Assessment of Infant Cardiopulmonary Resuscitation Rescue Breathing Technique: Relationship of Infant and Caregiver Facial Measurements

Cynthia A. Dembofsky, MD*; Eric Gibson, MD‡§; Vinay Nadkarni, MD‡¶; Sara Rubin*; and Jay S. Greenspan, MD‡§

ABSTRACT. Objective. Although a few infants ever require resuscitation, pediatric cardiopulmonary resuscitation (CPR) is performed most commonly under 1 year of age. American Heart Association guidelines for pediatric basic life support recommend that the caregiver place his/her mouth over the infant’s mouth and nose to create a seal. The way CPR is currently taught encourages parents to attempt to seal the nose and open the mouth of the infant for rescue breathing. Recent studies suggest some parents may have trouble sealing an infant’s nose and open mouth, but their study participant numbers were small. The aim of this report is to estimate, among a large cohort, the ability of caregivers to create a seal to their infants for the provision of rescue breathing according to current guidelines.

Methods. Infants up to 1 year of age (n = 281) and their caregivers were enrolled from Philadelphia pediatric offices. Facial measurements of the infants were obtained to estimate the length needed to seal the nose and open mouth, and the nose and closed mouth. Mouth widths of the caregivers were compared with their infant’s nose and mouth lengths. One-way analysis of variance with Tukey’s postmortem analysis and ordinary least squares means regression were used for univariate analysis with analysis of covariance used to control for the effects of multiple variables when necessary. Infant measurements were stratified into 3-month age quadrants to compare against matched adult caregiver measurements.

Results. Most caregivers (n = 270) were female. Females had smaller mouth widths than males (4.9 ± 0.5 cm vs 5.2 ± 0.5 cm). Infant nose and mouth length increased during the first year of life, with the largest increase between 0 to 3 months and 3 to 6 months (4.2 ± 0.4 cm to 4.7 ± 0.4 cm). As infant age and face length increased, a progressively higher rate of adult females were estimated not to be able to cover their infant’s nose and open mouth, with the greatest increase again between 0 to 3 months (9%) and 3 to 6 months (40%). All female caregivers except 1 were predicted to be able to seal their infant’s nose and closed mouth by our measurements.

Conclusions. Infant face length grows rapidly during the first year of life with the most rapid growth occurring during the first 6 months. As early as 3 to 6 months of infant age, many adult caregivers’ facial measurements, especially female, predict that they may not be able to form a seal for mouth-to-nose and open-mouth infant rescue breathing. By related measurements, nearly 100% of caregivers should be able to seal their infant’s nose and closed mouth. If facial measurement predictions correlate with functional inability to seal an infant’s nose and open mouth, infant CPR rescue breathing instruction will need to emphasize head position and creation of a seal over the mouth and nose without teaching that the mouth be open. Pediatrics 1999;103(2). URL: http://www.pediatrics.org/cgi/content/full/103/2/e17; pediatric basic life support, infant CPR, rescue breathing, sudden infant death syndrome, acute life-threatening episode.

ABBREVIATIONS. CPR, cardiopulmonary resuscitation; AHA, American Heart Association.

Although few infants ever require resuscitation, pediatric cardiopulmonary resuscitation (CPR) is performed most commonly under 1 year of age.1 A recent survey of North Carolina day care homes and centers reported 2.5% of day care centers used rescue breathing during a 36-month period.2 The Emergency Cardiac Care Committee of the American Heart Association (AHA) recommends that all expecting parents and parents of young children be offered training in CPR. Frequent causes of cardiopulmonary arrest under 1 year include sudden infant death syndrome, acute life-threatening episodes, respiratory diseases, airway obstruction, submersion, sepsis, and neurologic disease.1 Specific groups at increased risk for respiratory arrest include premature infants, siblings of sudden infant death syndrome victims, infants with breathing and neurologic disorders, and infants presenting with an acute life-threatening episode.3

