Using EIT to determine the role of gestational age on lung volume response during aeration at birth – A feasibility study

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Abstract: Electrical impedance tomography (EIT) measurements were used to study the first inflation of life in five lambs of different gestational ages. An exponential curve has previously been shown to describe the inflation process. Shorter inflation times were found in term lambs, whilst longer inflation times were calculated for preterm and extremely preterm lambs.

1 Introduction

Lung aeration is the first process the newly born lung needs to achieve at birth if the transition from in-utero life is to be successful. As the fetal lung is fluid-filled, the first inflations often need to be longer and of higher pressure to drive fluid reabsorption. A sustained inflation (SI) has been advocated as a method of augmenting lung aeration at birth. Lung behaviour during a SI is dependent on the SI pressure, duration and intrinsic lung mechanics. Mathematically, the resistance and compliance of the respiratory system (lung mechanics) will influence the time needed to achieve aeration as these parameters determine the time constant of the lung (τ), a measure of the time required to reach steady state lung volume (5τ). Gestational age is an indicator of the developmental status of the lung at birth, an important factor in the mechanical state of the lung. Presently, clinicians have no method of knowing lung volume, resistance or compliance in real-time at the bedside, hampering meaningful clinical techniques. Recently, we showed that EIT could be used to display the volumetric behaviour of the newly born lung at birth, particularly during the early aeration process. The aim of this study was to investigate the relationship between gestational age (GA) and time to reach lung volume stability (T_{stable}) during a SI.

2 Methods

The study protocol was approved by the Ethics Committee of the Murdoch Children's Research Institute, Melbourne Australia. A 40 cmH_2O SI was applied to lambs in five GA groups, representing equivalent GA for term, 32-34 week preterm, preterm (27-29 week), extremely preterm (25 week or less) and pre-viability (20-22 week) GA in humans. EIT measurements were performed with a modified EIT Pioneer Set (Swisstom AG, Switzerland). A special lamb interface was made of an elastic band carrying 32 contact pads made of gold plated pin arrays, (Figure 1). A standard electrically non-conductive ultrasound gel was used to reduce the impedance between these pins and the skin. Each of the arrays was connected via a cable to the active SensorBelt. The SI was applied until 10 s after visual volume stability (V_{stable}), or for 180 s maximum. To describe the mechanical status of the respiratory system we fitted an exponential curve to the impedance signal using Matlab (MathWorks, USA). The time constant (τ) was calculated to describe the inflation time and was estimated whenever the goodness of fit R^2 exceeded 0.9. Complete data for 8-10 lambs/gestational age group will be presented at meeting.

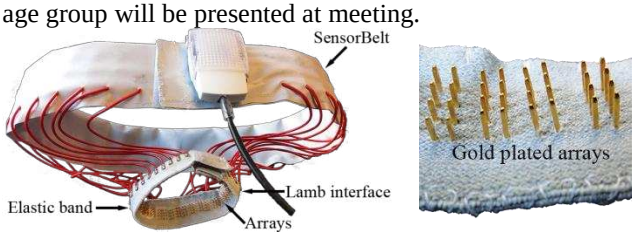
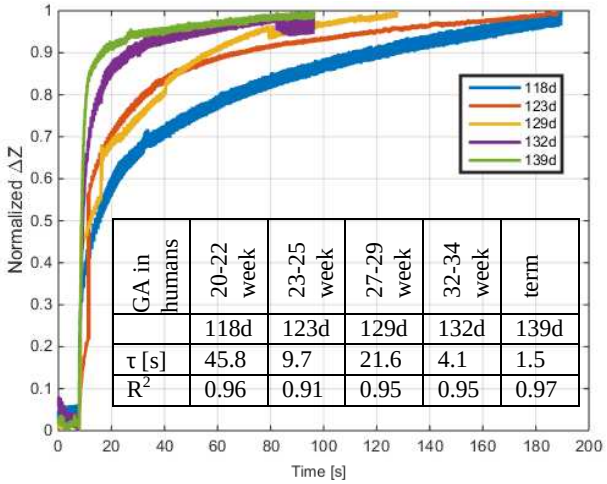


Figure 1: Lamb interface, consisting of an elastic band, 32 gold plated arrays and SensorBelt wrapped in a tarpaulin

3 Results

Figure 2 depicts five inflation curves, calculated as the relative impedance change over the EIT images. The smallest τ value of 1.5 s was estimated for the 139 day old lamb, and the highest τ of 45.8 s for the 118 day old lamb.



GA in humans	20-22 week	23-25 week	27-29 week	32-34 week	term
	118d	123d	129d	132d	139d
τ [s]	45.8	9.7	21.6	4.1	1.5
R^2	0.96	0.91	0.95	0.95	0.97

Figure 2: Five representative inflation curves for different gestational ages. The table shows the estimated τ values.

4 Conclusions and Outlook

The time to achieve aeration was estimated using the time constant τ. τ and therefore time to reach lung volume stability (T_{stable}) is shorter for term then for preterm and pre-viability lambs. In this feasibility study we estimated the τ only in 5 different preterm lambs with various gestational ages. Furthermore, we looked only at the global inflation curve and not at local ventilation distribution. In the future we should study more lambs and analyse the EIT images also on a local basis.