**Introduction/Background**

Premature and very low birthweight (VLBW) infants are susceptible to numerous injuries during, and after parturition. If these injuries are neurological in nature, they can result in long-term cognitive and motor skill deficiencies. Cerebral hemorrhaging is a disease that has disastrous consequences on preterm and VLBW infants, and the mechanism for this type of hemorrhaging is currently not known. Bleeding in the ventricle region of the brain is termed intraventricular hemorrhage (IVH) and occurs in 32% of infants with birth weights less than 1500 grams and born prior to 32 weeks gestation[1]; 75% of these will experience long-term neurological disabilities[2]. A lack of tissue structure of the cerebral vasculature in early stages of development is a possible underlying cause for such high occurrences of IVH[3,4,5]. Mechanical characterization of neonatal vasculature could show structural underdevelopment as the underlying cause of IVH and provide valuable insight into neonatal vascular development. We previously characterized the mechanical properties of whole umbilical cord arteries and found a correlation between vessel stiffness and gestational age[6]. Considerations of the helical structure of late term umbilical cord vessels prompted a revisit of the characterization of the vessels with altered testing methods. To negate the effects of the vessels’ tortuous structure on stiffness values, we tested axial and circumferential small strips of human umbilical cord artery at various gestational periods.

**Methods**

Umbilical Cord samples were obtained from Intermountain Medical Center in Murray, Utah following IRB procedures. Cords were grouped according to gestational time: 36-40 weeks, 31-35 weeks, 26-30 weeks or 25 weeks or less. Samples were transported in 0.9% NaCl and tested within 36 hours of parturition. 1.7 mm thick axial and circumferential strips (tT), of approximately 3-5 mm in length were cut from dissected arteries and mounted to our testing fixture with cyanoacrylate glue. A small ring was also cut from the dissected vessel and photographed with a microscopy digital camera to find tissue area. A visual resting length of the strips was acquired using a LabView program developed by our group. Specimens were preconditioned to 120% stretch through 7 cycles at 0.1 mm/sec velocity. At the end of the preconditioning cycles, the samples were distended to stretch values far beyond the resting length. A Transducer Techniques 2.5 lb load cell was used to measure the loading response. Images of this final distention were obtained with a high-resolution digital camera at 3 frames/sec.

Strip reference configurations were determined from force-displacement curves. The point in the force-displacement curve at which a noticeable increase in force from the initial baseline was observed was deemed the strip reference configuration. The image corresponding to this reference configuration was analyzed with Matlab imaging tools to obtain a reference length (λr) and strip wall thickness (tws). First Piola-Kirchhoff stresses (S) were calculated from reference configuration values and instantaneous force values (F) as: 

\[ S = \frac{F}{tTwS} \]

Tissue stiffness values were obtained from linear regions of the stress-strain curves, and total tissue area of vessel cross sections were obtained using Matlab imaging tools. Binary images of the outer and inner boundaries of the vessel cross-section were taken using the built-in function ‘roipoly’, and a mm/pixel conversion factor used to find...
the tissue area. Statistical significance between the group stiffness values and total tissue area was determined by a paired student t-test.

**Results/Discussion**

Axial stiffness values obtained from linear regression analysis of specimen stress-stretch curves showed a stiffness value of 140.9 ± 25.5 kPa/stretch for 36-40 week gestation (n=8), 138.8 ± 30.3 kPa/stretch for 31-35 week gestation (n=8), 129.48 ± 32.3 kPa/stretch for 26-30 week gestation (n=5), and 185.5 ± 32.1 kPa/stretch for 25 week or less gestation (n=3). Circumferential Stiffness values obtained through the same method showed stiffness values of 55.5 ± 23.9 kPa/stretch for 36-40 week gestation, 42.8 ± 13.2 kPa/stretch for 31-35 week gestation, 59.9 ± 10.7 kPa/stretch for 26-30 week gestation, and 42.6 ± 5.1 kPa/stretch for 25 week or less gestation. There was no statistical significance difference between any group for the axial and circumferential stiffnesses (p>0.1). Tissue areas for each gestational group were calculated as 3.82 ± 0.41 mm² for 36-40 week gestation, 2.73 ± 0.38 mm² for 31-35 week gestation, 2.50 ± 0.30 mm² for 26-30 week gestation and 1.28 ± 0.32 mm² for 25 weeks or less gestation. There was a statistically significance difference between the 36-40 and 26-30 and 25 or less week groups (p=0.043, p=0.006 respectively), the 31-35 week and 25 week or less groups (p=0.028), and the 26-30 and 25 week or less groups (p=0.041).

**Discussion**

The observed lack of correlation between stiffness values and gestational age indicates that the properties of umbilical cord artery do not change with age. This was surprising since vessels from older neonates were noticeably stiffer during dissection, but this was apparently due to the measured increase in dimensions rather than stiffness. These observations suggest that the correlative change previously found by our group on whole umbilical cord arteries was influenced by the increase in vessel helicity with age. While tissue properties apparently do not change, the dramatic change in tissue area over the last few weeks of gestation may explain why premature infants are more susceptible to IVH, since lower tissue areas to support the same physiological pressures would lead to higher stress values. Nevertheless, it is not currently known whether changes in the mechanical characteristics of umbilical arteries with age are reflective of those that may occur in the cerebral vessels.

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**References**