A Global Perspective on Feeding Assessment in the Neonatal Intensive Care Unit

Robin P. Glass, Lynn S. Wolf

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A comprehensive assessment of feeding performance of infants in the neonatal intensive care unit (NICU) includes not only the traditional approaches of evaluating oral motor control and sensory responses but also evaluation of other factors. Infant feeding is a highly complex and integrated process involving numerous body systems. A global assessment would determine the infant's feeding function in the key areas of state and behavior, tactile responses, motoric control, oral motor function, physiologic control, and coordination of sucking, swallowing, and breathing. Information is obtained through skilled clinical observation as well as from technological monitors or medical tests and procedures. This article provides an overview of a comprehensive assessment that occupational therapists may use when providing service to infants in the NICU.

The evaluation and treatment of feeding problems is an important area of practice for occupational therapists. Traditional approaches that are used to address feeding in the general pediatric population, however, often seem inadequate when used with the neonatal intensive care unit (NICU) population.

Several differences exist between infants in the NICU and the general pediatric population that affect the types of assessments used with these patients. Infants in an NICU have medical conditions that require a high level of technical medical care and skilled observation. Many have conditions that include a respiratory component, thus treatment with mechanical ventilation and oxygen therapy is common. In addition, these infants may have conditions with a component of central nervous system dysfunction or congenital anomalies. The physical environment of the NICU and the various caregiving and medical procedures that occur routinely are also factors that these infants must deal with at a time when they are immature or critically ill.

Another important difference is that infants feed by sucking, which is a more complex skill than it appears. Not only must oral motor skills be adequate for sucking, but sucking must also be intricately coordinated with both swallowing and breathing (Selley, Ellis, Flack, & Brooks, 1990). Dysfunction in any of these three individual functions or in their coordination can lead to feeding problems. Therefore, to provide effective therapy services to babies in the NICU, occupational therapists must thoroughly understand the complexity of infant feeding (Wolf & Glass, 1992).

Typically, feeding assessments have focused on oral motor skills, underlying postural and neuromotor control, and the tactile components of feeding. Assessment of the NICU infant must also include careful evaluation of swallowing function and respiratory function, as well as the coordination of all these activities during feeding. For the immature and medically compromised infant, feeding may be interpreted as a stressful event rather than a comforting and satisfying experience. Such stress can often lead to physiologic compromise (such as apnea or bradycardia) or to worsening medical status (Als, 1982, 1986).

Therefore, a comprehensive feeding assessment for infants in the NICU should be based on an understanding of the infant's medical problems, level of maturity, and evaluation of feeding performance as seen in these key areas: state and behavior, tactile responses, motoric control, oral motor function, physiologic control, and coordination of sucking, swallowing, and breathing. This type of assessment calls for multisensory observation, which implies gathering information by looking, feeling, and listening as the infant feeds, as well as analyzing data obtained from cardiorespiratory monitors, oximeters, or multichannel pneumograms (Wolf & Glass, 1992).

This article details a framework for comprehensive

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feeding assessment of infants in the NICU. It presents seven broad, key areas related to feeding performance to include in this type of assessment and highlights the interrelationships of the infant's medical condition, the NICU environment, and competence in feeding function.

State Control and Behavioral Responses

Two aspects of state control and behavioral responses related to infant feeding are that (a) the infant must be able to achieve and maintain an optimal state for feeding and (b) state and behavior reflect the infant's response to feeding.

State Control

Observing the range and clarity of an infant's states is an important feature of all neurobehavioral evaluations of neonates. The Neonatal Behavioral Assessment Scale (Brazelton, 1984), for example, defines a continuum of six states of consciousness ranging from deep sleep through awake states to crying. When an infant's state falls at the ends of this continuum—when the infant is either too sleepy or too fussy—it can interfere with feeding performance. In some cases, state is actually the primary limiting factor of feeding. For example, an infant who is irritable and cannot be calmed will be unable to feed effectively.

