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Enhanced Sucking Engagement by Preterm Infants During Intermittent Gavage Feedings

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ABSTRACT. Non-nutritive sucking (NNS) activities were recorded in preterm infants born at gestational age 32 weeks or less during nasogastric feedings. Six infants on intermittent nasogastric feeding schedules were tested with a pacifier in their mouth for three 5-minute periods (before, during, and after gavage feeding). Analysis of the recordings revealed that NNS activities increased markedly during the intermittent nasogastric feeding schedule. The overall proportions of sucking engagement, the mean duration of sucking burst, the mean number of sucks per burst, and the mean duration of individual sucks within a burst increased markedly during gavage feeding compared with both pre-test and post-test periods. NNS by a group of five infants on continuous nasogastric feedings was similar to the pre-test and post-test of the infants on the intermittent nasogastric feeding schedule. These results indicate that in the context of intermittent nasogastric feedings, NNS engagement in tube-fed infants depends on stomach cues and/or temperature changes associated with tube feedings. *J Dev Behav Pediatr 17:000–000, 1996.* Index terms: *continuous nasogastric feeding, intermittent nasogastric feeding, non-nutritive sucking, preterm infants, sucking activity.*

The mouth is the primary locus of transaction between the young infant and the environment. Oral activities in the newborn have been presented as the instrument of innate emotional expressions,[1] the first behavioral expression of sensorimotor intelligence,[2] the original source of pleasure,[3] and the "cradle" of perception.[4] Healthy newborns display a large repertoire of well-documented oromotor activities, including non-nutritive sucking (NNS),[5] expression,[6] nutritive sucking (NS),[7] mouthing and oral exploration,[8,9] as well as hand-mouth coordination.[10–12]

In healthy, full-term newborns, the co-ordination of sucking, breathing, and swallowing develops rapidly in the days after birth. Ultrasonographic studies[13,14] revealed that within the first 4 postnatal days, the suck-to-swallow ratio increases markedly, breathing becomes uninterrupted during swallowing, and the breathing pattern becomes increasingly coordinated with sucking. Within the same perinatal period, breast-fed and bottle-fed babies demonstrated different patterns of oromotor action when not sucking or swallowing.[13] This observation points to the plasticity of the oromotor activity of the healthy newborn. The study of sucking and swallowing by infants born prematurely at gestational age 32 to 34 weeks indicates that within 3 to 5 days after birth, NS varied with nipple flow and type of feed.[15] When presented with a "dry" (non-nutritive) nipple before feeding, sucking burst and rates by the same premature infants increase markedly and are accompanied by intermittent swallowing, beginning 2 to 4 weeks after birth and when the infant weighed approximately 2000 g.[15] Although oral sensations and activities in healthy newborns are predictably rich and varied, the consequences of reduced or adverse oral experiences on preterm infants that are tube fed for protracted periods are unknown.

Recently, evidence was reported suggesting that NNS is associated with a reduction of behavioral distress to iatrogenic stressors during gavage feeding in preterm infants of gestational age 33 weeks.[16] The opportunity to suck on a pacifier during heelstick procedure is shown to reduce fussing and crying by healthy, full-term neonates, as well as by preterm neonates treated either in minimal care or intensive care nurseries.[17] The opportunity to suck on a pacifier during gavage feeding is shown to accelerate the development of the sucking response and to facilitate the transition from gavage to oral feedings, and it is also associated with more rapid weight gain,[18,19] but see also Reference 20. It is unclear, however, what the underlying mechanisms of such effects are. A necessary step toward the unveiling of such mechanisms is to capture the determinants and contextual variations of NNS by premature infants. Within this general perspective, the specific aim of the present research was to study how NNS might vary as a function of tube-feeding schedule.

Address for reprints: Philippe Rochat, Ph.D., Department of Psychology, Emory University. This research was presented at a Society for Pediatric Research poster session in Washington, DC, in June 1993.

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METHOD

Patients

Eleven infants born at gestational age 32 weeks or less who required respiratory support for less than 7 days and 30% oxygen or less were enrolled. At the time of testing, five infants (one boy and four girls) were on continuous nasogastric feedings (CNG), and six infants (two boys and four girls) were on intermittent nasogastric feeding schedule (ING). The mean post-conceptual age of the CNG group was 34 weeks (± 2.0 SD) and 35 weeks (± 2.3 SD) for the ING group. At the time of testing, the infants were not receiving respiratory treatment, and they did not receive any medication that affected feeding.

