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Measurements from preterm infants to guide face mask size

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ABSTRACT

Objective International guidelines recommend that an appropriately sized face mask for providing positive pressure ventilation should cover the mouth and nose but not the eyes and should not overlap the chin. This study aimed to measure the dimensions of preterm infants' faces and compare these with the size of the most commonly available face masks (external diameter 50 mm) and the smallest masks available (external diameters 35 and 42 mm).

Methods Infants 24–33 weeks' postmenstrual age (PMA) were photographed in a standardised manner. Images were analysed using ImageJ software (National Institute of Health, USA) to calculate the distance from the nasofrontal groove to the mental protuberance. This facial measurement corresponds to the external diameter of an optimally fitting mask.

Results A cohort of 107 infants between 24 and 33 weeks' gestational age, including at least 10 infants per week of gestation, was photographed within 72 h after birth and weekly until 33 weeks' PMA. 347 photographs were analysed. Infants of 24, 26, 28, 30 and 32 weeks' PMA had mean (SD) facial measurements of 32 (2), 36 (3), 38 (4), 41 (2) and 43 (4) mm, respectively. There were no significant differences when examined by gender or when small for gestational age infants were excluded.

Conclusions The smallest size of some brands of mask is too large for many preterm infants. Masks of 35 mm diameter are suitable for infants <29 weeks' PMA or 1000 g. Masks of 42 mm diameter are suitable for infants 27–33 weeks' PMA or 750–2500 g.

What is already known on this topic

- Preterm infants frequently receive respiratory support via a face mask.
- Face mask positive pressure ventilation is frequently complicated by obstruction or leak around the mask.
- International guidelines recommend criteria to determine the optimal size of a face mask.

What this study adds

- Facial measurements of preterm infants support recommendations on suitable mask size.
- Postnatal face growth correlates with intrauterine face growth.
- Many commonly available face masks are too large for preterm infants' faces.

INTRODUCTION

Respiratory support including intermittent positive pressure ventilation (IPPV) or continuous positive airway pressure (CPAP) is commonly delivered via a mask applied to an infant's face connected to a T piece or resuscitation bag. Delivering effective mask IPPV or CPAP is challenging. Delivery room studies have found that mask IPPV is frequently complicated by intermittent airway obstruction[1] or leak between the mask and the infant's face.[2–5] Leak is common, variable and often not detected by the resuscitator.[2–5]

International recommendations from the UK, USA and Australia regarding mask size and shape emphasise the importance of a well-fitting face mask.[6–8] These recommendations emphasise the need to cover the nose and mouth and to avoid covering the eyes, overlapping the chin or occluding the nose. O'Donnell *et al*[9] surveyed 46 neonatal intensive care units in 23 countries and found that round face masks were used in 85% and anatomically shaped masks used in 15%. Surveys have not however established which type or size of round masks are most commonly used,[10–12] and there are no recommendations regarding mask size for specific weight or gestation infants. There are many brands of round neonatal masks available in a range of sizes. Most brands start with smallest external diameter around 50 mm. To our knowledge, there is only one brand of smaller mask available—Infant Resuscitation Masks (Fisher & Paykel Healthcare, Auckland, New Zealand), sizes small and extra small, with external diameters of 42 and 35 mm, respectively.

There are no data available regarding the size of preterm infants' faces or how their facial dimensions change in the weeks following preterm birth. The aims of this study were to (1) measure the dimensions of preterm infants' faces across a range of gestational ages at birth and over the first weeks of life, (2) compare these results with the dimensions of commonly available round masks and (3) make recommendations regarding appropriate mask size for preterm infants.

METHODS

Preterm infants <34 weeks' gestational age admitted to neonatal intensive and special care were eligible for inclusion. As this is the first study of its kind, there were no data on which to base a sample

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size calculation. Therefore, a study population with a minimum of 10 infants per each completed week of gestation from 24 to 33 weeks was chosen. Infants considered to have any dysmorphic features or congenital facial anomalies by the attending clinical team were excluded. Demographic details were collected including gender, gestation, corrected gestation, birth weight, weight on the day of each measurement and whether or not birth weight was <3rd centile.