During a feeding evaluation the infant's state is noted before, during, and after feeding with a standard format from a neurobehavioral evaluation (Brazelton, 1984; Dubowitz & Dubowitz, 1981). If at any point the infant is not in an appropriate state for feeding, the therapist determines whether the infant can be brought into an appropriate state for feeding. If so, the amount of assistance the infant needs to change states and what techniques are used should be noted. The therapist may also observe how much assistance the infant requires from the feeder to maintain an appropriate state for feeding.

The optimal state for feeding is an awake, alert, or active state, although some infants can feed adequately in a drowsy state. When feeding is first introduced to sick and preterm infants, the ability to stay awake and alert may only be emerging. These infants, therefore, may frequently be drowsy, or move in and out of light sleep during feeding (VandenBerg, 1990). If state control difficulties are influencing a preterm infant's feeding performance, the gestational age expectations for state of alertness should be considered, as well as the functional effect that state control problems have on feeding. State control difficulties may also be components of a variety of other medical conditions. For example, infants who have had intrauterine toxin exposure may often be in a too heightened or disorganized state to feed adequately.

Behavioral Responses

An infant's state and behavior are methods by which the infant communicates his or her ability to adapt to changing environmental demands. The feeding process places many demands on the infant. These demands may be internal, such as increased respiratory and digestive functions, or external, such as oral–tactile experiences during feeding or variations in ambient temperature, noise, or light. If these demands are beyond the infant's adaptive capacities, the infant may respond with behaviors that reflect stress (Als, 1982).

Als (1982) has termed these behaviors stress signals and stated that these cues may be observed in several domains of behavior including motoric, autonomic, and state or attentional responses (see Table 1). Although the notion of stress cues was first developed for the premature population, it is also directly applicable to term and other chronically ill infants (Gorski, Davison, & Brazelton, 1979). If stress cues are noted before, during, or after a feeding, the source of the stress needs to be identified. Is stress secondary to environmental sources, such as bright lights, liquid flowing too fast, or discomfort from gastroesophageal reflux? When a hypothesis about the source of the infant's stress is made, modification of that aspect of the feeding process, if possible, may improve feeding performance.

Responses to Tactile Input

Even in the preterm infant, the tactile system is relatively sophisticated at birth because tactile sensitivity around the face and in the mouth is present at 12 weeks' gestation (Humphrey, 1964). Reflexes in and around the mouth assist the infant in locating and obtaining nutrition. Because the mouth and face are richly supplied with tactually based sensory receptors, the infant's response to tactile input is an important component of effective feeding (Morris & Klein, 1987). Evaluation of the infant's response to tactile input focuses on two broad areas—oral reflexes and behavioral responses to tactile input.

Oval Reflexes

The elicitation of specific oral reflexes during a feeding evaluation can give the therapist information about the integrity or maturity of the infant's neurologic system. In addition, it provides information regarding the quality of the infant's response to tactile input externally in the oral-facial area and internally in the oral-pharyngeal region. Oral reflexes can be either adaptive or protective. The adaptive reflexes assist the infant in locating and obtaining food and include the rooting reflex and the sucking reflex. Protective oral reflexes keep the airway free of foreign material or expel it if it enters the airway. These reflexes include the cough and the gag reflex (Sant'Am-
Table 1
Infant Stress Cues