Procedure

NNS activities in terms of positive pressure variations applied on a pacifier were recorded on one channel of an FM recorder (TEAC portable cassette recorder; TEAC, Tokyo, Japan). The Kip ortho pacifier model 1219 was connected to an air pressure transducer (Grass Instruments, Quincy, MA). This type of pacifier was used routinely in the neonatal intensive care unit and provided to the infant at the discretion of the caretaker. During a 15-second pretest phase, the signal picked up by the transducer was amplified to match the upper limit of the decibel control dial on the FM recorder. Thus, the decibel level or signal amplitude was calibrated and set for each individual baby before testing. This adjustment provided comparability, despite the varying sucking vigor expressed by each individual infant. Simultaneous to the recording of sucking, a research assistant signaled the beginning and end of each test period by means of a microphone and the audio channel of the FM recorder. After testing, the recorded sucking activity was transferred from the FM recorder to the graphic paper of an ink polygraph (Grass, model 5). These hard copies of the recording were used for the subsequent quantitative analysis of sucking engagement.

Infants on the ING feeding schedule were tested for one 15-minute block of time divided into three consecutive 5-minute periods: 5 minutes before the starting of gavage feeding, 5 minutes from the beginning of gavage feeding, and 5 minutes after gavage. Infants on the CNG feeding schedule were tested for one continuous 5-minute period. This design allowed comparisons within and between groups of 5-minute periods of NNS recording. Infants were in isolettes, typically in a calm state with eyes closed, during the test. Testing was interrupted and postponed if the infant cried. The data from the partial sessions were discarded and attempted later the same afternoon. No session had to be rescheduled for another day. The infants were placed supine with the head turned to the left or right side. For all of the infants, the testing was performed in the afternoon, when routine cares and visits were at a minimum in the neonatal intensive care unit. Although routine procedure in the unit was to give infants access to a pacifier, it was not introduced systematically and never during gavage feeding of the ING babies. Pacifier presentation was at the discretion of the caretaker, hence it was difficult to assess the amount of previous experience with it for a particular infant.

Assessment of sucking engagement on the polygraphic recordings was based on operational definitions of individual suck and sucking burst.[8,9] This assessment was performed by hand, by two individual scorers, on the hard copy of the polygraphic recording. Reliability among scorers was assessed, and percentage agreement was greater than 92% for the following measures:

- Individual suck: Deflection of the polygraph pen from the zero baseline, corresponding to at least one-third of the maximal signal amplitude recorded in the particular condition. This measure was evaluated by hand, on the basis of the crossing of the zero baseline at the start of the suck (the first of the two crossing of baseline characterizing the polygraphic recording of a suck).
- Sucking burst: Successive sucks, separated by less than two seconds and varying in amplitude by no more than one third of the preceding one.

On the basis of these definitions, sucking engagement within a 5-minute recording period was assessed relative to the percentage of time engaged in sucking, the mean sucking burst duration, the mean number of sucks per burst, and the mean individual suck duration within a burst (sucking burst duration divided by number of sucks). Sucking intensity could not be analyzed because the signal amplitude was adjusted for each individual infant.

RESULTS

The analysis revealed that for the intermittent nasogastric feeding (ING) group, the percent of time engaged in sucking (proportion of sucking during the 5-minute test period) increased during gavage compared with the preceding and consecutive baseline phases. The sucking activity of the

