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Effect of interface dead space on the time taken to achieve changes in set FiO_2 during T-piece ventilation: is face mask the optimal interface for neonatal stabilisation?

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ABSTRACT

Background T-piece is recommended for respiratory support during neonatal stabilisation. Bench studies have shown a delay >30 s in achieving changes in fraction of inspired oxygen (FiO₂) at the airway when using the T-piece. Using a face mask adds dead space (DS) to the patient airway. We hypothesised that adding face mask to T-piece systems adversely affects the time required for a change in FiO₂ to reach the patient.

Methods Neopuff (Fisher and Paykel, Auckland, New Zealand) and rPAP (Inspiration Healthcare, Croydon, UK) were used to ventilate a test lung. DS equivalent to neonatal face masks was added between the T-piece and test lung. Additionally, rPAP was tested with nasal prongs. Time course for change in FiO₂ to be achieved at the airway was measured for increase (0.3–0.6) and decrease (1.0–0.5) in FiO₂. Primary outcome was time to reach FiO₂+/–0.05 of the set target. One-way analysis of variance was used to compare mean time to reach the primary outcome between different DS volumes.

Results In all experiments, the mean time to reach the primary outcome was significantly shorter for rPAP with prongs compared with Neopuff and rPAP with face mask DS (p<0.001). The largest observed difference occurred when testing a decrease in FiO₂ with 10 mL tidal volume (TV) without leakage (18.3 s for rPAP with prongs vs 153.4 s for Neopuff with face mask DS). The shortest observed time was 13.3 s when increasing FiO₂ with 10 mL TV with prongs with leakage and the longest time was 172.7 s when decreasing FiO₂ with 4 mL TV and added face mask DS without leak.

Conclusion There was a delay in achieving changes in oxygen delivery at the airway during simulated ventilation attributable to the mask volume. This delay was greatly reduced when using nasal prongs as an interface. This should be examined in clinical trials.

While most newborn infants breathe spontaneously

at birth,¹ many require respiratory support to estab-

lish regular breathing.² This is more common in

preterm infants and reaches 100% for the smallest

preterm infants. Positive pressure ventilation (PPV)

is delivered with devices such as conventional

and variable flow T-pieces and self-inflating and

flow-inflating bags.³ During stabilisation, supple-

mental oxygen is adjusted to maintain the desired

INTRODUCTION

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WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous bench studies have shown a delay in achieving changes in fraction of inspired oxygen (FiO₂) at the airway when using the Tpiece for positive pressure ventilation.

WHAT THIS STUDY ADDS

⇒ We found that the delay in changes of FiO₂ to reach the patient's airway during simulated ventilation is largely related to the interface dead space (DS) added to the respiratory circuit. This delay can be greatly reduced by using nasal prongs as the interface. The differences in mean time between different DS volumes ranged from twofold to eightfold.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These results raise questions about whether or not the face mask is the optimal interface for neonatal stabilisation.

oxygen saturation (SpO₂) based on recommended targets.^{4 5} Both hypoxia and hyperoxia can be potentially harmful⁶ and recommendations for initial oxygen concentration during neonatal stabilisation have changed considerably during the last 20 years.^{7 8}

Previous studies have shown clinically important delays (>30s) in the time required for changes in fraction of inspired oxygen (FiO₂) at the blender to reach the patient's airway in simulated PPV tested with T-piece devices.^{9 10} Those studies focused on different gas flow rates and leakages but no reason-able explanation was identified as a cause for this delay. The use of face masks during neonatal stabi-lication is well-established ¹¹ However, providing lisation is well-established.¹¹ However, providing PPV with a face mask can be challenging and ventilation can be compromised by leaks and airway obstruction.^{12 13} Using a face mask as the interface substantially increases dead space (DS) outside the patient's airway. Nasal prongs are an alternative interface with very low DS. We hypothesised that the added DS of the airway interface (mask or prongs) would significantly affect the time taken for changes in FiO, at the blender to reach the patient's airway.



Figure 1 The equipment setup used for the experiment. Fresh gas flow was set to 10 litres per minute. FiO_2 was adjusted with a blender. Dead space was added by connecting straight cylinders to the Neopuff and rPAP. The respiratory system was connected to an O_2 sensor and directly to a 50 mL Dräger Bellows test lung. Tests were performed at two levels of tidal volumes which were altered by applying or removing clamps to the test lung. Measurements were done with and without leaks. FiO_2 , fraction of inspired oxygen.