<table>
<thead>
<tr>
<th>State and Attentional Stress Cues</th>
<th>Motoric Stress Cues</th>
<th>Autonomic Stress Cues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritability</td>
<td>Motoric flaccidity: trunk, extremities, face (gape face)</td>
<td>Moderate stress</td>
</tr>
<tr>
<td>Crying</td>
<td>Motoric hypertonicity: Hyperextensions of the legs (sitting on air, leg bracing)</td>
<td>Sighing, yawning</td>
</tr>
<tr>
<td>Frenzy, inconsolability</td>
<td>Hyperextensions of the arms and hands (saluining, airplaning, fingers splayed)</td>
<td>Sneezing</td>
</tr>
<tr>
<td>Rapid state changes</td>
<td>Truncal hyperextensions (arching, opisthotonos)</td>
<td>Sweating (diaphoresis)</td>
</tr>
<tr>
<td>Drowsy alertness</td>
<td>Hyperflexions (fetal tucking, lashing)</td>
<td>Hiccupping</td>
</tr>
<tr>
<td>Strained alertness</td>
<td>Facial grimacing</td>
<td>Trembling</td>
</tr>
<tr>
<td>Panicked alertness, hyperalertness</td>
<td>Frantic, diffuse activity</td>
<td>Startling</td>
</tr>
<tr>
<td>Diffuse sleep or awake states</td>
<td></td>
<td>Gasping</td>
</tr>
<tr>
<td>Staring</td>
<td></td>
<td>Straining</td>
</tr>
<tr>
<td>Frequent gaze aversion</td>
<td></td>
<td>Major stress (when seen with feeding)</td>
</tr>
<tr>
<td>Strained fussing or crying</td>
<td></td>
<td>Frequent or prolonged coughing</td>
</tr>
<tr>
<td>Silent crying</td>
<td></td>
<td>Spitting up</td>
</tr>
</tbody>
</table>


It may be more clinically relevant to observe the interplay of the oral reflexes with functional feeding behaviors, rather than simply noting the presence or absence of a particular reflex, because the expression of any oral reflex is extremely variable and can change depending on the infant's level of hunger or state of alertness (Ingram, 1982). For example, although the presence of the rooting reflex can be a behavioral cue that the infant is receptive to eating, its expression can vary depending on the infant's state of alertness or level of hunger.

Coughing can be a reflex response to touch or pressure from food or secretions in the pharynx or larynx (Leith, 1985). If coughing is observed, the events surrounding the cough, the infant's physiologic response to the cough, and how quickly the infant recovers should be noted. These factors will provide information regarding the significance of coughing for that particular infant. In addition, the timing of the cough may indicate the etiology. If the cough occurs during sucking and swallowing it may indicate material crossing near or entering the airway as it descends through the pharynx. If coughing is observed during sucking pauses, or after feeding, it may indicate material ascending into the pharynx from gastroesophageal reflux (Orenstein & Orenstein, 1988).

If the protective reflexes of gag and cough are absent or diminished, therapists are often faced with the question of when an infant can be fed safely. The primary purpose of the gag reflex is to protect the infant from ingesting a bolus that is too large to safely pass through the pharynx or esophagus (Morris & Klein, 1987). Bolus size is reasonably controlled because infants who are nipple feeding receive a liquid diet; thus the presence of an effective cough reflex is a more important prerequisite for the initiation of oral feeding (Wolf & Glass, 1992).

**Behavioral Responses to Tactile Input**

The ability to register and respond to tactile input in an organized fashion is an important prerequisite to being an effective feeder. During feeding, the infant accommodates to a wide variety of tactile stimuli within the mouth, such as the touch of the nipple on the tongue and the taste of the liquid, as well as external stimuli from the touch of the feeder's hands on the infant's face or the touch-pressure of being held. The infant must perceive the tactile input appropriately to produce the appropriate motoric responses for feeding.

Many infants in the NICU, however, perceive tactile input as a stress even if the input was meant to be comforting. They respond with a variety of stress reactions manifesting as alterations in motor control, physiologic stability, or behavioral state (Als, 1986) (see Table 1). For example, when handled for routine diaper changes or when the face is wiped during feeding, some infants respond with the motoric stress behaviors of arching or increasing muscle tone. If stress reactions are observed during a feeding evaluation, both the intensity of the response and the type of response are noted.

To deal with the bombardment of stimuli sometimes present in the NICU, some infants may have exaggerated responses to tactile input, or may underrespond by turning out. Common NICU medical treatments such as intubation, tube feeding, or suctioning provide negative and aversive stimuli to the oral-facial area. The introduction of feeding may be extremely delayed because of lengthy
intubation and mechanical ventilation or the ongoing presence of respiratory compromise that is incompatible with oral feeding. In addition, the infant may be unable to engage in normal, pleasurable oral exploration because of motoric immaturity or delay, intubation, or lack of experience. Thus, the infant has a period of relative sensory deprivation from normal oral experiences, combined with pervasive negative oral experiences imposed on an immature central nervous system. This situation results in a pattern of learned negative or aversive behaviors that persist well beyond the period during which the infant was critically ill and may persist even after discharge from the NICU (Illingworth & Lister, 1964).

