Introduction: Acute compartment syndrome (ACS) is produced by elevated intramuscular pressure (IMP) leading to impaired perfusion of intracompartmental tissues. Clinical findings associated with ACS include six Ps: pressure, pain, paresthesia, paralysis, pink skin, and good distal pulse [1]. However, these findings are often more useful by their absence for excluding the diagnosis than they are when present. Direct measurement of IMP is useful as an adjunct in making the diagnosis for unclear and unreliable clinical presentations as may be encountered in children and unconscious patients. The current gold standard for detection of elevated IMP requires invasive pressure monitoring by insertion of a slit catheter or similar device directly into the muscle compartment at risk. The invasive method is accurate and reproducible, but is accompanied by pain and infection risk. The development of a fast, reliable, and non-invasive technique for measuring IMP at multiple locations within a compartment would improve diagnosis of ACS. Previously analog ultrasound technology was correlated with compartment pressure in humans with ACS [2]. The purpose of the present study was to test a new digital non-invasive ultrasound device, yet to be FDA approved, for measuring fascial displacement in a porcine model of ACS over a much greater range of IMPs. We hypothesize that fascial displacement is significantly greater at impaired perfusion pressures (PP) associated with ACS in the infused leg as compared to that in the contralateral, non-infused leg.

Materials and Methods: Model ACS was generated in 7 farm pigs in our IACUC approved protocol. The pigs were sedated, intubated, placed on a ventilator, and anesthetized. Dissection was then performed to gain access to the carotid arteries and a single intra-arterial catheter was inserted for invasive arterial blood pressure monitoring throughout the experiment. Slit catheters were inserted into the anterior compartment of each hind limb to monitor IMP continuously. An infusion catheter was inserted into the anterior compartment of the experimental limb and connected to an IV solution of bovine albumin (0.045%) in 0.9% NaCl. A ultrasound sensor was placed over the anterior compartment of both hind limbs. In each pig ACS was generated in the infused limb by adjusting the rate of infusion of the albumin solution to attain IMPs of 10 mmHg, 20 mmHg, 30 mm Hg, 40 mm Hg, 50 mm Hg, 60 mm Hg, 70 mm Hg, 80 mm Hg, 90 mm Hg, and 100 mm Hg. A two minute ultrasound recording of pulsatile fascial displacements was obtained at baseline and each IMP level. Fascial displacements were grouped by PP (mean arterial pressure – IMP from slit catheter) and analyzed using repeated measures ANOVA and contrast analysis. Mean arterial pressure (MAP) was 80 mmHg and ranged from 60 to 99 mmHg. PP was grouped in 10 mmHg increments, from -40 mmHg to 80 mmHg. Mean fascial displacements were calculated for each perfusion pressure group and all groups were compared for statistically significant differences using contrast analysis. A Tukey post-hoc analysis was performed between the infused and non-infused compartments for PP between 20 and 80 mmHg with α < 0.05.

Results: In this model of ACS in pigs, mean arterial pressure (MAP) was 80 mmHg and ranged from 60 to 99 mmHg. Slit catheter measurements of baseline IMP (mean ± SE) obtained in the infused and control compartments were 10.2 ± 2.2 mmHg and 5.9 ± 1.3 mmHg, respectively. Two-way repeated measures ANOVA yielded a significant interaction between infusion and PP (p = 0.03) for PPs ranging between -40 and 80 mmHg. Fascial displacement in the infused compartment at each PP increment was significantly greater than that in the control compartment for all PPs between -20 and 40 mmHg (contrast analysis, p < 0.014). Tukey's post-hoc analysis performed for PPs between 20 and 80 mmHg revealed significant differences.

Discussion: In this study we employ a quantitative and graded porcine ACS model by infusing an albumin solution and generating a wide range of IMPs and PPs. Fascial displacement in the infused compartments at clinically relevant PPs from -20 to 40 mmHg is significantly greater than that for the control compartments by contrast analysis, making this technique a potentially useful tool for non-invasive diagnosis of ACS. One limitation of the present study includes the use of an animal model of acute compartment syndrome. For example, the porcine hindlimb anterior compartment is smaller than human compartments. Values of MAP and IMP recorded in our animal model, however, are similar to values observed in humans. In summary, our study demonstrates the ability of a new digital PPLL ultrasound device for monitoring amplitudes of fascial displacement in the anterior compartment of a porcine model ACS. Fascial displacements in the infused compartment are significantly greater than those in the control compartment at clinically relevant PPs between -20 and 40 mmHg, making this ultrasound device a potentially-useful tool for non-invasive diagnosis of ACS.


Acknowledgements: Luna Innovations is gratefully acknowledged for supporting this study. Also supported by NIH Training Grant 2 T32 AR07484-22.