AHA guidelines for pediatric basic life support recommend that the caregiver place his/her mouth over the infant’s mouth and nose to create a seal, then blow gently to inflate the lungs in a head tilt position. The recommendations and teaching have remained essentially unchanged since the Ad Hoc Committee on CPR first published its recommendations in October 1966.4 The current AHA Pediatric Basic Life Support Textbook5 describing the rescue breathing techniques does not state that the infant’s mouth must be open, but in most classes, CPR is taught on an infant mannequin with a fixed open mouth. This encourages parents to attempt to seal the nose and open mouth of the infant for rescue
breathing. The most commonly used mannequin for infant CPR instruction, the Laerdal Resuscibaby (Stavanger, Norway), has a midnose to open mouth length equal to that of a typical newborn (3.9 cm). Although being able to seal the nose and open mouth on the mannequin should insure that the rescuer will physically be able to seal the nose and open mouth of a typical newborn, this may not guarantee the ability to seal the nose and open mouth of older infants.

Until recently the AHA recommendations had gone unchallenged in the medical literature. In June of 1995, a study by Tonkin et al6 measured the facial dimensions of 28 2- to 4-month-old infants and their mothers. They suggested that none of the mothers’ mouths were wide enough to seal their infant’s nose and mouth. They recommended that mouth-to-nose instead of mouth to nose-and-mouth rescue breathing be taught to parents of infants under 6 months of age. After this study, the 1997 advisory statement from the Pediatric Working Group of the International Liaison Committee on Resuscitation continued to recommend mouth to mouth-and-nose ventilation as the optimal method for delivering breaths to infants under 1 year of age, but noted that mouth-to-nose ventilation may be adequate for this population. A second study in November 1997 by Sorribes et al8 had similar findings in 40 infants under 2 months old. They concluded that mouth-to-nose rescue breathing is the best method for ventilation in basic CPR in infants under 2 months of age. The purpose of this study is to estimate the ability of caregivers to seal their infant’s nose and mouth for the provision of rescue breathing, based on the comparison of facial measurements of the infant and their adult caregiver in a large, diverse United States population.

METHODS

Patient Selection

Infants less than 1 year of age and their caregivers were recruited from four pediatric clinics, two private offices, and two day care centers throughout Philadelphia, PA, from August 1996 through February 1997. Infants with known or suspected craniofacial anomalies were excluded. The study was approved by the Thomas Jefferson University Internal Review Board, and informed consent was obtained from all participating caregivers.

Infant Measurements

Before initiating our study, we tested several techniques for obtaining infant length measurements on infants in the newborn nursery, including the technique described by Tonkin et al. There was little variation between repeated midnose to closed-lip measurements (0.0 cm to 0.2 cm), but repeated midnose to open-mouth measurements were more inconsistent because of variations in the degree of opening of the mouth (0.2 cm to 0.4 cm). We chose, therefore, to estimate this measurement with the mouth closed. The average difference between open lips and closed lips in the infant’s mouth approximates the length of the midnose to the lower lip with the mouth closed, and the lower lip to the tip of the chin. The length from the nasal bridge to the lower lip with the mouth closed approximates the length of the midnose to the lower lip with the mouth opened. Nasal bridge to lower lip length was defined to estimate the width required by the rescuer mouth to seal the infant’s nose and open mouth. Midnose was calculated as one half the distance between the nasal bridge and upper philtrum and used for the midnose to closed lower lip length (Fig 1). Midnose to lower lip length was defined to estimate the width required by the rescuer mouth to seal the infant’s nose and closed mouth.

Caregiver Measurements

Before initiating this study, we made pilot measurements with a standard tape measure to test the consistency of our technique. Repeat measurements of 10 male and female adult open-mouth widths by the same data collector initially showed a 0.1- to 0.4-cm variation that was partially because of participant effort. The variation was reduced by giving specific instructions and encouragement on opening the mouth widely. We decided to measure the midnose to closed-mouth width in addition to the open-mouth width because the measurement is not effort-dependent. The two measurements were made on all adult participants in the study. First, their mouth width was measured in a horizontal straight line with their mouths closed. Study participants were then asked to open their mouths wide as if they had to give a rescue breath to their infant, and their widest open width was measured. During the study, study participants were later asked if their measurements could be repeated. Variation between the initial and repeat measurements ranged from 0.0 to 0.2 cm. All participants were asked if they would participate in a final measurement by applying lipstick or petroleum jelly to their lips. They were instructed to open their mouths, as if to give a rescue breath, and make a lip imprint onto a piece of tissue paper placed over a pad of soft, pliable gel (Fig 2).