Evaluation of behavioral responses to tactile input can be observed in several ways. Casual observation of the infant's response to the feeding situation may provide the therapist with sufficient information, especially for the younger or sicker infant. For some infants, especially older infants, a more structured evaluation of tactile responses may be indicated to clearly delineate the threshold beyond which the infant has an inappropriate behavioral response to tactile input. A wide variety of behavioral responses to tactile input can be observed, including absent, hyposensitive, hypersensitive, or aversive responses. The infant who begins to gag when the lips are touched with a finger or nipple is exhibiting a hypersensitive tactile response.

**General Motoric Control**

Components of motoric control, such as muscle tone, primitive reflex activity, and postural support, influence control of oral motor functions and affect the feeding position. These functions can be assessed with standard protocols for neurodevelopmental evaluation (Capute, Accardo, Vining, Rubenstein, & Harryman, 1978; Chandler, Andrews, & Swanson, 1980; Dubowitz & Dubowitz, 1981; Morgan, Koch, Lee, & Aldag, 1988) or through casual observation as the therapist prepares to feed the infant.

**Feeding Position**

An optimal position for young infants is characterized by orientation around midline, neutral anterior–posterior alignment of the head and neck, neutral alignment or slight flexion of the trunk, and flexed hips and knees. The infant's position should be symmetrical with a predominance of flexion. The neuromotor components described above, the infant's medical condition, and environmental factors (including the feeder's body mechanics) can have a strong influence on feeding position. When the feeding position is not satisfactory, the underlying factors affecting the position should be identified to develop appropriate positioning techniques.

For example, infants diagnosed with infant respiratory distress syndrome, bronchopulmonary dysplasia, or meconium aspiration frequently demonstrate excessive neck extension, though the mechanisms are not clearly understood. The interplay of prolonged mechanical ventilation and attempts to maximize the size and stability of the airway (Ardran & Kemp, 1968), in conjunction with decreased muscle tone, strength, and postural control at the neck, may be contributing factors. This neck extension posture may become a habitual response and the infant may assume a position of neck hyperextension when held to feed. If the therapist attempts to move the head into a more neutral alignment, the infant may feel as though airway stability is threatened and may resist. Therefore, the baseline feeding position and changes that the therapist wishes to make in feeding position need to be considered in terms of the infant's overall medical status.

The possibility of airway collapse is another aspect of airway patency. Studies suggest that the airway is more prone to collapse with neck flexion (Ardran & Kemp, 1968; Thach & Stark, 1979). Bosma (1988) presented the principle that cranio cervical posture and pharyngeal airway stability are interconnected. Therefore, when positioning infants for feeding who have minimal cranio cervical control (which may include premature infants, hypotonic infants, and some full term infants), excessive neck flexion (whereby the chin nearly touches the chest) should be avoided to minimize the risk of airway collapse.

**Motoric Activity as a Reflection of Stress**

Although therapists often evaluate an infant's motor status from the perspective of skill development or neuromotor integrity, motoric responses can also be behaviors that the infant uses for communication. Als (1986) described hyperflexion and hyperextension of the trunk and extremities as examples of behavioral cues that the infant is experiencing stress. When these behaviors occur during feeding, the source of the stress must be identified, as described above in the discussion of state control and behavior. When these types of motor responses are the infant's predominant motor patterns, the therapist is often faced with the dilemma of determining whether these patterns are truly reflections of abnormal neurologic integrity or are motoric responses to stress.