METHODS

The experimental setup is shown in figure 1. The primary outcome was time to reach a FiO₂ 0.05 from the set target. For the two starting points, FiO₂ 0.30 and 1.0, this was the time to reach FiO₂ of 0.55. The FiO₂ 0.05 was similar to the 5% margin between the two sensors used by Dekker et al.⁹ The respiratory support systems tested were Neopuff (Fisher and Paykel, Auckland, New Zealand) and rPAP (Inspiration Healthcare, Croydon, UK). The DS of the face mask was simulated by connecting straight 15 mm connectors to the T-piece. The inner space of Laerdal face masks (Laerdal Global Health, Stavanger, Norway) size 00 and 0 was measured by injecting water into the masks. The volume was 18 mL for size 00 and 31 mL for size 0. To make the simulation more clinically relevant, we decreased the estimated added mask DS by 5 mL for each mask on the basis that parts of the face will protrude into the face mask and compression of the face mask for seal may reduce the volume. The DS added was 13 mL and 26 mL to represent the volume of the size 00 and 0 masks respectively. The medium short binasal prongs used with the rPAP had an estimated volume of less than 1 mL. The respiratory support device and added interface DS/ rPAP prongs were connected leak-free to a custom-built threedimensional printed connector for the O₂ sensor (5 mL DS) and this was connected directly to a 50 mL Dräger Bellows MP20050 (Dräger, Lübeck, Germany). (online supplemental figure 1). There was no humidification circuit.

To simulate clinical problems with leakage during mask ventilation, the tests were performed both with and without leakage. Leakage between the resuscitation system and the oxygen sensor was generated through a 0.80*50 mm steel needle (21G Sterican, Braun, Melsungen, Germany) that could be turned on using an intravenous line valve. Tidal volumes (TVs) and leaks were measured by a respiratory function monitor (RFM), Monivent Neo100 (Monivent, Gothenburg, Sweden). With the leak activated, the relative leak for 10 mL TV was 29.9% (SD 1.8, for 12 inflations) and for 4.0 mL 47.5% (SD 5.8, 12 inflations). The absolute leakage was the same for both TVs. The Monivent connector piece was removed before the experiments were started to avoid introducing DS to the circuit.

All tests were performed using PPV at 60 breaths per minute with a peak inspiratory pressure (PIP) of $24 \text{ cm H}_2\text{O}$ and positive end-expiratory pressure (PEP) of $6 \text{ cm H}_2\text{O}$. Fresh gas flow was set to 10.0 L/min. All flows and pressures were calibrated using Fluke VT650 Gas Flow Analyser (Fluke, Washington, USA). Tests were performed at two levels of TVs which were altered by applying or removing clamps to the test lung to restrict movement and reduce compliance. The experiments were performed at 4 mL and 10 mL TV. These volumes represent the TV used to ventilate infants of appropriate weight for Laerdal face mask sizes 00 and 0, delivering 6 mL/kg per inflation for infants weighing 750g and 1750g respectively. The 13 mL DS was used for the 4 mL TV and 26 mL for the 10 mL TV. The less clinically

Table 1 Time until reaching FiO₂ 0.05 from the set target when decreasing FiO₂ from 1.0 to 0.5 and increasing from 0.3 to 0.6. One-way ANOVA for comparison. * Post hoc test Bonferroni