Each infant was photographed while supine with their head in the neutral position and their jaw neutral, that is, the position in which they would be placed to receive mask IPPV. A plastic scale was placed next to and level with the infant's face and included in the photograph. Infants receiving CPAP via nasal prongs or those who had endotracheal, nasogastric or orogastric tubes in situ were included as long as their nose and chin were not distorted and could be clearly seen. The infants receiving CPAP via nasal prongs had their photographs taken when the prongs were removed for cares whenever possible. Images were taken using a Sony NEX-3 digital SLR camera with a SEL1855 lens using a focal length of 35 mm from a distance of 10 cm directly above the centre of the infant's face. Each image was then analysed using ImageJ software (National Institute of Health, USA) (figure 1), a public domain, java-based image processing program developed at the National Institute of Health.[13]

The distance from the infant's nasofrontal grove to their mental protuberance was measured (figure 1). These landmarks were chosen because the distance between them equates to the diameter of a suitably fitting mask in accordance with international guidelines.[6 7] Infants were photographed within 72 h after birth and weekly until they reached 33+6 weeks' postmenstrual age or were discharged or transferred to another hospital.

Measurements were combined to determine (i) measurements of newborns (<72 h of age)—presented as mean (SD) distance in millimetres for each completed week of gestation and by birth weight divided into 250 g cohorts; and (ii) measurements of growing infants—presented as mean (SD) distance in millimetres for each completed corrected week of gestation and by weight divided into 250 g cohorts.

Measurements were compared against three different round masks—Laerdal 0/0 (Laerdal, Stavagner, Norway) and Fisher & Paykel Infant Resuscitation Masks 'small' and 'extra small'. The Laerdal 0/0 mask has an external diameter of 50 mm. It was chosen as it is the standard mask used at The Royal Women's Hospital, Melbourne, and is a commonly used mask worldwide. The Infant Resuscitation Masks, sizes small and extra small, are the smallest available masks and have external diameters of 42 and 35 mm, respectively.