An example is the infant who appears hypertonic and uses strong patterns of extension to move. This child may extend during feeding and be difficult to hold in the optimal feeding position. The underlying reasons for these motoric observations may be due to abnormalities of the central nervous system or due to other factors. Perhaps this is an infant who is using neck extension to maintain a patent airway or who is stressed by the tactile or gustatory aspects of feeding.

Identifying the underlying causes for the motor behavior is important to choosing the appropriate treat-
ment modalities. Although neurodevelopmental treatment techniques may be effective for the infant with central nervous system dysfunction, they may have limited applicability for the infant with problems of airway patency.

Oral Motor Control

Evaluation of oral motor control in infants focuses on the oral structures involved in sucking: the tongue, jaw, lips, cheeks, and palate. During sucking, these structures work together, though each has specific functions in creating pressure gradients that bring food into the mouth, move the bolus posteriorly, and prepare the bolus for swallowing. Evaluation of each structure focuses on both the characteristics of the resting position and the components of movement that contribute to these functions (see Appendix). The developmental progression of skill acquisition of each of these structures should also be considered. Assessment of the specific function of each structure is most effective if the infant sucks on the examiner’s gloved finger.

In evaluating oral motor functions in the NICU population, anatomic differences between the term infant and the preterm infant must also be considered. The term infant is born with a substantial amount of subcutaneous fat and well-defined fat pads, also called sucking pads (Bosma, 1980). The tongue fills the oral cavity and is in physical contact with all the surfaces of the oral cavity. Bosma (1972) described these anatomical features as providing the term infant with an exoskeleton that provides a high degree of positional stability. At birth, the term infant has strong physiologic flexor tone that, combined with the exoskeleton, provides a stable base for the oral structures.

In contrast, the premature infant has less muscle bulk and poorly developed tendinous and ligamentous structures (Bosma, 1972). Although the fat pads are present, there is significantly diminished body fat. These features lead to decreased opposition of the tongue to the surfaces of the oral cavity. There is also reduced flexor tone through the head and neck, with neck hyperextension. All these factors may combine to decrease the amount of positional stability available to support feeding function in the preterm infant (Bosma, 1967). This lack of positional stability may lead to abnormal oral motor patterns, such as excessive jaw movements, or tongue tip elevation (Wolf & Glass, 1992).

A wide variety of oral motor difficulties may be observed in infants in the NICU. Only a few of the more frequently seen patterns are highlighted here. More detail on these and other abnormal patterns, as well as the developmental progression of oral motor skills, is available elsewhere (Morris & Klein, 1987; Wolf & Glass, 1992).

Tongue-Tip Elevation

This pattern is believed to be an attempt by the infant to attain stability in the oral area when intrinsic stability is poor. The tip of the tongue is held firmly against the hard palate behind the upper alveolar ridge, thus potentially interfering with nipple insertion. Tongue-tip elevation is frequently observed in premature infants, possibly secondary to their inherent lack of stability (Bosma, 1967, 1972).

Tongue Retraction

The tongue sits back in the mouth, well behind the alveolar ridges. This pattern interferes with sucking because there is often poor contact between the tongue and nipple to stimulate appropriate tongue movements. A retracted tongue can also be thick and bunched with an inadequate central groove, further compromising effective tongue movement. Strong neck hyperextension can contribute to tongue retraction by pulling the tongue back into the mouth.

Tongue Protrusion

During sucking, the tongue normally moves in a wavelike anterior–posterior pattern. In contrast, when a tongue protrusion pattern is present, the movement distinctly pushes outward. The tongue may simply compress the nipple, with little suction generated, leading to inefficient sucking. During tongue protrusion, the tongue generally does not protrude past the border of the lips. When the tongue protrudes farther, or the protrusion is very strong, it is often called tongue thrusting. Infants who have sucked on endotracheal tubes may develop a protrusion pattern. This pattern may also be seen in infants with low tone.

Excessive Jaw Excursion

In this pattern, the jaw moves in a greater range than expected and the movement is poorly graded, although it may be very rhythmic. Tongue contact on the nipple may be poor, diminishing both compression and suction, leading to inefficient sucking. Because the range of jaw movement is exaggerated, lip seal can also be compromised, further impairing sucking. This pattern appears to be a reflection of poor jaw stability.