The author and one assistant were the only data collectors for this study. Before initiating the study, pilot measurements were made on infants in the newborn nursery and adult coworkers at Thomas Jefferson University Hospital. Repeat measurements by the same collector were made on the pilot study participants and compared with earlier measurements for consistency. The two data collectors compared measurements on the same pilot study participants to ensure consistency between data gatherers. Periodically throughout the study, participants were asked to participate in repeat measurements later in their visit to evaluate consistency of measurements to ensure intrarater reliability. The average measurements taken by the two data gatherers (n = 251,
Measurements were analyzed for 281 infants older than 1 year, and 19 infants who were infants with craniofacial anomaly syndromes, 3 in the study. Twenty-five infants were excluded: 3 whose infants were inconsolable and unable to cooperate for measurements. Caregivers who agreed to participate in the study but whose infants were in some other way excluded were excluded from the study analysis.

Statistical Analyses
Mean ± SD were calculated for each of the infant and caregiver measurements. One-way analysis of variance with Tukey’s post-mortem analysis and ordinary least squares means regression were used for univariate analysis with analysis of covariance used to control for the effects of multiple variables when necessary on Systat and SPSS statistical packages (SPSS, Inc, Chicago, IL). χ² was used for comparison of groups by primary outcome. Significance was considered P < .05. Infant measurements were stratified into 3-month age quadrants to compare against adult measurements.

RESULTS
Caregivers of 306 infants consented to participate in the study. Twenty-five infants were excluded: 3 infants with craniofacial anomaly syndromes, 3 infants older than 1 year, and 19 infants who were unable to cooperate to sufficiently obtain accurate measurements. Measurements were analyzed for 281 infants and their caregivers. Table 1 displays infant and caregiver demographics by age, birth weight, sex, and race. Most of the low birth weight infants (<2500 g) were African-American (79%) and female (76%). The average age (plus/minus one standard deviation) was similar for males (147 ± 105 days) and females (148 ± 102 days). The average age was younger among the Hispanic infants (114 ± 92 days) than African-Americans (150 ± 103 days), white (155 ± 107 days), and Asian-Americans (164 ± 99 days), but this difference was not significant (P = .12).

The three types of mouth width measurements taken on caregivers are shown in Table 2 by sex. Female mouth width was smaller than male mouth width by open width, closed width, and imprint width. The three measurements of female mouth width differed from one another: imprint width < open width < closed width. The three measurements of male mouth width did not differ from one another (P = .48). Mouth width varied among races, with female mouth width averaging 0.2 to 0.3 cm larger among African-Americans than other races by all three measurements (P < .01).

Infant nose-to-mouth length is compared by infant age in Table 3. Both estimated nose-to-open mouth and nose-to-closed mouth measurements increased consistently with increasing infant age. The largest increase occurred between 0 to 3 months and 3 to 6 months. Seventy percent of the difference in infant nose-to-mouth length could be predicted by infant age (Pearson r = 0.7). Female infants had smaller average nose-to-open mouth length (4.5 ± 0.5 cm) than male infants (4.7 ± 0.5 cm) (P < .01). Infant facial length was smaller among Hispanics (4.4 ± 0.4 cm) than African-Americans (4.7 ± 0.6 cm) even after controlling for infant sex and age (P < .01). Low birth weight infants had no difference in nose-to-mouth length even when adjusted for age (P = .14).

There was a 0.1- to 0.2-cm interrater difference in the average of the three adult mouth width measurements between the two data collectors. There was no difference in measurements of infant facial length between the two data collectors when controlling for infant age.