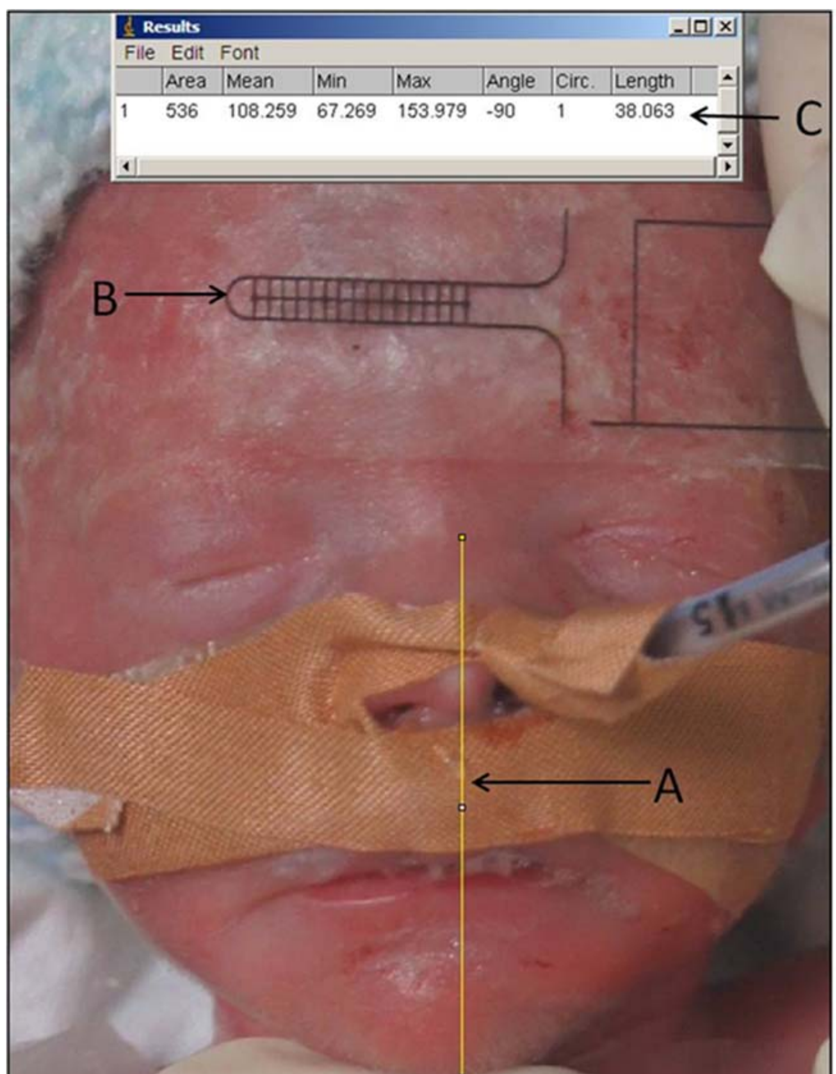

Figure 1 Example of study photograph taken and analysed. (A) Distance from the nasofrontal groove to the mental protuberance. (B) A plastic scale placed level with the infant's face. (C) Measurement calculated when analysed by ImageJ.

Table 1 Demographic details of the study population

Number of infants	Gestational age	Birth weight (g) mean (SD)	Percentage male	Percentage small for gestational age
10	24	649 (82)	60	10
10	25	728 (143)	40	20
10	26	934 (171)	50	10
10	27	988 (208)	40	10
12	28	1102 (183)	25	8
12	29	1082 (302)	25	25
12	30	1617 (215)	67	0
10	31	1638 (335)	20	10
11	32	1839 (198)	45	0
10	33	1839 (392)	40	30

RESULTS

A cohort of 107 infants between 24 and 33 weeks' gestational age were recruited between September 2011 and September 2013. There was a median (range) of 10 (10–12) infants per each completed week of gestation. Demographic details of the infants are presented in table 1.

There were 347 facial measurements made from photographs of the infants, median (range) of 3 (1–11) per infant. Figure 2A, B displays the results. Both the initial measurements taken shortly after birth and the serial measurements of infants from birth until 33 weeks' postmenstrual age are presented. Figure 2A displays the results for each completed week of gestation, and figure 2B displays the results for weight divided into 250 g strata. The initial measurements for each gestational age closely parallel serial measurements for postmenstrual age, suggesting that postnatal facial growth continues at a similar rate to antenatal growth despite preterm birth. Figure 2A, B also indicates the three different mask sizes alongside the measurements.

Table 2 presents newborn measurements for each week of gestation for the whole group, by gender, and infants with birth weight >3rd centile.

No significant differences were seen in facial size between male and female infants, or when small for gestational age infants were excluded. Small for gestational age infants have