Physiologic Control

Because feeding is an infant’s aerobic work, the infant will have physiologic responses to that work (Browning & Bricker, 1990; Guyton, 1991). Typically these include small increases in heart rate and respiratory rate. If an infant is not able to cope effectively with the work of
feeding, these responses may include significant changes in heart rate or respiratory rate, decreases in oxygen saturation, autonomic indicators of stress (such as color changes), and poor endurance.

When assessing physiologic control during feeding, each parameter is evaluated at baseline, during feeding, and after feeding to determine the infant's recovery. Changes in physiologic parameters may be gradual. If abrupt changes are seen, however (such as bradycardia, sudden desaturation, or marked color change), the surrounding events should be noted carefully. These associated events may lead to an understanding of the etiology of these physiologic changes.

Heart Rate
To measure heart rate accurately and continuously, a cardiorespiratory monitor is used. In term infants, heart rate is typically in the range of 120 to 140 beats per minute (Chow, Durand, Feldman, & Mills, 1984; Crave, 1986). Resting heart rate in premature infants is slightly higher.

In a small sample of 32- to 35-week premature infants Sweeney (1986) found a mean rate of 145 beats per minute with a standard deviation of 15. It is not uncommon to find premature infants with resting heart rates of 160 to 170 beats per minute. Tachycardia (a very high resting heart rate) may indicate that the infant is working harder to maintain homeostasis.

Research has indicated that term infants and preterm infants respond to the demands of their environment (such as handling, caregiving, and social interaction) with increases in heart rate (Gorski, Hole, Leonard, & Martin, 1983; Sweeney, 1986). Studies have not specifically targeted feeding, but clinically it is not uncommon to see heart rate increases of about 10 beats per minute during feeding. Larger increases may indicate that feeding is placing excessive demands on the infant. In an infant with a high baseline resting heart rate, even smaller increases in heart rate during feeding can indicate great physiologic stress.

Bradycardia (a drop in heart rate to below 100 beats per minute) (Talner, 1990) can also be observed during feeding in high-risk infants, and is a potentially life threatening event. When it is noted during feeding, the surrounding events should be observed carefully. For example, the bradycardia might occur after oxygen desaturation, or with a suspected reflux event, or with position change. If the trigger for the bradycardia can be identified, modifications can often be made to the feeding practices to decrease the likelihood of its occurrence.

There are several common reasons for bradycardia in immature and medically compromised infants. In some cases it is a vagally mediated response to stimulation of sensory receptors in the pharyngeal-laryngeal area. Bradycardia may be triggered via stretch receptors within the pharynx that may be stimulated by a large bolus.

Touch-pressure receptors can be stimulated by the presence of nasogastric tubes, or chemoreceptors can be stimulated by microaspiration of food or by reflux of gastric contents. Decreases in oxygen saturation can also lead to bradycardia (Mathew & Sant'Ambrogio, 1988).

Respiratory Rate
The most accurate method of measuring respiratory rate (RR) is counting the infant's breaths. Although cardiorespiratory monitors are often used in the NICU, their measurements of respiratory rate are influenced by movement artifact and the averaging of values; thus, their validity as a measure of respiratory rate during feeding may be limited. Baseline measurement is made with the infant awake, because RR is significantly lower during sleep (Morley, Thornton, Fowler, Cole, & Hewson, 1990).

Normal values for term infants are 30 to 60 breaths per minute (Crane, 1986; Gould, 1991). In healthy preterm infants, RR may be slightly higher than in term infants (Gorski et al., 1983; Sweeney, 1986). In infants with any type of respiratory compromise, however, RR can be significantly elevated. When pulmonary mechanics are altered by poor pulmonary compliance, airway restriction, or impaired gas exchange, increased RR is one common compensatory mechanism (Redding, Morray, & Rea, 1987). With respiratory compromise, however, respiratory reserve is also low, so the extra work load of feeding can result in further increases in respiratory rate.

