Modifications to Innocor gas analyzer increases accuracy of functional residual capacity measurement by multiple breath washout of SF6 in an infant lung model

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ABSTRACT

Background

The Innocor gas analyzer offers advantages over current technologies for Multiple Breath Washout (MBW) measurements in terms of cost, size and SF6 signal resolution. It has previously been modified for use in older children and adults, but remains untested in children <5yrs old and may be unsuitable due to prolonged gas signal rise time (165ms) and large equipment dead space (>2ml/kg).

Methods

Using a mechanical model to mimic infant lung parameters, multiple breath washouts (MBW) of 0.2% SF6 were performed before and after novel hardware and calibration alterations. The lung model was set with a tidal volume of 50ml, rate 40/min and FRC of 219ml, approximately equivalent to a 6-8 month old infant. Prior to analysis the gas signal was aligned with the flow reading to compensate for flow gas delay.

Results

See table 1

Conclusions

Without further modification, there is significant error in the integration of gas and flow signals. Modification to reduce gas analyser rise time greatly reduces the error in FRC calculation. In principle, this demonstrates the accuracy of the modified Innocor gas analyser for measurement of FRC and ventilation heterogeneity in younger children, with the potential for future in-vivo clinical studies.

BACKGROUND

We have previously demonstrated the use of a novel gas analyser (Innocor, Innovision) for Multiple Breath Washout (MBW) measurements for assessment of ventilation heterogeneity in adults and older children (≥5yrs). Current standards for MBW in young children require low equipment deadspace, linear flowmeter, fast analyser rise time (10-90% rise time ≤100milliseconds (ms)), accurate signal alignment and compensation for lost sample flow gas.

The standard Innocor gas analyser may have too slow a rise time to measure expired gas concentration in young children with fast respiratory rates and low tidal volumes. Prior to in-vivo comparison studies, we assessed the accuracy of functional residual capacity (FRC) measurements using a mechanical lung model and a modified gas analyser.

METHODS

The Innocor gas analyser setup was altered by bypassing an internal analysis step and improving sample tubing connections to shorten the 10-90% rise time. We initially compared washouts using the lung model before and after modification to assess the error between expected and measured FRC. Taking into account flow gas delay and lost gas because of high sample flow rate (2ml/s), we conducted a series of lung model washouts altering tidal volume and FRC to reflect a variety of infant parameters.

We used a simple mechanical lung model (courtesy of Inselspital, Bern, Switzerland). This consists of a plastic water tank with variable FRC (figure 1) and motorised syringe with a measurable tidal volume (Vt).

Figure 1

Error was assessed by comparing measured FRC with expected (%). A t-test compared mean FRC results, with Bland-Altmann analysis to assess evidence of systematic error.

RESULTS

Comparing the Innocor before and after gas analyser modifications, FRC was greatly overestimated due to slow analyser response. (Table 1)

Table 1

Measurement	Before modification	After modification
SF_6 10-90% rise time	165(ms)	97(ms)
Flow gas delay	1496(ms)	450(ms)
Gas sample flow rate	120 (ml/s)	120 (ml/s)
Expected FRC	219(ml)	219(ml)
Mean(SD) measured FRC	260.7(3.27) (ml)	221.6(2.74) (ml)
Mean(SD) error in FRC	**19.03 (1.49) (%)**	**1.18 (2.25) (%)**

Over a subsequent series of 7 experiments, conducted with a respiratory rate of 50-60/min and variable tidal volume (28 and 58mls) and FRC (98-162ml), there was no significant difference between the expected and measured mean(SD) FRC (129.52 (24.8) vs. 128.81 (24.08), p=0.88). The mean(SD) error in FRC calculation (expected-measured) did not differ significantly from zero (0.46(1.87)%, p=0.08). Mean(SD) error in volume was 0.71(2.32)ml, [range -3.57 to 5.74]. (Table 2)

Table 2

	Lung model parameters		No of repeats	Mean(SD) measured FRC (ml)	Mean(SD) Error (%)
	Vt (ml)	FRC (ml)			
1	28	98	8	98.30 (3.52)	**-0.31 (3.59)**
2	28	114	6	113.11 (2.15)	**0.78 (1.88)**
3	28	142.5	6	141.92 (1.94)	**0.40 (1.36)**
4	58	101	6	100.91 (0.71)	**0.09 (0.70)**
5	58	118	6	118.06 (0.87)	**-0.06 (0.74)**
6	58	139.5	6	138.32 (2.41)	**0.009 (0.55)**
7	58	162	14	159.83 (2.62)	**1.34 (1.62)**

Variability was increased in washouts conducted with the smaller tidal volume setting (p<0.01) however mean (SD) % errors were not significantly different between these 2 groups (0.23(2.53) vs. (0.60(1.33) p=0.5). Bland-Altmann analysis shows no clear influence of size of FRC on accuracy of measurement. (figure 2)

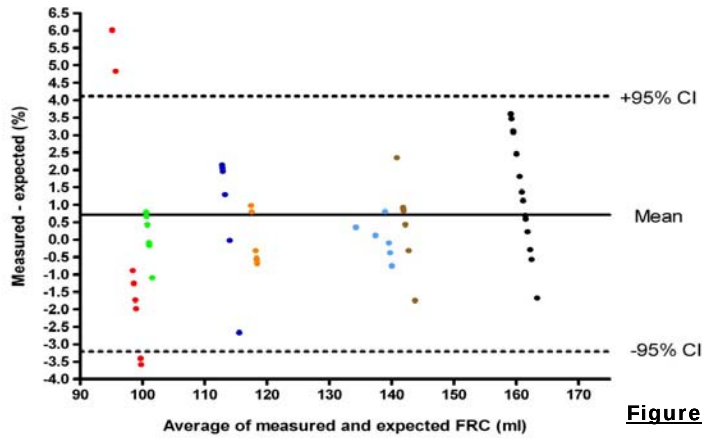

Figure 2

DISCUSSION

- **Unaltered, the Innocor device shows unacceptable error in FRC calculation using infant parameters in a lung model**
- **After improving the gas analyser response, however, FRC was measured accurately in an infant sized lung model.**
- **This study shows potential suitability of the Innocor device for MBW in infants, in preparation for future in-vivo device comparison studies**

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