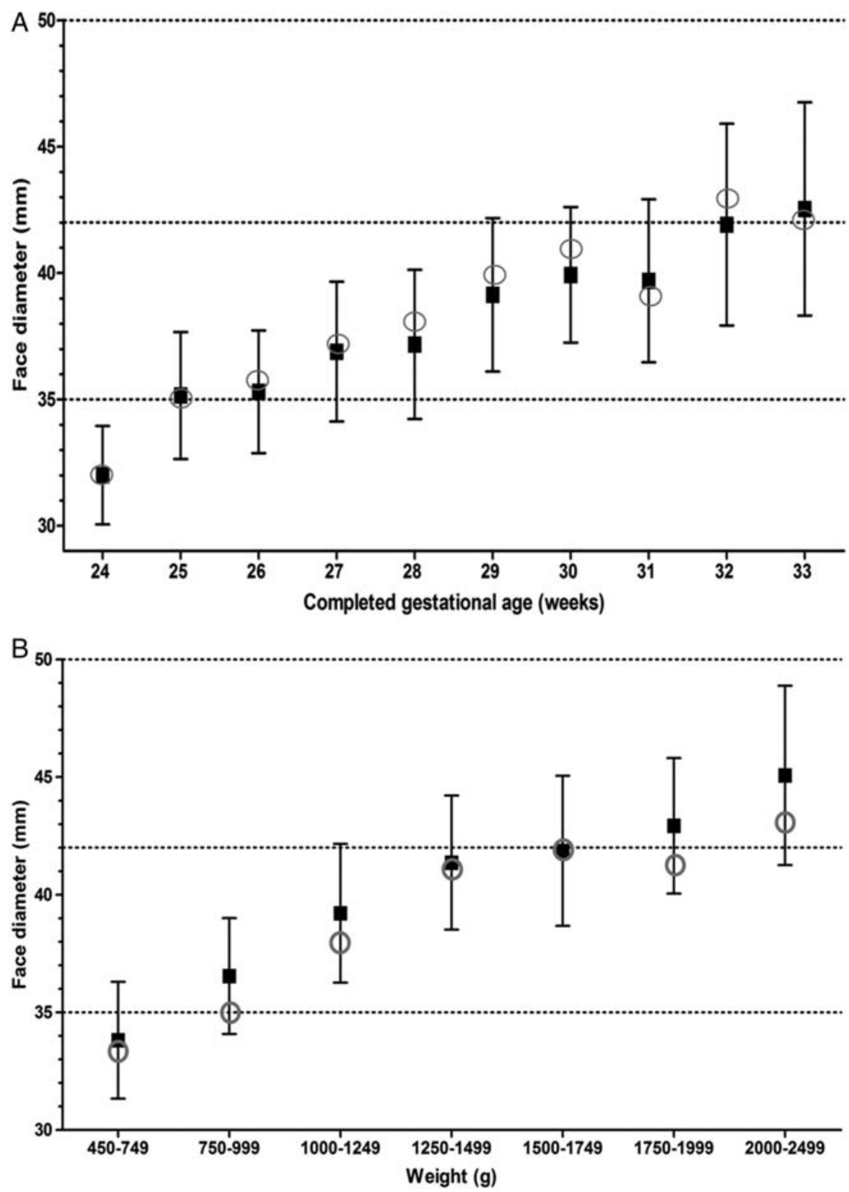

Figure 2 Mean measurements for (A) each completed week of gestation and (B) weight divided into 250 g cohorts. (A, B) The hollow circle represents the mean first measurements taken shortly after birth, and the black box and whiskers represent the mean (SD) of measurements taken from birth to 33 weeks' postmenstrual age.

Table 2 Initial measurements presented for each week of gestation for the whole study population by sex and excluding the growth-restricted infants

Number of infants	Gestation (completed weeks)	Initial measurement mean (SD) mm			
		All infants	Male only	Female only	Infants with birth weight >3rd centile
10	24	32 (2)	31 (2)	34 (2)	32 (2)
10	25	35 (3)	35 (3)	35 (3)	36 (3)
10	26	36 (3)	37 (3)	35 (3)	36 (3)
10	27	37 (3)	36 (1)	37 (4)	37 (4)
12	28	38 (4)	41 (4)	37 (4)	38 (4)
12	29	40 (4)	39 (3)	39 (5)	40 (4)
12	30	41 (2)	41 (2)	41 (2)	41 (2)
10	31	39 (4)	38 (1)	40 (4)	40 (3)
11	32	43 (4)	42 (4)	44 (5)	43 (4)
10	33	42 (5)	43 (3)	42 (6)	43 (5)

smaller faces, the degree of which depends on the severity of the growth restriction.

DISCUSSION

This study shows that a mask with an external diameter of 50 mm may be too large for infants <34 weeks' postmenstrual age. A 35 mm mask fits infants <29 weeks' postmenstrual age. For babies born at 27–28 weeks' gestational age, having both 35 and 42 mm masks available allows clinicians to choose the best-fitting mask for a particular baby. The 42 mm mask is appropriate for infants up to 33 weeks' postmenstrual age. However, having the 42 and 50 mm masks available may help select the best one for babies born at 32–33 weeks' gestational age.

During admission, both charts (figure 3A, B) can be used to choose the appropriate mask size as the infants grow.

There are four studies that have examined mask IPPV in preterm infants <34 weeks' postmenstrual age. All have found a significant leak around the mask, the magnitude of which varied from a median of 29–55%.[2–5] All of these studies used a 50 mm diameter mask that may have been too large to form an optimal seal. To date, there are no studies assessing leak using smaller and perhaps better-fitting masks. Our data could now be used to assess whether correctly sized masks result in less leak in vivo. There is more to the process of providing IPPV than simply choosing a mask of correct size. Head position, mask hold, applied pressure, ventilation rate and clinical experience also determine the effectiveness of IPPV. However, using an appropriate mask size is important and is highlighted in international training programmes.[6–8]

This study has several strengths. It is the first study to measure the dimensions of preterm infants' faces and to compare these measurements with those of commonly available masks. A large cohort of preterm infants was enrolled shortly after birth and followed to 33 weeks' postmenstrual age. The results have demonstrated that postnatal growth in these infants' facial measurements closely resembles growth in utero. The study cohort was evenly distributed across the range of gestational ages allowing for good representation of the extremely low birthweight infants. This is important because even though the extremely low birthweight infants make up a small proportion of the entire preterm population, they are the group most likely to require respiratory support. Respiratory outcomes of infants managed from birth with non-invasive versus invasive respiratory support are superior;[14] therefore, it is essential that mask IPPV and CPAP are optimised. These mask size recommendations ensure a better fit and may reduce mask repositioning during resuscitation. Some masks are reusable, whereas others are single-patient use, with an inherent cost implication. This study provides clinicians with the information to enable them to anticipate the appropriate mask size at birth and during admission, minimising that cost.