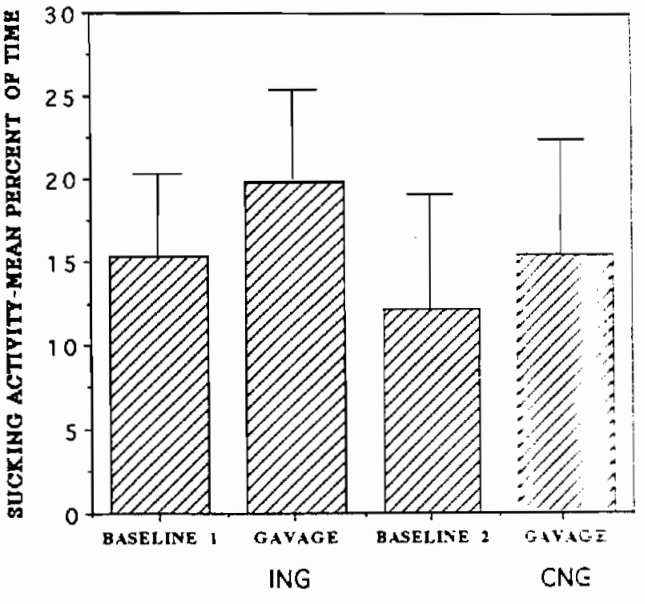

FIGURE 1. Mean percent of time engaged in sucking activities during baseline 1 (before gavage), gavage, and baseline 2 (after gavage) for the intermittent nasogastric group (ING), and the 5-minute testing of the continuous nasogastric group (CNG).

continuous nasogastric feeding (CNG) group was equivalent to both baselines of the ING group (Fig. 1). ANOVA with repeated measure on the percentage of time spent in sucking (n = 6 ING infants) yielded no significant overall difference between the three sucking phases [$F(2,10) = .888$; $p < .441$]. A trend analysis, however, yielded a marginally significant quadratic trend [$F(1,5) = 5.73$; $p < .062$], corresponding to the one displayed on Figure 1 for the ING group. Given the small sample size (n = 6), the effect can be considered as substantial in magnitude.[21] The total treatment variance (r^2) accounted for by the quadratic component is .83, and the partial omega squared is .278.[22] This result indicated that sucking engagement increased during the gavage phase in infants on an ING schedule. Five of the six infants in the ING group showed an increase in the proportion of sucking from baseline 1 to gavage, and one infant showed stability. None of the infants showed a decrease in the proportion of sucking from baseline 1 to gavage phase (binomial test for equal probability of outcome, $p < .02$).

A similar pattern was observed in the mean sucking burst duration measure. The average sucking burst duration doubled during the gavage phase for the ING group and was comparable between the CNG group and the two baseline periods of the ING group (Fig. 2). In the ING group, all six of the infants showed an increase in the average sucking burst duration from baseline 1 to gavage feeding and a decrease from gavage to baseline 2 (binomial test, $p < .02$). These results demonstrated that the infants on the ING schedule tended to engage in prolonged sucking bursts during gavage. ANOVA with repeated measures across conditions confirmed this trend by yielding a significant condition main effect [$F(2,10) = 3.91$; $p < .05$]. Trend analysis yielded a significant quadratic trend, [$F(1,5) = 6.51$; $p < .05$], corresponding to the one displayed on Figure 2 for the ING group.

Measure of the mean number of sucks per burst also captured the increase in sucking engagement by the ING group during gavage. The ING group sucked at a greater frequency within a sucking burst during gavage compared with both baseline periods and the recorded period with the CNG group of infants. Five of the six infants of the ING group showed an increase in the mean number of sucks per burst from baseline 1 to gavage and a decrease from gavage to baseline (Fig. 3). ANOVA with repeated measure on mean number of sucks per burst (n = 6 ING infants) yielded no significant difference between the three sucking phases [$F(2,10) = 2.73$; $p < .113$]. A trend analysis, however, yielded a significant quadratic trend [$F(1,5) = 6.51$; $p < .051$].

Finally, analysis of the average duration of individual sucks indicated a significant increase by the ING group during gavage, as shown on Figure 4. ANOVA with repeated measures of individual suck duration for the ING group across conditions yielded a significant effect of condition [$F(2,10) = 5.05$; $p < .03$]. Trend analysis confirmed the significant quadratic trend illustrated on Figure 4 for the ING group [$F(1,5) = 6.5$; $p < .05$]. Five of the six infants of the ING group showed an increase in individual suck duration from baseline 1 to gavage feeding period.