Research shows that bottle-feeding infants causes changes in respiratory rate and other respiratory parameters (Mathew, 1988; Mathew, Clarke, Pronkske, Luna-Solarzano, & Peterson, 1985; Shivpuri, Martin, Carlo, & Farnaroff, 1983). During active sucking the respiratory rate is low, but it is higher during the pauses, leading to an overall composite RR that may be adequate for effective ventilation. In term infants and preterm infants, during the early part of feeding when the infant is sucking eagerly, the respiratory rate decreases significantly from baseline values. As the feeding progresses and the infant sucks less eagerly, taking more pauses to breathe, the respiratory rate increases toward baseline. Older premature infants and term infants who have returned to their baseline RR by the end of the feeding. Younger premature infants not only show greater decrease in RR during the early part of the feeding, but also are slower to return to baseline.

This information has several implications for feeding assessment. Infants who require a high respiratory rate to maintain homeostasis may not be able to tolerate the suppression in respiration that occurs in the early part of feeding. The infant may fatigue easily or may be at risk for aspiration as he or she tries to gasp for air. Our clinical experience suggests that infants with a resting RR (when awake) above 65 to 70 breaths per minute are often un-
able to maintain adequate ventilation during feeding, and are therefore not good candidates for standard oral feeding (Wolf & Glass, 1992). Respiratory rate during feeding is measured during pauses in sucking. If the RR is above 80 breaths per minute during these pauses, it often indicates that the work of feeding is too great for the infant. In this case, it is recommended that feeding be terminated and nonoral feeding be considered until respiratory work during feeding is reduced (Wolf & Glass, 1992).

**Oxygen Saturation**

Current practice in the NICU includes generous use of pulse oximeters to monitor the infant’s oxygen saturation and identify hypoxemia. Oximeters are noninvasive, give continuous readings, and can be useful in identifying the infant’s response to activities, including feeding. Oxygen saturation in the blood is expressed as a percentage of 100, with values in the high 90s being normal. Lower values are often considered acceptable for premature infants and those with respiratory compromise, and are established by the infant’s physician. When values fall below 88% to 90%, however, the infant is considered to be hypoxemic (Hay, 1987b).

Pulse oximetry, however, has limitations. Factors that influence the accuracy of the readings include movement artifact, skin color, and the presence of ambient light (Hay, 1987a). Probes also become inaccurate over time and need replacement. Oximetry values are averaged over 4 to 10 sec, often concealing brief periods of desaturation such as those that may be significant during feeding (Kopotic, Mannino, Colley, & Horning, 1987). Each machine also has a standard error of measurement of 1% to 3%. The standard error of measurement is most important when oximetry values are around 90%, because the true value could be as high as 93% or as low as 87% (Hay, 1987a). If it appears that any of these limitations are interfering with accurate assessment of oxygen saturation during feeding, evaluation with more sophisticated and sensitive equipment may be needed. The computerized multichannel pneumogram, including oximetry, would be such an evaluation (Wolf & Glass, 1992).

Studies indicate that term and preterm infants experience slight but measurable oxygen desaturation with feeding (Mathew, 1988a; Mathew, Clarke, Pronskie, Luna-Solarzano, & Peterson, 1985; Shivpuri et al., 1983). Although this slight desaturation is not functionally significant in the infant with normal saturations, for the compromised infant with borderline saturations, such reductions may be significant. If desaturation is observed during feeding evaluation, the pattern of desaturation should be noted. Sudden dips may be associated with apneic or bradycardic episodes, whereas a gradual decline may indicate inadequate respiratory support for feeding (Wolf & Glass, 1992).

**Autonomic Responses During Feeding**

Autonomic responses during feeding, such as color change or coughing, choking, and gagging, can indicate decreased physiologic control during feeding related to the infant’s underlying medical condition. For instance, coughing, choking, and gagging can be associated with swallowing dysfunction and aspiration. Frequent or intense spitting up can be associated with gastroesophageal reflux. These responses can also be autonomic indicators of stress (Als, 1986). As with motoric behaviors, the challenge to the therapist is to work with other care providers to differentiate between autonomic signs that have a medical etiology and those that are indicators of stress.

