Evaluation of NIRS, Serum Biomarker and Muscle Damage in a Porcine Balloon Compression Model of Extremity Compartment Syndrome

Steven Budsberg¹, Michael Shuler², Brett Freedman³, Elizabeth Uhl¹, Megan Hansen¹.
¹University of Georgia, Athens, GA, USA, ²Dept. Upper Extremity and Micro Surgery, Athens Orthopedic Clinic, Athens, GA, USA, ³Landstuhl Regional Medical Center, Landstuhl, Germany.

Disclosures:

Introduction: Extremity compartment syndrome (ECS) can result in devastating consequences if missed or if treatment is delayed. Near Infrared Spectroscopy (NIRS) has been shown to provide continual, real time, non-invasive measurement of regional perfusion in an infusion model of ECS.¹ The objective of the present study was to assess and correlate NIRS, tibial intra-compartmental pressure (TICP), tibial intra-compartmental perfusion pressure (TIPP), serum markers of inflammation and muscle injury in a balloon compression model of extremity compartment syndrome (ECS).²

Methods: Six landrace swine were used in the study. Pigs were maintained on isoflurane and positioned in dorsal recumbency. NIRS sensors (Nonin Medical, Plymouth, MN) were placed on each leg with 1 cm of cranialateral compartment musculature proximal, and cranial/caudal to the sensor. Two 18-gauge needles were centered under the sensor on both limbs and used for direct pressure transducer measurement of compartmental pressure. After a period of equilibration, a balloon catheter was placed between the tibia and the cranial tibialis muscle in the test limb. The balloon was then inflated to 30 mm Hg over mean arterial pressure (MAP). This pressure was maintained for six hours. Continual time synchronized measurements of systemic blood pressure (systolic, diastolic, and mean arterial pressures, pulse rate, respiratory rate, compartmental pressures, and regional oximetry from the NIRS sensors) were collected during equilibration and every hour during balloon inflation. At 6 hours, the balloon was deflated and removed. Additional measurements were obtained at 5, 10, 15, 30, 45, and 60 minutes after deflation and then hourly for an additional 7 hours. At that time pigs were euthanized and the cranial tibial (CT) muscle was collected from both limbs for histopathological scoring of muscle damage. Serum was collected at each measurement time point for measurement of inflammatory biomarkers creatine kinase (CK), myoglobin, TNF-α, IL-1β, and IL-6. All pigs were euthanized at the end of the experiment. Data Analysis: A repeated measures ANOVA was used to test for differences in TICP, NIRS and TIPP measurements between and within test and control limbs at each time point. A repeated measures ANOVA was also used to compare CK, myoglobin, TNF-α, IL-1β, and IL-6 between time points. Multiple comparisons were adjusted using Tukey’s test. A Wilcoxon signed-rank test was used to compare muscle scores between test and control legs for proximal, middle, distal and average cross-sectional and longitudinal scores. Pearson’s correlations were calculated between muscle degeneration and edema and NIRS at the final measurement time.

Results: The model successfully created increases in TICP and decreases in TIPP consistent with ECS after balloon deflation. NIRS also detected significant changes in tissue oxygenation at all the same points (Figure 1). Specifically, the test limb TIPP significantly decreased from baseline during balloon inflation and at 15 minutes post deflation throughout the remainder of the study period. Test limb TICP significantly increased compared to baseline during balloon inflation and at 1 hour to 6 hours following deflation. NIRS measurements were significantly lower than baseline at balloon inflation and throughout the remainder of the study period. Myoglobin concentrations significantly increased over baseline at balloon deflation and remained high throughout the study period. CK concentrations significantly increased over baseline 2 hours post balloon deflation and remained high (Figure 2). No changes were seen in TNF-α, IL-1β, and IL-6 during the study. Significant muscle degeneration and edema were found in the test CT muscle (Figure 3). There was a significant correlation of muscle degeneration and edema with NIRS at the final measurement time. Significant correlation coefficients existed between degeneration and NIRS (r = -0.67), edema and NIRS (r = -0.60), and hemorrhage and NIRS (r = -0.67).
Figure 1

Figure Legend: TIPP and NIRS values throughout balloon inflation/deflation.
Figure 2

Figure legend: Serum CK concentrations throughout balloon inflation-deflation in the ICS compression model. All values from 3 hr post-deflation on are significantly higher than baseline.
**Discussion:** NIRS of the compartment provided a reliable, sensitive measure correlating to both an increase and decrease in TICP and TIPP in this porcine balloon model. CK and myoglobin significantly increased following balloon removal. Significant correlations between muscle degeneration, edema, hemorrhage and NIRS were found.

**Significance:**

**Acknowledgments:**

ORS 2014 Annual Meeting
Poster No: 1398