							One-way ANOV Mean differenc	A e (p value*)	
FiO ₂ change	Leak	Tidal volume	System	Dead space	Mean time sec		rPAP mask	Neopuff mask	rPAP prongs
1.0->0.5	Yes	4 mL	rPAP	13 mL	66.7	One-way ANOVA	NA	2.9 (<0.001)	34.4 (<0.001)
			Neopuff	13 mL	69.6		2.9 (<0.001)	NA	37.3 (>0.001)
			rPAP	Prongs	32.3		34.4 (<0.001)	37.3 (>0.001)	NA
		10 mL	rPAP	26 mL	83.0	One-way ANOVA	NA	4.1 (<0.001)	64.6 (<0.001)
			Neopuff	26 mL	78.9		4.1 (<0.001)	NA	60.5 (<0.001)
			rPAP	Prongs	18.3		64.6 (<0.001)	60.5 (<0.001)	NA
	No	4 mL	rPAP	13 mL	154.6	One-way ANOVA	NA	18.1 (<0.001)	121.3 (<0.001)
			Neopuff	13 mL	172.7		18.1 (<0.001)	NA	139.4 (<0.001)
			rPAP	Prongs	33.3		121.3 (<0.001)	139.4 (<0.001)	NA
		10 mL	rPAP	26 mL	143.8	One-way ANOVA	NA	9.6 (<0.001)	125.5 (<0.001)
			Neopuff	26 mL	153.4		9.6 (<0.001)	NA	135.1 (<0.001)
			rPAP	Prongs	18.3		125.5 (<0.001)	135.1 (<0.001)	NA
0.3–>0.6	Yes	4 mL	rPAP	13 mL	47.1	One-way ANOVA	NA	4.3 (<0.001)	23.3 (<0.001)
			Neopuff	13 mL	51.4		4.3 (<0.001)	NA	27.6) (<0.001)
			rPAP	Prongs	23.8		23.3 (<0.001)	27.6<0.001)	NA
		10 mL	rPAP	26 mL	56.2	One-way ANOVA	NA	0.7 (0.01)	42.9 (<0.001)
			Neopuff	26 mL	55.5		0.7 (0.01)	NA	42.2 (<0.001)
			rPAP	Prongs	13.3		42.9 (<0.001)	42.2 (<0.001)	NA
	No	4 mL	rPAP	13 mL	113.1	One-way ANOVA	NA	24.5 (<0.001)	88.1<0.001)
			Neopuff	13 mL	137.6		24.5 (<0.001)	NA	112.6 (<0.001)
			rPAP	Prongs	25.0		88.1 (<0.001)	112.6 (<0.001)	NA
		10 mL	rPAP	26 mL	103.7	One-way ANOVA	NA	11.9 (<0.001)	88.9 (<0.001)
			Neopuff	26 mL	115.6		11.9 (<0.001)	NA	100.8 (<0.001)
			rPAP	Prongs	14.8		88.9 (<0.001)	100.8 (<0.001)	NA
			£ :						

ANOVA, analysis of variance; FiO₂, fraction of inspired oxygen.

relevant combinations (13 mL DS with 10 mL TV and 26 mL DS with 4 mL) are available as supplement (online supplemental table 1).

 ${\rm FiO}_2$ was adjusted from 0.30 to 0.60 and from 1.00 to 0.50. ${\rm FiO}_2$ was adjusted manually using a blender and the time was set to zero when ${\rm FiO}_2$ deviated from baseline at an oxygen sensor positioned after the blender. ${\rm FiO}_2$ was measured using chemical sensors (R-17MED, Teledyne Analytical Instruments, California, USA). Data was collected until equilibrium was reached at the patient interface or a maximum of 3 min. Data was acquired using NI NI-9205 and LabVIEW 2015 (National Instruments, Austin, Texas, USA) at 100 Hz.

Each experiment was repeated three times to ensure a low variance of the measuring method. Data were compiled and analysed in SPSS (IBM, Armonk, New York, USA). One-way analysis of variance (ANOVA) was used to compare means in seconds to reach FiO₂ 0.55 for all combinations of TV, presence of a leak or not and upwards and downwards titration of oxygen. This resulted in eight ANOVA tests. Post hoc comparisons to reveal within group difference were done using Bonferroni. Assumptions were checked with normal probability plots and the assumption of equality of variance was tested with Levene's test. Statistical significance was set to p<0.05.

RESULTS

Mean time to reach FiO_2 within 0.05 of the set target was significantly shorter for rPAP with prongs compared with Neopuff and rPAP with higher DSs representing facemask volumes. This was seen in all measurements, in both set TVs and with or without

leakage (table 1). The largest difference was found when testing the decrease in FiO_2 with 10 mL TV without leakage where it took 18.3 s for rPAP with prongs compared with 153.4 s for Neopuff with face mask DS (p<0.001, 95% CI 134.4 to 135.7) (table 1). This difference was mainly related to the interface DS and not the type of resuscitation device.

There was a delay of >10 s in reaching the set oxygen concentration at the patient interface in every measurement (table 1, figures 2 and 3). Comparisons between different DS volumes, for both TVs, both T-piece devices, with and without leakage, were all statistically significant, p = <0.001, in one-way ANOVA, post hoc analysis with Bonferroni. Statistical analyses and 95% CI are available as a supplement (online supplemental tables 2,3).