Infant nose-to-open mouth length and infant nose-to-closed mouth length were compared with their female caregivers’ mouth widths by all three measurements in Fig 3. When stratified by age groups, the increase in proportion of adult female caregivers predicted to be unable to cover their infant’s nose and open mouth by their open-mouth width was similar to the rise in infant facial length, with the largest increase occurring between 0 to 3 months (9.7%) and 3 to 6 months (40%). Only 1 out of the 270 female caregivers was predicted to be unable to cover her infant’s nose and closed mouth by our measurements. Male caregivers had larger average open-mouth widths than female caregivers and were estimated to be able to seal the nose and open mouth of their infants in all but 8% with infants <6 months of age and 17.8% overall. All male caregivers were predicted to seal their infant’s nose and closed mouth by their open-width measurement. There was no difference by adult or infant race in the percent of female caregivers predicted to be unable to seal their infant’s nose and open mouth (P = .26). Female caregivers were unable to seal the nose and closed mouth by their open-mouth width when adjusted for infant race. Caregiver race has a similar distribution.

http://www.pediatrics.org/cgi/content/full/103/2/e17

TABLE 1. Study Population Demographics

<table>
<thead>
<tr>
<th>Infant Race* n (%)</th>
<th>Infant Age</th>
<th>Infant Birth Weight</th>
<th>Infant Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>African-American</td>
<td>Mean 147 ± 107 days</td>
<td>0-3 mo 110 (39%)</td>
<td>Male 146 (52%)</td>
</tr>
<tr>
<td>White</td>
<td>Mean 147 ± 107 days</td>
<td>0-3 mo 110 (39%)</td>
<td>Male 146 (52%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>Mean 147 ± 107 days</td>
<td>0-3 mo 110 (39%)</td>
<td>Female 135 (48%)</td>
</tr>
<tr>
<td>Asian-American</td>
<td>Mean 147 ± 107 days</td>
<td>0-3 mo 110 (39%)</td>
<td>Caregiver sex</td>
</tr>
<tr>
<td>Biracial</td>
<td>Mean 147 ± 107 days</td>
<td>0-3 mo 110 (39%)</td>
<td>Male 45 (14%)</td>
</tr>
</tbody>
</table>

* Caregiver race has a similar distribution.
measurements averaged 0.13 cm larger than open-mouth width measurements. Closed-mouth might still be intimidating and not give a full effort by some participants, in the public setting of our study, though we found statistically significant differences in measurements, and is the most generous measurement to compare to infant facial length. Comparing closed-mouth width measurements to infant measurements, there was still an impressive increase from 0 to 3 months to 3 to 6 months infant age of 4.6% to 27.1% of female caregivers with a smaller closed-mouth width than their infant’s estimated midnose-to-open mouth length. By our most conservative estimates, >25% of female caregivers would be unlikely to form an adequate seal over their 3- to 6-month-old infant’s nose and open mouth.

**DISCUSSION**

This study demonstrates that infant face length grows rapidly during the first year of life, with the most rapid growth occurring during the first 6 months. During this period, many infant’s estimated nose and open-mouth lengths surpasses their female caregiver’s mouth widths. We concentrated our analysis on female caregivers because they had significantly smaller mouth widths than males, and would be more likely to have difficulty sealing their infant’s nose and mouth during rescue breathing. Females would presumably be more likely to perform CPR because the majority of caregivers in the study (86%) were female. The open-mouth width of 99% of the adult females in our study was at least as long as the midnose-to-open mouth length of our infant resuscitation mannequin, indicating most women would likely be able to appropriately seal the mannequin to perform rescue breathing. However, when comparing the same adult female mouth widths to that of their 3- to 6-month-old infants, 41% had smaller open-mouth widths than their infant’s estimated midnose-to-open mouth length, indicating they would likely be unable to seal the nose and open mouth of their infants during rescue breathing. We report infant measurement comparisons by sex and race because these measurements have not been previously reported on a large, diverse population. Although we found statistically significant differences in measurements by sex and race, the differences were small. A large percent of female caregivers in all groups are predicted not to be able to seal their infant’s nose and open mouth, and for the purpose of the present study, the differences in measurements by race and sex are not clinically significant.