DISCUSSION

The present study indicated that tube-fed, preterm infants on an intermittent nasogastric feeding (ING) schedule showed a marked increase in non-nutritive sucking (NNS) activities during gavage, compared with pregavage and postgavage feeding baseline periods. During gavage, the infants in the ING group had more sucking, longer bursts, a higher frequency of sucks per burst, and a longer duration of indi-

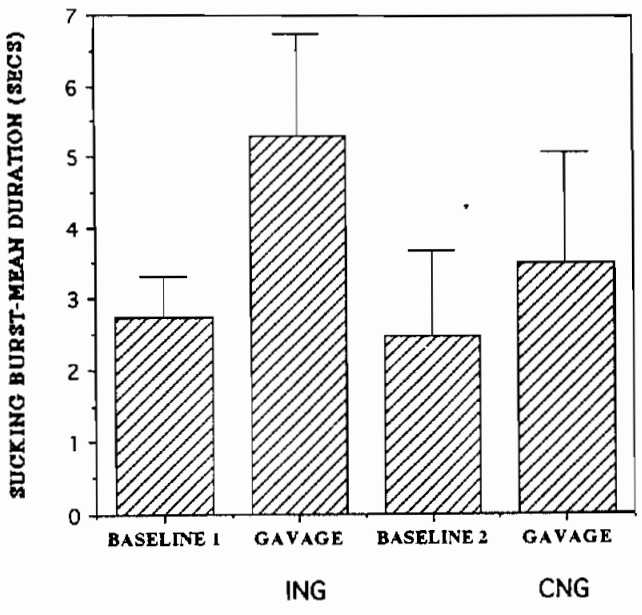

FIGURE 2. Mean duration of the sucking burst during baseline 1 (before gavage), gavage, and baseline 2 (after gavage) for the intermittent nasogastric group (ING), and the 5-minute testing of the continuous nasogastric group (CNG).

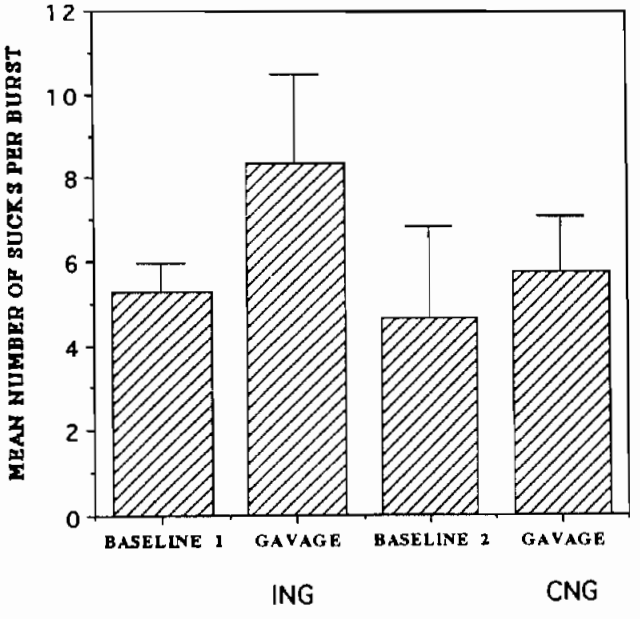

FIGURE 3. Mean number of sucks per burst during baseline 1 (before gavage), gavage, and baseline 2 (after gavage) for the intermittent nasogastric group (ING), and the 5-minute testing of the continuous nasogastric group (CNG).

vidual sucks within a burst. Because it is associated with enhanced NNS, ING feeding could potentially contribute to an earlier transition to oral feeding.[18,19]

Feedings introduced by means of a nasogastric tube deprive the infant of the gustatory experience associated with orally ingested food. In addition, gavage feeding eliminates the opportunity to explore an intraoral stimulus from which food can be expressed. Furthermore, a continuous nasogastric feeding (CNG) schedule deprives the infant of the contrasts between alternating periods of fasting and feeding. This deprivation seems to be particularly important, in light of recent evidence demonstrating that long-term continuous nutrition does not allow for the establishment of the circadian modulation of heart rate.[23] Salzarulo et al[23] found, however, that CNG infants manifested the same fluctuations in combined responses characterizing behavioral states, i.e., electroencephalogram, electro-oculogram, electromyelogram, electrocardiogram, respiration, and NNS, as a group of infants that had regular oral meals. Lepecq et al[24] reported that older CNG infants manifested the same average frequency and a comparable pattern of spontaneous NNS in the various behavioral states they displayed during a full 24-hour period. These infants were 1 to 13 months old, however, born at term and fed on a CNG schedule only because of significant medical or surgical digestive pathologies.