DISCUSSION

This bench study shows that with current equipment used for neonatal stabilisation at birth there is a substantial time delay between when FiO_2 is adjusted at the blender and when the new intended FiO_2 is achieved at the patient interface. This is particularly prolonged with the system DS of a commonly used face mask interface and much reduced with a low DS nasal prong interface. Our results indicate that during PPV in the smallest infants, when changing the O_2 concentration at the blender from 30% to 60%, the concentration may reach 40% first after 30s and 50% after almost 1.5 min to only come close to the target concentration of 60% nearly 3 min after adjustment. The same is likely to apply for downward titration from 100% to 50% where the O_2 concentration may be at 80% 30 s after changes made at the blender and at 60% after approximately 2 min. Two previous

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Figure 2 Oxygen measured at the patient interface for the first 90s after adjustments from FiO, 1.0 to 0.5, downward titration and from FiO, 0.3 to 0.6, upward titration. On the left simulations with tidal volume 4 mL and dead space 13 mL: On the right simulations with tidal volume 10 mL and dead space 26 mL. Orange line; rPAP with prongs (<1 mL dead space). Blue line; rPAP with 13 mL and 26 mL added dead space. Green line; Neopuff with 13 mL and 26 mL added dead space. Measurements with leaks. FiO₂, fraction of inspired oxygen.

studies identified a time lag in oxygen adjustments^{8 9} but did not measure the additional substantial effect of the mask DS in the set-up. These time delays are clinically important because they are a lot longer than clinicians manually titrating FiO₂ against SpO₂ or automated oxygen adjustment systems would allow between FiO_2 changes.^{9 14} These time delays may explain the observation that clinicians are frequently undershooting and later overshooting the target SpO2 in the delivery room. This may result in unnecessary oxygen exposure which in turn may contribute to hyperoxia in the first few minutes of life. This may also explain why many preterm infants are not able to achieve SpO, of 80% at 5 min after birth. SpO₂<80% at 5 min is associated with death

and severe intraventricular hemorrhage (IVH) in preterm infants <32 weeks gestational age (GA).¹⁵ The results also highlight the potential value of further clinical studies comparing different interfaces for respiratory support during initial stabilisation.

The reason we opted to use the time to reach a FiO, 0.05 from the set target as the primary outcome is that a change in FiO, over time is exponential in our setup. That means that the final few percent of change takes a long time with the majority of change occurring earlier. This is also in harmony with methods used earlier.9

In a study from 2017, Hishikawa et al reported delayed oxygen titration during face mask CPAP in term infants. Their



Figure 3 Oxygen measured at the patient interface for the first 90s after adjustments from FiO, 1.0 to 0.50, downward titration and from FiO, 0.3 to 0.6, upward titration. On the left simulations with tidal volume 4 mL and added dead space 13 mL: On the right simulations with tidal volume 10 mL and added dead space 26 mL. Orange line; rPAP with prongs (<1 mL dead space). Blue line; rPAP with 13 mL and 26 mL added dead space. Green line; Neopuff with 13 mL and 26 mL added dead space. Measurements without leaks. FiO., fraction of inspired oxygen.

explanation was that due to DS in the face mask, ventilation was less efficient. When leaks were added to their model by making holes in the face mask, oxygen titration time was shorter.¹⁶ Similar results were reported by Dekker et al where leaks reduced the time needed to achieve the desired FiO, after adjustments using the T-piece system during PPV.9 This concurs with our results on the shorter time needed when leaks were introduced in the model compared with measurements without leaks. Studies on PPV with face mask have shown that leakage is common and is often very large.^{12 13} However, with the increasing use of RFM during stabilisation the users get feedback on the leak in real time which leads to less leakage.¹⁷ This facilitates stable PEEP and the

establishment of functional residual capacity (FRC). However, reduced leaks will increase the delay of accurate oxygen delivery to the patient after adjustments.

The ratio between DS and TV (DS/TV) in mechanically ventilated preterm infants has been shown to be around 0.4-0.8.¹⁸ Placing a face mask on the infant during stabilisation adds DS volume to the anatomical DS. The DS of the neonatal face mask greatly exceeds the anatomical DS making the DS/TV ratio during face mask ventilation for the infants unfavourable. The smallest infants with respiratory distress syndrome (RDS) and non-compliant lungs will have a reduced TV before surfactant is given. FRC will also be low initially and will then gradually increase. All of these factors may influence oxygen delivery after adjustments.