Despite our instructions there was concern that some participants, in the public setting of our study, might still be intimidated and not give a full effort for open-mouth width measurements. Closed-mouth measurements averaged 0.13 cm larger than open-mouth measurements, and is the most generous measurement to compare to infant facial length.

### TABLE 2. Measured Mouth Widths of Adult Caregivers (cm ± SD)

<table>
<thead>
<tr>
<th>Caregiver</th>
<th>Open</th>
<th>Closed</th>
<th>Imprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>4.9 ± 0.5*</td>
<td>5.0 ± 0.4*</td>
<td>4.7 ± 0.5*</td>
</tr>
<tr>
<td></td>
<td>(n = 270)</td>
<td>(n = 270)</td>
<td>(n = 249)</td>
</tr>
<tr>
<td>Male</td>
<td>5.2 ± 0.3†</td>
<td>5.2 ± 0.4†</td>
<td>5.1 ± 0.6†</td>
</tr>
<tr>
<td></td>
<td>(n = 45)</td>
<td>(n = 45)</td>
<td>(n = 21)</td>
</tr>
</tbody>
</table>

* Differs from other female caregiver mouth width measurements (P < .01, analysis of variance).
† Differs from female mouth width measurement (P < .01, analysis of variance).

 caregivers, on average, were more likely to be able to seal their female infant’s (76%) than their male infant’s (60%) nose and open mouth (P < .01).

**TABLE 3. Infant Nose-to-Mouth Length (cm ± SD) by Age**

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>0-90</th>
<th>90-180</th>
<th>180-270</th>
<th>270-360</th>
<th>0-360</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nose-to-open mouth</td>
<td>4.2 ± 0.4</td>
<td>4.7 ± 0.4</td>
<td>4.9 ± 0.4</td>
<td>5.2 ± 0.4</td>
<td>4.6 ± 0.5</td>
</tr>
<tr>
<td>Nose-to-closed mouth</td>
<td>3.2 ± 0.4</td>
<td>3.6 ± 0.3</td>
<td>3.7 ± 0.4</td>
<td>3.8 ± 0.3</td>
<td>3.5 ± 0.4</td>
</tr>
</tbody>
</table>

**Fig 3.** Percentage of infants with nose and mouth length greater than their female caregivers mouth width. BL indicates nose-to-open mouth width; ML, nose-to-closed mouth length; OW, open mouth width; CW, closed mouth width; and IW, imprint mouth width.
between the two studies. The difference between our results and Sorribes' results is also dramatic. At 0 to 2 months 16% of female caregivers were estimated to be unable to seal their infant’s nose and open mouth by the imprint measurement in this study, whereas 75% failed in Sorribes’ study. Of note, the Resuscibaby infant mannequin typically used to teach infant CPR rescue breathing in this country has a midnose to lower lip (with an open mouth) length of 3.9 cm. If the measurements of adult mouth widths in the two previous studies are representative of functional ability to form a seal for effective mouth to nose-and-mouth rescue breathing, essentially none of the caregivers in either of the studies should be able to form a seal on the Resuscibaby to perform infant mouth to nose-and-mouth rescue breathing during CPR training. If this were the case, it would be surprising that there have not been reports of inability to seal the infant mannequin during the teaching of infant CPR rescue breathing.