Enteral nutrition is of paramount importance for preterm, very low birth weight infants, and various modes of feedings are chosen to achieve this goal. The developmental consequences of enteral feeding modes on learning and on behavioral and physiological state regulation are mostly unknown. The present data suggest that the expression and pattern of NNS in gavage-fed, preterm infants are influenced by ING or CNG feedings. This conclusion, however, should be considered in light of the fact that in the present study, the ING group was, on average, 1 week older than the CNG group at the time of testing. Although a 1-week age difference might not account for much of the phenomena reported here, this age confound should be controlled in future research to provide additional support to our conclusion.

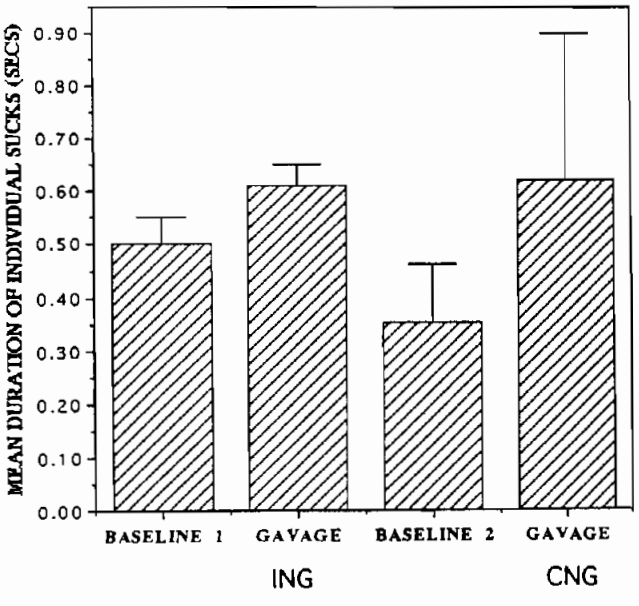

FIGURE 4. Mean duration in seconds of individual sucks within a burst during baseline 1 (before gavage), gavage, and baseline 2 (after gavage) for the intermittent nasogastric group (ING), and the 5-minute testing of the continuous nasogastric group (CNG).

Questions remain concerning the behavioral consequences of CNG feeding compared with alternating periods of fasting and feeding. NNS and the opportunity to suck on a pacifier have been associated with significant weight gain and maturation in tube-fed, preterm infants.[18,20,25] A similar link between NNS and positive outcome can be hypothesized concerning the transition from tube to regular oral feedings. Because the transition from tube to oral feedings depends on the development of functionally mature sucking, an increase of oromotor activities, such as NNS exercise, might be a factor to the reduction of the protracted and aversive period of tube feeding in preterm infants.

The recorded sucking response corresponds to what is commonly described as NNS. This pattern of response is characterized by a rhythmic alternation of bursts and pause periods.[5,24] NNS is distinct from a pattern of nutritive sucking (NS), which is described as a more continuous stream of sucks that occur at a slower pace.[24] Wolff [5] proposed that because of their differential patterns, NNS and NS are functionally distinct and controlled by different central mechanisms. This suggests that NS is functionally oriented toward feeding, whereas NNS is not. The observations reported here, however, indicate that the functional distinction between NNS and NS is not clear cut. The NNS responses we recorded do seem to depend on a feeding context, i.e., the bolus gavage feeding occuring with the ING schedule. These observations demonstrate that in the context of ING feedings, NNS engagement in tube-fed infants depends on stomach cues and/or temperature changes associated with tube feedings.

Because learning and practice are integral to the development of mature sucking,[2] early ING feeding combined with the opportunity to suck on a pacifier should foster an earlier transition to regular oral feeding in very low birth weight infants. The contrast between alternating periods of fasting and feeding offered by the ING schedule might play a role in enhancing motivational systems responsible for the infant sucking engagement.[23]

On the basis of the present observations, we suggest that the pacifier should be introduced during gavage periods to optimize the functional link between sucking and feeding in very low birth weight infants. Future studies should assess the effect of such intervention on the development of mature sucking responses in preterm infants, in particular its contribution to the accelerated development of sucking and the potential reduction of the period of tube feeding.