In all the experiments performed, we used ventilation rates of 60 with an inspiratory to expiratory (I:E) ratio of 1:1 and a PEEP of 6 cm H_2O . If lower inflation rates were used, which are included in some international guidelines,⁴ the oxygen adjustment time may be longer. The delay in change in FiO₂ due to DS will also apply when providing PEEP/CPAP to a spontaneously breathing infant with a face mask. The delay could be different compared with the presented PPV results depending on spontaneous respiratory rate, lower mask leakage and wash out of DS. Furthermore, the titration frequency and increments will affect the oxygen concentration at the airway level. All of the above should be investigated in future research, preferably in clinical settings.

Limitations

This study reflects the delay observed in vitro. These results need to be confirmed in a clinical study. The added DS in our respiratory circuit model was a straight cylinder and not in the face mask shape. Different types and brands of face masks will have different volumes. However, the experiment was only designed to show the relationship between added DS and TV and the effect that this has on oxygen delivery time after adjustments. In the clinical setting leakage, inflation rate, I:E ratio, TV, PEEP, glottic closure, intermittent spontaneous breathing and FRC will be variable and this could not be accounted for in our lab settings.

Conclusion

There is a substantial delay in the time taken for changes in FiO₂ made at the blender to reach the patient's airway during simulated ventilation when face mask DS is added to the respiratory circuit used for neonatal stabilisation. This should be recognised in guidelines and research protocols. Using nasal interfaces with low DS might be more appropriate for infants to minimise the risk for hypo-oxygenation and hyper-oxygenation during initial stabilisation.

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Contributors KG: Study design, data collection, data and statistical analysis, manuscript writing and review. BJS, EEF, VK: Study design, manuscript writing and review. TD: Study design, data collection, equipment development, manuscript writing and review. SD: Study design, manuscript writing and review. Study guarantor.

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Competing interests TD is one of the designers of the original rPAP respiratory support system.

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Supplemental Figure 1: Illustration of the T-connector (A) used for oxygen sensor (B) and the bellows (C). Compared to standard oxygen cell connectors the internal volume was reduced and a participating wall (D) diverts flow to the sensor (blue dashed line in section view to the right). This was to reduce the dead space and the response time of the oxygen meassurements. STEP files for 3D printing can be requested from the corresponding author. The leak was connected before (E) the participating wall.



Supplemental material

Table S-1: Results from measurements with less clinically relevant combinations of mask size and tidal volume.

O2 start	Leak	Tidal volume	Dead space	System	Sec (mean)	95% CI	SD
100 %	Yes	4 ml	26 ml	rPAP	70.6	70.5-70.8	3.4
			26 ml	neopuff	76.4	76.3-76-6	3.9
		10 ml	13 ml	rPAP	58.3	58.0-58.8	4.6
			13 ml	neopuff	63.7	63.5-63.9	4.6
	No	4 ml	26 ml	rPAP	*		
			26 ml	neopuff	*		
		10 ml	13 ml	rPAP	72.4	72.2-72.5	3.8
			13 ml	neopuff	86.0	85.8-86.2	4.3
30 %	Yes	4 ml	26 ml	rPAP	51.6	51.5-51.8	3.5
			26 ml	neopuff	55.5	55.4-55.7	3.7
		10 ml	13 ml	rPAP	40.5	40.3-40.6	3.3
			13 ml	neopuff	44.2	44.0-44.3	3.3
	No	4 ml	26 ml	rPAP	189.4	188.8-189.9	0.7
			26 ml	neopuff	*		
		10 ml	13 ml	rPAP	53.7	53.5-53.9	3.6
			13 ml	neopuff	61.9	61.8-62.1	3.9

Supplement table 1 (S-1): Time until 0.05 +/- from target O2 concentration when decreasing FiO2 from 1.0 to 0.5 and when incresing FiO2 from 0.3 to 0.6. *Never reached 0.05 from target during the 240 seconds of measurements.

Table S-2 shows mean FiO_2 measured at the patient interface 15, 30, 45, 60, 90 and 180 seconds after FiO_2 adjustment at the blender, according to the added dead-space, tidal volume and presence or absence of leak.