There are limitations to this study. Although photographs of the infants were taken in a standardised way to minimise distortion, the facial measurements were made indirectly. In addition, we have measured the face only in the horizontal plane and have not attempted to assess variations in dimensions in the sagittal plane. These variations are difficult to assess but may be important in influencing the amount of mask leak. Many of these infants were unwell and could not tolerate excessive handling. We therefore felt it would not have been appropriate to take measurements directly. Studies comparing measurements of photographs with direct measurements have found the method to be accurate and have very high inter-rater and intra-rater reliability.[15–20] The software package ImageJ that we used to measure the photographs is a public domain, java-based, image processing program developed at the National Institute of Health in 1997.[13] The program has been used for a diverse range of applications, including wound measurement, assessing skin texture and measuring orbital tumours and motion of soft tissue.[16 21 22]

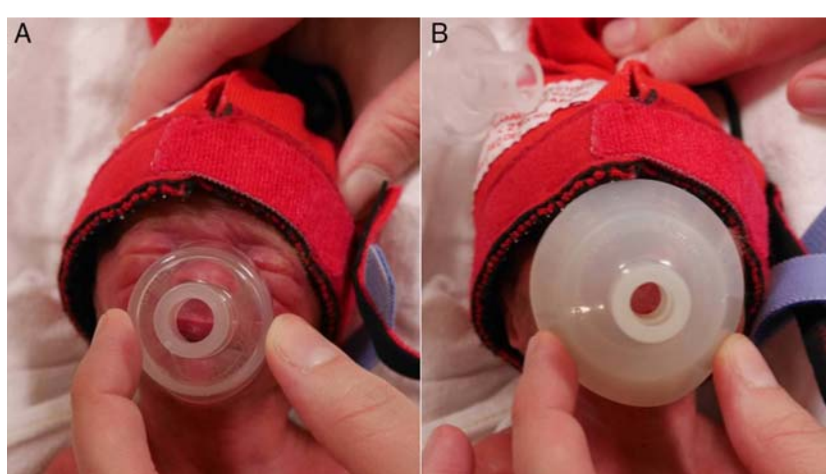

Figure 3 Newborn baby girl, 26+0 weeks' postmenstrual age, birth weight 805 g. (A) 35 mm mask applied to face; (B) 50 mm mask applied to face.

The mask sizes discussed in this study are all defined by their external diameter. However, the masks all have a rim of varying thickness and therefore a smaller internal diameter. If the external diameter of the mask fulfils the recommended criteria but has a rim that is wide enough to compress the infant's nose, then it may not be an effective interface for positive pressure ventilation. This study is limited in that the measurements were taken to assess the optimal external diameter for a suitable mask fit but the differing-sized masks were not studied during clinical use on different-sized infants. Future studies are needed to assess the effectiveness of different-sized masks in preterm infants.

CONCLUSION

The findings of this study suggest that round masks with an external diameter of 50 mm are too large for many preterm infants, particularly the extremely low birthweight infants. Smaller masks with external diameters of 35 and 42 mm are suitable for infants <29 weeks' postmenstrual age or <1000 g and 29–33 weeks' postmenstrual age or 1000–2500 g, respectively.

Contributors JEO was involved in study design, patient recruitment, data collection and analysis and has written the manuscript. MT was involved in study design, patient recruitment, data collection and analysis and has also reviewed and contributed to each draft of the manuscript. LSO was involved in study design and has reviewed and contributed to each draft of the manuscript, CW was involved in study design, patient recruitment, data collection and has approved the manuscript. JAD was involved in study design and has contributed to each draft of the manuscript. PGD was involved in study design, project supervision and has seen and contributed to each draft of the manuscript.

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Competing interests None.

Patient consent Obtained.

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