MAGNETIC RESONANCE IMAGING OF CENTRAL NERVOUS SYSTEM DECOMPRESSION SICKNESS IN SHEEP UNDERGOING HYPERBARIC EXPOSURE.

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Background:

We have previously demonstrated that oxygen pre-breathing before "drop-out" decompression reduces the risk of decompression sickness (DCS) in the UW sheep model[1]. However, little is known about the incidence and mechanisms of neurological injury in these models, or the effects of decompression strategies on ameliorating neurological DCS. We have undertaken magnetic resonance imaging (MRI) studies, including Diffusion Tensor Imaging (DTI) to define the incidence and mechanism of CNS injury in a sheep model of decompression sickness.

Materials and Methods:

Ten adult ewes (91.4 ± 9.2 SD kg) underwent dry chamber air exposure at 60 fsw (2.8 atm abs) for 24 hours, followed by varying durations (0, 15, and 180 minutes) of oxygen pre-breathe (88-92%) prior to "dropout" decompression at 30 feet/min (0.9 atm/min) to surface. Another two control animals were not exposed to the hyperbaric chamber. Six weeks after exposure, surviving animals were sacrificed and the spinal cords fixed in formalin. Using a Varian 4.7T MRI scanner, high resolution Diffusion Tensor Imaging was performed. Semi-automated regions of interest were used to delineate gray and white matter regions and DTI values were calculated and analyzed using histograms and laterality index.

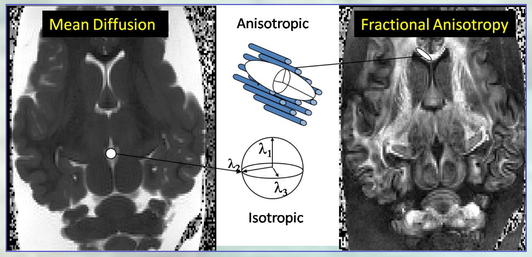

Figure 1 Diffusion tensor Imaging (DTI) is based on the 3 dimensional diffusion of water and allows visualization and quantification of tissue microstructural properties by indices of diffusion including fractional anisotropy (FA) and mean diffusion (MD). Images are shown of a fixed sheep brain to illustrate FA and MD maps and diffusion properties of brain tissues.

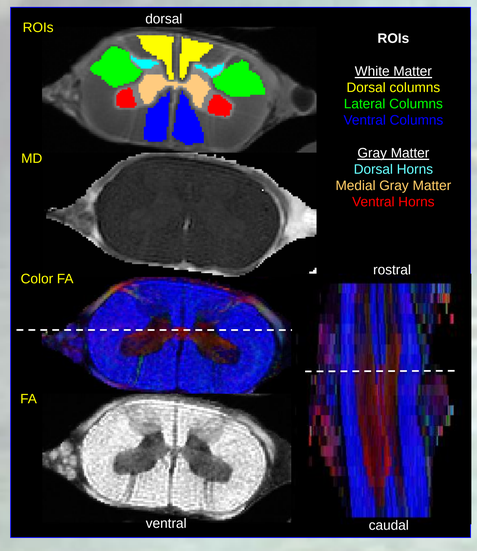

Figure 2 DTI of fixed sheep spinal cord including MD, FA and directional color FA maps (red: left-right, green: dorsal-ventral and blue: rostral-caudal axes). ROIs are shown for white and gray matter areas.

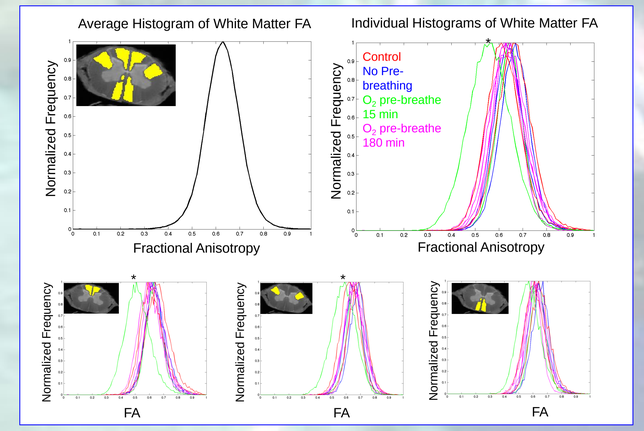

Figure 3 Histogram analysis of white matter FA from samples of different treatment paradigms indicate a shift toward lower FA for one sample from the 15 minute O_2 pre-breathing treatment group, however all sample histograms from the 180 minute O_2 pre-breathing group resemble the average.
* denotes a mean that is more than 2 standard deviations from the overall mean.

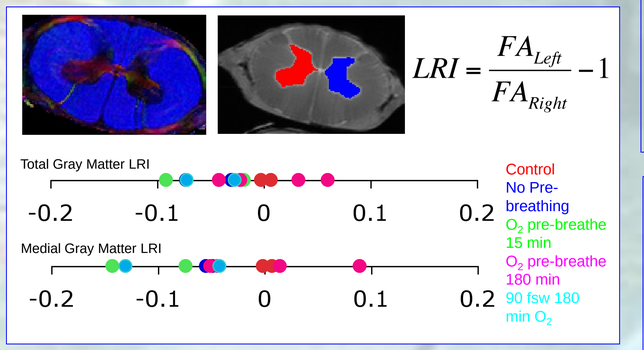

Figure 4 Laterality index (LRI) was calculated using ROIs from analogous regions in the left and right gray matter to determine lateralized reduction in gray matter FA (top). Results for laterality (bottom) indicate an increased deviation from zero (no laterality) for samples from sheep receiving minimal treatment. This difference was greatest in the medial regions of gray matter.

Results:

Decompression without O_2 pre-breathing resulted in 100% mortality, while all the O_2 pre-breathing animals survived the dive. T2 weighted MRI revealed no evidence of focal ischemia or hemorrhage in these animals.
Diffusion Tensor Imaging revealed two types of injury profiles:

- **White matter FA reduction** was evident in one of the 15min O_2 pre-breathing animals, but not any of the 180min O_2 pre-breathing animals.
- A **lateralized decrease in gray matter FA** that was greatest in a different 15min O_2 pre-breathing animal.

Discussion and Conclusions:

- Thus far we see no evidence of discreet spinal cord infarction as would occur with arterial gas embolism.
- O_2 pre-breathing may be CNS protective.
  - DTI values are abnormal in minimal intervention treatment
  - Values are normal for 180min O_2 pre-breathing treatment
- DTI biomarkers may identify spinal DCS injury.
  - White Matter: Lower FA may be an indicator of diffuse chronic injury
  - Gray matter: Lateralized decreases in FA suggest focal abnormalities.
- Future Directions for MRI of the sheep DCS model:
  - Characterize DTI patterns of injury in spinal cord and brain tissue
  - *In-vivo* imaging and histopathology
  - Investigate CNS effects of additional Dive scenarios including Deep Stop

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Selected Reference:

1. Sobakin AS, Wilson MA, Lehner CE, Dueland RT, Gendron-Fitzpatrick AP. *Oxygen pre-breathing decreases dysbaric diseases in UW sheep undergoing hyperbaric exposure*. Undersea Hyperb Med. 2008 Jan-Feb;35(1):61-7.