	Mean FiO₂ at time interval									
Leak	тν	Dead- space	System	FiO2 changes	15 sec	30 sec	45 sec	60 sec	90 sec	180 sec
	4 mL	Prongs	rPAP	1.00->0.5	.63	.56	.53	.52	.51	
		13 mL	rPAP	1.00->0.5	.85	.78	.73	.68	.62	.54
		13 mL	Neopuff	1.00->0.5	.89	.81	.76	.71	.65	.55
	10 mL	Prongs	rPAP	1.00->0.5	.57	.51	.50	.50	.50	
		26 mL	rPAP	1.00->0.5	.87	.79	.73	.68	.61	.53
No		26 mL	Neopuff	1.00->0.5	.88	.80	.74	.69	.62	.53
leak	4 mL	Prongs	rPAP	0.3->0.6	.52	.56	.58	.59	.60	
		13 mL	rPAP	0.3->0.6	.39	.43	.47	.49	.53	.58
		13 mL	Neopuff	0.3->0.6	.37	.41	.45	.47	.51	.57
	10 mL	Prongs	rPAP	0.3->0.6	.55	.59	.60	.60	.60	
		26 mL	rPAP	0.3->0.6	.38	.43	.47	.50	.54	.59
		26 mL	Neopuff	0.3->0.6	.37	.42	.46	.49	.53	.58
	4 mL	Prongs	rPAP	1.00->0.5	.62	.55	.53	.51	.50	
		13 mL	rPAP	1.00->0.5	.73	.65	.59	.56	.53	.50
		13 mL	Neopuff	1.00->0.5	.75	.65	.60	.57	.53	.50
	10 mL	Prongs	rPAP	1.00->0.5	.57	.52	.50	.50	.50	
		26 mL	rPAP	1.00->0.5	.80	.70	.63	.59	.54	.51
With		26 mL	Neopuff	1.00->0.5	.79	.69	.63	.58	.54	.50
leak	4 mL	Prongs	rPAP	0.3->0.6	.52	.56	.58	.59	.60	
		13 mL	rPAP	0.3->0.6	.46	.52	.55	.57	.59	.60
		13 mL	Neopuff	0.3->0.6	.45	.51	.54	.56	.58	.60
	10 mL	Prongs	rPAP	0.3->0.6	.56	.59	.60	.60	.60	
		26 mL	rPAP	0.3->0.6	.43	.49	.53	.56	.58	.60
		26 mL	Neopuff	0.3->0.6	.43	.49	.53	.56	.58	.60

Supplemental table 2 (S-2): Mean oxygen concentration at different time intervals after adjustments. As the set O2 level was achieved earlier for rpap with prongs compared to rPAP and neopuff with added dead-space, measurements were stopped before 180 seconds.

Table S-3 shows the mean time (sec) it took to reach 0.05 +/- from target O2 concentration when decreasing FiO_2 from 1.0 to 0.5 and when increasing from 0.3 to 0.6. Shown with 95% confidence interval and standard deviations.

O2 start	Leak	Tidal volume	Dead space	System	Sec (mean)	95% CI	SD
100 %	Yes	4 ml	13 ml	rPAP	66.65	66.49-66.81	3.76
			13 ml	neopuff	69.56	69.40-69.72	3.80
			Prongs	rPAP	32.29	32.11-32.47	3.23
		10 ml	26 ml	rPAP	82.96	82.81-83.12	4.0
			26 ml	neopuff	78.87	78.71-79.03	3.79
			prongs	rPAP	18.34	18.18-18.49	1.97
	No	4 ml	13 ml	rPAP	154.59	154.41-154.77	6.22
			13 ml	neopuff	172.71	172.46-172.97	7.42
			Prong	rPAP	33.30	33.13-33.47	3.12
		10 ml	26 ml	rPAP	143.82	143.65-143.98	5.29
			26 ml	neopuff	153.37	153.15-153.60	7.56
			prongs	rPAP	18.30	18.14-18.46	2.01
30 %	Yes	4 ml	13 ml	rPAP	47.06	46.91-47.21	3.38
			13 ml	neopuff	51.36	51.21-51.51	3.49
			prongs	rPAP	23.76	23.57-23.94	3.43
		10 ml	26 ml	rPAP	56.19	56.04-56.34	3.39
			26 ml	neopuff	55.52	55.37-55.68	3.41
			prongs	rPAP	13.32	13.15-13.49	2.13
	No	4 ml	13 ml	rPAP	113.10	112.95-113.25	4.93
			13 ml	neopuff	137.59	137.43-137.75	5.85
			prongs	rPAP	25.00	24.82-25.18	3.49
		10 ml	26 ml	rPAP	103.68	103.45-103.92	7.18
			26 ml	neopuff	115.60	115.44-115.76	5.26
			prongs	rPAP	14.79	14.64-14.94	2.05

Supplement table 3 (S-3): Time until 0.05 +/- from target O2 concentration when decreasing FiO₂ from 1.0 to 0.5 and when increasing from 0.3 to 0.6.