Tonkin et al also measured the nasal bridge to the closed lower lip on their infants. In contrast to our assumption that an adequate seal could be made and effective rescue breathing given if the caregiver is able to cover the midnose to closed lower lip of the infant, they assumed the entire nose and mouth would have to be covered for a good seal. Therefore, although we used the nasal bridge-to-closed mouth length to estimate ability to seal the nose and open mouth, they used the same measurement to estimate ability to seal the nose and closed mouth. However, comparing the same average nasal bridge-to-closed lower lip measurement at 2 to 4 months in our study to Tonkin’s study, the average length of our infants was 0.5 cm less than in Tonkin’s study (4.6 ± 0.4 cm vs 5.1 ± 0.8 cm). The reason for this difference is unclear because similar techniques were used. We could not find other documented nose to mouth lengths during the first year of life in the literature, but Goodman and Gorlin published an average vertical nose length of 2.2 cm at 0 to 15 weeks of age. Our nose length measurements for 0 to 15 weeks averaged 2.1 cm. They also published philtrum lengths of 0.8 cm at birth increasing to 1.2 cm at 12 months. Our measurements for philtrum length increased from 1.0 cm at 0 to 3 months to 1.2 cm at 9 to 12 months. This suggests that our measurements are reproducible and consistent with published standards. Sorribes et al used a slightly different measurement technique from either Tonkin’s study or our study. They measured from the midnose to the midchin to estimate the length needed to cover the mouth and nose. The average facial length of 0- to 2-month-old infants using this technique was 3.7 ± 0.5 cm as opposed to a 4.1 ± 0.4 cm average of 0- to 2-month-olds measuring the nasal bridge to lower lip in our study.

Two measurements in the infants were prospectively defined as critical estimates. First was the length required to form an adequate seal over the nose and open mouth and give a rescue breath through both the mouth and nose—the estimated midnose to open lower lip length. This would predict the ability to perform rescue breathing as it is currently taught on mannequins. Second was the length needed to form an adequate seal over the nose and closed mouth and predict the ability to perform rescue breathing through the nose—the estimated midnose to closed lower lip length. Whereas sealing the nose and closed mouth is not typically emphasized in CPR classes, it is also an acceptable method of resuscitation. The airway anatomy of the infant leads to nasal breathing as the preferred passage for air entry, and unless there is complete nasal obstruction, mouth-to-nose rescue breathing should be feasible if there is a good seal and proper head position. Segedin et al supported the acceptability of nasal rescue breathing when they compared nasal-only to oral-only mask ventilation in 20 infants undergoing general anesthesia. They found the nasal route superior to the oral route but did not compare nasal-only to nose-and-mouth ventilation. A follow-up study by Wilson-Davis et al compared postmortem tracheal and esophageal airway opening pressures with a mask seal of the nose alone, mouth alone, and nose and mouth in head extended, neutral and flexed positions on 8 infants 1 to 11 months of age who had died unexpectedly. They found that the nasal route of air entry was more effective (ie, required lower airway opening pressures) than the mouth alone or combined nose and mouth routes and that neck flexion impeded air entry under these conditions.

These data represent an indirect assessment of the ability of female caregivers to perform rescue breathing on their infants. We conclude that rapid growth in infant nose and mouth length during the first year, and especially in the first 6 months, correlates with an increasing percentage of female caregivers unlikely to be able to seal their infant’s nose and open mouth. This raises the concern that the current method of teaching CPR may not be feasible for some caregivers beyond the neonatal period. However, nearly 100% of caregivers with infants up to a year of age should have no difficulty, by our measurements, sealing their infant’s nose and closed mouth to perform mouth-to-nose rescue breathing. The AHA guidelines do not comment on the position of the infant’s mouth, stating: “Maintain pressure on the infant’s forehead and keep the head tilted. With the other hand lift the chin, open your mouth wide and take a deep breath. Cover the infant’s mouth and nose with your mouth, making a tight seal. Breath into the infant’s mouth.” We speculate that during teaching of pediatric basic life support emphasis may need to be placed on head position and creating a seal over the mouth and nose without specifically emphasizing opening the mouth.

Our results, along with previous work, are based on indirect comparisons between measurements of the caregiver and infant. One noninvasive but also indirect way of assessing caregiver attempts to form a seal and give rescue breaths would be to assess caregivers’ resuscitation attempts on mannequins with facial dimensions comparable to those of older infants. The ultimate way to substantiate these results, however, would require direct functional assessment of caregivers’ attempts to seal their infants’
noses and mouths and deliver effective rescue breaths. These studies would be more invasive, requiring infant sedation and close monitoring. Direct functional assessment of caregiver rescue breathing on the infant was beyond the scope of this study. Further studies are needed to confirm our results before recommending any change in current infant CPR guidelines.

REFERENCES

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