INTRODUCTION:
Acute compartment syndrome (ACS) can result in devastating consequences if missed or if treatment is delayed. Physicians currently rely on clinical exam findings to diagnose ACS; however this can be very difficult in the obtunded or unconscious patient. Near Infrared Spectroscopy (NIRS) has been proposed to provide continual, real time, non-invasive monitoring of traumatized extremities. Limited data exists regarding what constitutes a significant change in perfusion or where perfusion becomes compromised, and whether NIRS technology can provide useful noninvasive clinically relevant information. 1,2 Currently no studies have correlated NIRS values with perfusion pressures (diastolic pressure minus intra-compartment pressure). The aim of the study reported here was to correlate NIRS values and the tibial intra-compartmental perfusion pressure (TIPP) in a porcine model of acute compartment syndrome.

METHODS:
Sixteen landrace swine (48-68 kg) were used in the study (IACUC # A2010 1-012). Pigs were maintained on isoflurane with mechanical positive pressure ventilation. A circulating warm water pad maintained rectal body temperatures between 98 and 101 degrees Fahrenheit. A 20 gauge catheter was placed in an auricular vein for constant infusion of lactated ringer’s solution at 5 ml/kg/hr. Pigs were positioned in dorsal recumbency. Surgical cut downs exposed a median saphenous artery for direct arterial pressure measurement, and the right jugular and femoral venous catheters for direct arterial pressure measurement, and the right jugular and femoral vein for blood sampling of the test leg via 18 gauge catheters. Both tibia were cleaned with 4% chlorhexidine scrub and alcohol. NIRS sensors (Nonin Medical, Plymouth, MN) were placed on each leg with 1 cm of cranialolateral compartment musculature proximal, and cranial and caudal to the sensor. Four 18 gauge needles were centered on each side of the sensor on the test leg, and angled 20 degrees toward the center of the sensor. The proximal and distal needles were attached via a T-connection for infusion of 5% albumin to manually elevate the compartmental pressure at predetermined intervals. The cranial and caudal needles were used for direct pressure transducer measurement of compartmental pressure by averaging the values. A single 18 gauge needle was placed on the lateral aspect of the control leg sensor for direct pressure transducer measurement of compartmental pressure.

Continual time synchronized measurements of systemic blood pressure – systolic (SAP), diastolic (DAP), and mean pressures (MAP), pulse rate, respiratory rate, systemic pulse oximetry, body temperature, compartmental pressures (2 transducers on test leg and one on control leg), and regional oximetry from the NIRS sensors from each leg were collected. Once compartmental transducers were zeroed, TIPP of the test leg was increased in increments by albumin infusion. Measurements were taken at baseline (0 mm Hg) for 10 minutes, TIPP of 40 mm Hg for 5 minutes, TIPP of 30 mm Hg for 5 minutes, TIPP of 20 mm Hg for 5 minutes, TIPP of 10 mm Hg for 5 minutes, and TIPP of 0 mm Hg for 10 minutes, TIPP equal to MAP for 10 minutes, SAP for 10 minutes and SAP +10 mm Hg for ten minutes. At this time fasciotomies were performed and measurements taken for an additional 10 minutes. The first fasciotomy was performed by sharp incision caudolateral of the NIRS sensor from stifle to hock to a depth through all fascial layers of the muscular compartment. The second cranial fasciotomy was done in a similar manner along the cranialolateral aspect of the tibia. All pigs were euthanized at the end of the experiment. Total time of altered TIPP was 70 minutes. A repeated measures model that recognized multiple observations was used to test for differences in tibial intra-compartmental pressure (TICP), TIPP and NIRS values between test and control and time points. The full model included factors for group, time point and a group by time point interaction. Multiple comparisons were adjusted for using Tukey’s test. All hypothesis tests were 2-sided and the significance level was α = 0.05. Pearson’s correlations were calculated between TICP and NIRS measurements and between TIPP and NIRS.

RESULTS:
The model successfully created consistent, reproducible increases in TICP and decreases in TIPP. Significant increases in TICP between test and control limbs at all time points with the exception of TIPP of 40 mHg and at 5 and 10 minutes following fasciotomies were found (Figure 1). Concurrently, NIRS was able to detect significant changes in tissue oxygenation at all the same time points (Figure 1). Furthermore, significant increases in all test TICP measurements compared to baseline except for 10 minutes following fasciotomy were found. Similarly, significant decreases in NIRS values were found compared to baseline once the TIPP reached 20 mHg and did not return to baseline levels until 5 and 10 minutes after the fasciotomies. There was a significant negative correlation of TICP and NIRS measurements (r=0.79, p<0.0001). Figure 1

DISCUSSION:
NIRS of the compartment provided a reliable, sensitive measure correlating to both an increase and decrease in TICP and TIPP in this porcine tibial model. Further research is needed to determine at what NIRS reading that a fasciotomy may be indicated to prevent permanent tissue damage.

SIGNIFICANCE:
ACS diagnosis can be difficult in certain trauma patients. Our study provides data that establishes a correlation between NIRS measurement of hemoglobin oxygen saturation and TIPP.

REFERENCES: