

## SHORT REPORT

## Nasal continuous positive airway pressure: does bubbling improve gas exchange?

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In a randomised crossover trial, 26 babies, treated with Hudson prong continuous positive airway pressure (CPAP) from a bubbling bottle, received vigorous, high amplitude, or slow bubbling for 30 minutes. Pulse oximetry, transcutaneous carbon dioxide, and respiratory rate were recorded. The bubbling rates had no effect on carbon dioxide, oxygenation, or respiratory rate.

Nasal continuous positive airway pressure (CPAP) is an effective mode of respiratory support for neonates used in many nurseries.<sup>1</sup> It can be delivered in several different ways. One technique uses short binasal prongs—for example, Hudson prongs—where the pressure in the device is generated by a continuous flow of gas past the nasal prongs with the distal end placed a set depth under water.<sup>2</sup> As the gas flows through the system, it bubbles out underwater (fig 1). It has been suggested that oscillations in the pressure, due to bubbling, contribute to gas exchange by delivering low amplitude, high frequency oscillations to the lungs.<sup>3</sup> If true, this simple, inexpensive system would be a useful method of improving the effectiveness of nasal CPAP.

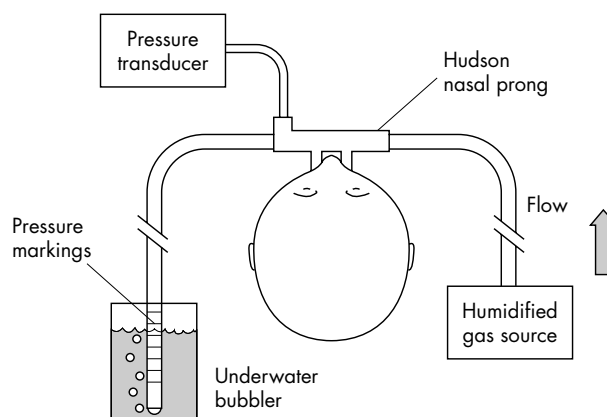
This study aimed to determine whether the pressure oscillations caused by bubbling affect transcutaneous carbon dioxide ( $TcCO_2$ ), transcutaneous oxygen ( $TcPO_2$ ), oxygen saturation ( $SpO_2$ ), heart rate, and respiratory rate.

## METHODS

This study is based on two concepts. Firstly, the vigorousness of underwater bubbling changes as flow through the CPAP system is altered. With high flow, bubbling is very vigorous with a high pressure amplitude. Flow can be reduced to a level where bubbling almost stops, but pressure is maintained with the meniscus still at the bottom of the underwater tube. Secondly, high frequency oscillation improves the removal of carbon dioxide from lungs and blood.<sup>4</sup>  $TcCO_2$  is easily measured and is closely related to arterial carbon dioxide ( $Paco_2$ ) over short time periods.<sup>5</sup>

We decided to exploit these concepts to investigate whether bubbling that was vigorous, with a high amplitude, or slow influenced a baby's gas exchange.

A convenience sample of stable preterm babies treated with bubble nasal CPAP (Fisher & Paykel Healthcare, Auckland, New Zealand) using Hudson prongs (Hudson Respiratory Care Inc, Temecula, California, USA) was studied. They were randomised, using sealed envelopes, to start on either vigorous, high amplitude, or slow bubbling. Slow bubbling was achieved by lowering the gas flow to the point when the bubbling "just" occurred so that the pressure was maintained with the gas/water meniscus at the end of the underwater tube. The vigorous, high amplitude bubbling was obtained by increasing the gas flow through the system by 3 litres/min above the flow required to obtain the lowest possible



**Figure 1** Diagram of "Bubbly Bottle" nasal continuous positive airway pressure (CPAP) system.

bubbling. Babies were studied for 30 minutes, and then crossed over to the alternative level of bubbling. During this time, the inspired oxygen and gas flow rate were not changed and the baby was not handled. The Royal Women's Hospital Research and Ethics Committees approved the study.

The nasal CPAP was measured from a side port on the prongs using a low range transducer (Sensym; Sentechnics, Puchheim, Germany; range 0–13 cm  $H_2O$ ). A transcutaneous monitor measured carbon dioxide and oxygen, and a pulse oximeter measured  $SpO_2$  and heart rate. Respiration rate was measured using the Graseby monitor (Graseby Medical Ltd, Watford, Hertfordshire, UK). Signals from these devices were recorded at 100 Hz using the Spectra physiological recording system (Grove Medical Ltd, Hampton, TW12 2EG, UK). The median value for each signal was calculated over each 10 seconds and recorded as a trend during the study. The last 15 minutes of each 30 minute recording was analysed to provide the most stable signal and allow washout of any effects from the previous flow rate.<sup>4</sup>

The study of 26 babies was sufficient to detect a difference of 3.0 mm Hg (0.39 kPa) in  $Paco_2$  with 80% power, if the SD of the difference was 5.0 mm Hg (0.65 kPa), derived from previous data.

## RESULTS

Twenty six babies were studied. Their median gestational age was 27 weeks (range 24–32), birth weight 1033 g (range 604–1980). The nasal CPAP was 6 cm  $H_2O$  (range 5–9). The baseline gas flow rate was 6 litres/min (range 5–9), and the inspired oxygen 21% (range 21–30).

**Abbreviations:** CPAP, continuous positive airway pressure;  $Paco_2$ , arterial carbon dioxide;  $SpO_2$ , oxygen saturation;  $TcCO_2$ , transcutaneous carbon dioxide concentration;  $TcPO_2$ , transcutaneous oxygen

**Table 1** Effect of bubbling rate on TcCO<sub>2</sub>, TcPO<sub>2</sub>, SpO<sub>2</sub>, heart rate, and respiratory rate

	Vigorous, high amplitude bubbling	Slow bubbling	p Value
CPAP (cm H <sub>2</sub> O)	5.98 (1.3)	5.28 (1.2)	<0.001
TcCO <sub>2</sub> (mm Hg)	50 (17)	51 (18)	0.30
TcPO <sub>2</sub> (mm Hg)	70 (18)	69 (17)	0.27
SpO <sub>2</sub> (%)	95 (4)	95 (4)	0.67
Heart rate (beats/min)	154 (10)	156 (9)	0.47
Respiratory rate (breaths/min)	44 (15)	43 (16)	0.66

Values are mean (SD).

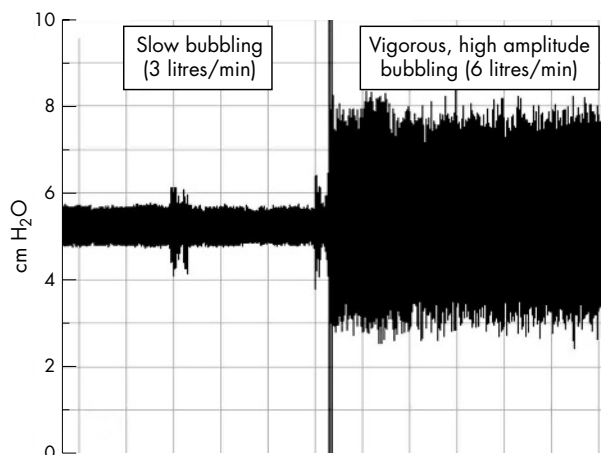
Table 1 shows the results obtained during vigorous, high amplitude bubbling and slow bubbling. There was no effect of bubbling rate on TcCO<sub>2</sub>, TcPO<sub>2</sub>, SpO<sub>2</sub>, heart rate, or respiratory rate. The correlation coefficient for TcCO<sub>2</sub> between the two bubbling rates was 0.936.

Despite the fact that we were very careful to not change the CPAP pressure between the different bubbling regimens, there was a slightly lower pressure with slower bubbling (table 1). Figure 2 shows an example of the pressure amplitude at the device during vigorous, high amplitude and slow bubbling. For all episodes, the median (interquartile range) was 2.7 cm H<sub>2</sub>O (2.5–4.0) for slow and 6 cm H<sub>2</sub>O (4.6 to 7.1) for vigorous, high amplitude bubbling.

## CONCLUSIONS

This study has shown that, after changing from vigorous, high amplitude to slow bubbling for 30 minutes there was no difference between TcCO<sub>2</sub>, SpO<sub>2</sub>, heart rate, or respiratory rate. The lack of effect on TcCO<sub>2</sub> and SpO<sub>2</sub> is similar to the results of Lee *et al.*,<sup>3</sup> who did a crossover study of bubble CPAP, compared with CPAP from a ventilator, through an endotracheal tube. Although they saw a small reduction in respiratory rate, and minute volume, which we could not measure with nasal CPAP. This may be because the oscillation amplitude at the device was relatively small, at about 5 cm H<sub>2</sub>O even with vigorous, high amplitude bubbling. This is about 10% of the pressure amplitude applied to an endotracheal tube during high frequency ventilation. Once transmitted to the alveoli, this pressure difference is unlikely to have much effect on PaCO<sub>2</sub>.

There was a small but significant difference in the CPAP prong pressure between vigorous and low bubbling. This had no effect on the TcCO<sub>2</sub> or oxygenation. We realised this was due to the effect of the bubble (just over 1 cm in diameter) on the end of the underwater tube. With vigorous bubbling there was a bubble present all the time, but with slow bubbling it was intermittent. In summary, we found no evidence to support the suggestion that pressure



**Figure 2** A recording, at 100Hz and displayed at 1 cm/s, of the pressure recorded at the nasal continuous positive airway pressure device during slow bubbling and vigorous, high amplitude bubbling. The y axis shows pressure in cm H<sub>2</sub>O.

oscillations during Bubble Bottle CPAP improve gas exchange.

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