skin, subcutaneous fat, skull, etc.) and is either absorbed by

continued >

## StO<sub>2</sub> Research Presentations cont.

chromophores (oxy- and deoxyhemoglobin and myoglobin) or scattered within the tissue. At 760 nm, hemoglobin and myoglobin occur in the deoxygenated form whereas at 850 nm, these chromophores occur primarily in the oxygenated state. The **InSpectra™** System manufactured by Hutchinson Technology (Hutchinson, MN) measures tissue hemoglobin oxygenation based on spectrophotometric principles that relate light absorption to chemical concentration. Using a wavelength band of 680–800 nm, a scaled second derivative absorbency value and an empirically derived calibration curve, this system provides a means to calculate the ratio of oxygenated hemoglobin to total hemoglobin expressed as percent hemoglobin saturation (%StO<sub>2</sub>).

The NIRO-300 (Hamamatsu Photonics, Hamamatsu City, Japan) utilizes continuous wavelength (CW) light in combination with spatially resolved spectroscopy (SRS) to measure changes in oxyhemoglobin/deoxyhemoglobin. In SRS, which uses CW light and a multi-distance approach, the slope of NIR light attenuation versus distance is measured at a point of the light input, from which the absolute ratio of O<sub>2</sub>Hb to the total hemoglobin can be determined, and hence average tissue oxygen saturation can be calculated using the photon diffusion

theory, which is expressed as a tissue oxygen index (TOI). The purpose of this study was to determine if any difference exists between two NIRS systems that use different methods of signal sampling during progressive treadmill exercise.

**Methods:** Ten healthy subjects (age = 24±1 yrs) exercised on a treadmill to voluntary fatigue using a progressive running protocol. Experimental measurements included %StO<sub>2</sub>, TOI, heart rate (HR), Rate of Perceived Exertion (RPE), and SpO<sub>2</sub> (arterial saturation from pulse oximetry). NIRS probes were placed on the medial and lateral heads of the right gastrocnemius muscle in a counter-balanced fashion. %StO<sub>2</sub> and TOI were continuously measured for at least 3 minutes supine, sitting, and standing before exercise, during exercise and at least 3 minutes standing after exercise. Arterial saturation (%SpO<sub>2</sub> from pulse oximetry), along with HR and RPE, was also measured at the end of each stage.

### Results:

1. HR and RPE increased with progressive stages of exercise.
2. %SpO<sub>2</sub> did not change throughout the test in 9 subjects. In one subject %SpO<sub>2</sub> dropped to ~71% at maximal exercise.
3. When reviewing a few seconds of oxygen saturation from each system, there was a greater fluctuation in TOI (±5%) while StO<sub>2</sub> was more stable (±1%); when reviewing changes throughout an

entire treadmill test, TOI had a small range from rest to maximal exercise (~20%), while %StO<sub>2</sub> was more robust (~60%).

4. Correlation between HR and StO<sub>2</sub> was  $r = 0.75$ ,  $p < 0.001$ . (Correlation between HR and TOI was  $r = 0.27$ ,  $p < 0.01$  (Fig. 2) and the correlation between StO<sub>2</sub> and TOI was  $r = 0.4$ ,  $p < 0.01$ . Although all correlations were significant, practical significance appears questionable for TOI.

**Conclusion:** The study determined whether two different devices for measuring near infrared spectroscopy produced similar oxygen saturation during progressive treadmill exercise. The NIRO-300 (TOI) provides subtle changes in tissue oxygen saturation, and the **InSpectra™** System (%StO<sub>2</sub>) is more sensitive to overall changes in oxygen saturation than NIRO-300. One possible reason for subtle changes in TOI might be the measurement position in the skeletal muscle since other studies on quadriceps oxygen saturation using NIRO-300 had a considerable range of TOI value (~40%). Therefore, there is a stronger relationship in metabolic parameters and oxygen saturation measured by the **InSpectra™** system. Although TOI is not practical to correlate heart rate in this study, the correlation between TOI and %StO<sub>2</sub> determines both of the NIRS systems are able to reflect the changes of oxygen saturation during exercise.

---

Note: The **InSpectra™** Tissue Spectrometer has not been cleared by the FDA for predicting, diagnosing, or assessing hemorrhagic shock or sepsis. The study results are currently being reviewed for publication and may have limitations. Additional clinical studies are required to establish the value of these measurements in assessing patient status related to any of these conditions.

Hutchinson Technology Incorporated's **InSpectra™** System, Model 325, is a non-invasive monitoring system that measures an approximated value of percent hemoglobin oxygen saturation (StO<sub>2</sub>). The **InSpectra™** System is indicated for use in monitoring patients during circulatory or perfusion examinations of skeletal muscle or when there is a suspicion of compromised circulation. The **InSpectra™** System is intended to non-invasively and continuously measure hemoglobin oxygen saturation in the upper extremity, shoulder, or lower extremity.



## StO<sub>2</sub> Research Publications

### **Can Near-Infrared Spectroscopy Identify the Severity of Shock in Trauma Patients?**

Crookes BA, Cohn SM, Bloch S, Amortegui J, Manning R, Li P, Proctor MS, Hallal A, Blackbourne LH, Benjamin R, Soffer D, Habib F, Schulman CI, Duncan R, Proctor KG. *Journal of Trauma*. April 2005; Vol 58(4); 806-816.

The purpose of this study was to establish the normal range of thenar muscle StO<sub>2</sub> in humans and the relationship between shock state and StO<sub>2</sub> in trauma patients. Decreased thenar muscle tissue oxygen saturation reflects the presence of severe hypoperfusion and near-infrared spectroscopy may be a novel method for rapidly and non-invasively assessing changes in tissue dysoxia.

### **Use of Near-infrared Spectroscopy in Early Determination of Irreversible Hemorrhagic Shock**

Taylor JH, Mullier KE, Myers DE, Beilman GJ. *Journal of Trauma*. June 2005; Vol 58(6); 1119-1125.

In field situations, patient triage may require early determination of patients progressing to irreversible shock. We investigated the utility of near-infrared spectroscopy (NIRS) in early detection of irreversible hemorrhagic shock. Non-invasive NIRS monitoring of leg and stomach StO<sub>2</sub> differentiates resuscitatable from unresuscitatable animals (pigs) after the initial resuscitative bolus. Use of this non-invasive tool may guide appropriate use of resuscitative fluids and has possible point-of-care applications.



**Hutchinson**  
TECHNOLOGY®  
*Advancing Better Therapies*

#### **Hutchinson Technology Incorporated** BioMeasurement Division

40 West Highland Park Drive NE  
Hutchinson, MN 55350-9784  
USA

tel: 800.419.1007  
tel: 320.587.1926  
fax: 320.587.1555

biom.usa@hti.htch.com  
www.htibiomeasurement.com

European Business Office  
IJsselburcht 3  
6825 BS Arnhem  
The Netherlands

tel: +31 26 365 3371  
fax: +31 26 365 3372

biom.eu@hti.htch.com  
www.inspectra.info