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REFERENCES

1. Darwin C: The Expression of the Emotions in Man and the Animals. London, John Murray, 1872
2. Piaget J: The Origins of Intelligence in Children. New York, International Universities Press, 1952
3. Abraham K: The influence of oral eroticism on character formation, in ~~XXX XX (ed)~~: Selected Papers of Karl Abraham. New York, NY, Basic Books, 1927
4. Spitz RA: The First Year of Life: A Psychoanalytic Study of Normal and Deviant Development of Object Relations. New York, NY, International Universities Press, 1965
5. Wolff PH: The serial organization of sucking in the young infant. Pediatrics 42:943–956, 1968
6. Sameroff AJ: The components of sucking in the human newborn. J Exp Child Psychol 6:607–623, 1968
7. Crook CK: The organization and control of infant sucking, in Reese HW, Lipsitt LP (eds): Adv Child Dev Behav 14:209–246, 1979
8. Rochat P: Oral touch in young infants: Responses to variations of nipple characteristics in the first months of life. Int J Behav Dev 6:123–133, 1983
9. Rochat P: Mouthing and grasping in neonates: Evidence for the early detection of what hard or soft substances afford for action. Infant Behav Dev 10:435–449, 1987
10. Butterworth G, Hopkins B: Hand-mouth coordination in the new-born baby. Br J Dev Psychol 6:303–314, 1988
11. Rochat P, Blass EM, Hoffmeyer LB. Oropharyngeal control of hand-mouth coordination in newborn infants. Dev Psychol 24:459–463, 1988
12. Blass EM, Fillion T, Rochat P, Hoffmeyer LB, Metzger MA: Sensorimotor and motivational determinants of hand-mouth coordination in 1–3-day-old human infants. Dev Psychol 25:963–975, 1989
13. Weber F, Woolridge MW, Baum JD: An ultrasonic study of the organisation of sucking and swallowing by newborn infants. Dev Med Child Neurol 28:19–24, 1986
14. Selley,WG, Ellis RE, Flack FC, Curtis H, Callon M: Ultrasonic study of sucking and swallowing by newborn infants. Dev Med Child Neurol 28:814–823, 1986
15. Gryboski JD: Suck and swallow in the premature infant. Pediatrics 43:96–102, 1969
16. DiPietro JA, Cusson RM, Cauhy MO, Fox NA: Behavioral and physiologic effects of non-nutritive during gavage feeding in preterm infants. Pediatr Res 36:207–214, 1994
17. Field T, Goldson E: Pacifying effects of non-nutritive sucking on term and preterm neonates during heelstick procedures. Pediatrics 74:1012–1015, 1984
18. Bernbaum JC, Pereira GR, Watkins JB. Peckham GJ: Non-nutritive sucking during gavage feeding enhances growth and maturation in premature infants. Pediatrics 71:41–45, 1983
19. Anderson GC, Burroughs AK, Measel CP: Non-nutritive sucking opportunities: A safe and effective treatment for preterm infants, in Fields T, Sostek A (eds): Infants Born at Risk: Physiological, Perceptual and Cognitive Processes, ch 6. New York, NY, Grune & Stratton, 1983, pp 129–146
20. Ernst JA, Rickard KA, Neal PR, Yu PL, Oei TO, Lemons JA: Lack of improved growth outcome related to non-nutritive sucking in very low birth weight premature infants fed a controlled nutrient intake: A randomized prospective study. Pediatrics 83:706–716, 1989
21. Rosnow RL, Rosenthal R: Statistical procedures and the justification of knowledge in psychological science. Am Psychol 44:1276–1284, 1989
22. Keppel G: Design and Analysis: A Researcher's Handbook, 3rd ed. Englewood Cliffs, NJ: Prentice Hall, 1991
23. Salzarulo P, Fagioli I, Ricour C: Long-term continuously fed infants do not develop heart rate circadian rhythm. Early Hum Dev 12:285–289, 1985
24. Lepecq JC, Rigoard MT, Salzarulo P: Spontaneous non-nutritive sucking in continuously fed infants. Early Hum Dev 12:279–284, 1985
25. Field T, Ignatoff E, Stringer S, et al: Non-nutritive sucking during tube feedings: Effects on preterm neonates in an intensive care unit. Pediatrics 70:381–384, 1982