Color change (when the infant becomes dusky, gray, or cyanotic) can indicate oxygen desaturation (Endo & Nishioka, 1993). During feeding assessment, attention should be focused on the infant’s color around the mouth and eyes. If cyanosis is noted, it is recommended that the infant be fed with an oximeter in place to determine whether these color changes are reflective of oxygen desaturation. A lack of color change with feeding, however, does not necessarily imply that oxygen saturation is normal. Many infants can have relatively low oxygen saturations without external evidence such as cyanosis (Garg, Kurzner, Bautista, & Keens, 1988).

**Endurance**

Endurance is a reflection of the infant’s work to maintain homeostasis, work for other activity (such as feeding), and the infant’s cardiopulmonary reserve (Guyton, 1991). Endurance can be compromised by any disease process that causes the infant to use excessive energy to maintain homeostasis or to engage in normal activity. Endurance can also be poor when cardiopulmonary reserve is low. Many NICU infants have diagnoses that contain features of cardiac or pulmonary disease. Examples include bronchopulmonary dysplasia (chronic lung disease), and most other respiratory illnesses, congenital heart disease, and disease processes that include weakness such as myopathies. Poor endurance may result in the infant terminating the feeding before taking the required volume, or demonstrating poor weight gain despite acceptable intake.

**Sucking, Swallowing, and Breathing**

Although infant feeding is primarily by sucking, difficulties in sucking mechanics are only one possible source of feeding problems observed in the NICU. Because sucking is intimately related to swallowing and breathing, feeding difficulties can be attributed to problems in any one of these processes, or to incoordination among the three processes. Rhythmicity is the hallmark of normal infant feeding behavior and is a reflection of the smooth, split-
second coordination between sucking, swallowing, and breathing. An immaturity or abnormality in any of the three components can, therefore, have a profound effect on the other components and the infant's feeding abilities.

Within the pharynx, feeding and breathing share a common space. At rest, the structures within the pharynx are biased toward breathing. Changes in the position of the oral and pharyngeal structures and changes in the breathing pattern need to occur to accommodate the swallowing that occurs during active feeding. This dual role of the pharynx underlies the difficulties observed when sucking, swallowing, and breathing are not well coordinated (Mathew, 1988b).

Sucking
Sucking involves rhythmic movements of the tongue and jaw, with support from the lips and cheeks, that create changes in pressure that cause liquid to flow out of a nipple. Sucking is comprised of two types of pressure, positive pressure (compression) and negative pressure (suction) (Sameroff, 1968). Positive pressure pushes the liquid out of the nipple; negative pressure draws the liquid out of the nipple. Although both types of pressure are used during infant feeding, their relative contributions to breast-feeding or bottle-feeding are debated (Ardran, Kemp, & Lind, 1958a, 1958b; Colley & Creamer, 1958; Smith, Erenberg, & Nowak, 1988; Weber, Woolridge, & Baum, 1986). Term infants can control the amount of suction and compression they create, adjusting the type of pressure to the demands of the situation (Ellison, Vidyaagar, & Anderson, 1979; Sameroff, 1968).

Sucking characteristics can be described in terms of the sucking pattern, rate, rhythm, amount of pressure, and swallowing pattern. Nutritive sucking (NS) and nonnutritive sucking (NNS) are the two major types of sucking. Each has a distinct pattern of sucking bursts punctuated by pauses. Nonnutritive sucking is generally evaluated first to isolate the infant's sucking mechanics in the absence of liquid flow.

Nonnutritive sucking. NNS occurs in a highly organized, repetitive pattern of bursts and pauses with a high degree of consistency in the number of sucks per burst and length of pauses. The rate of sucking is about 2 sucks per second with a suck:swallow ratio of 6:1 (Wolff, 1968). Numerous sucks can be taken before a swallow because the infant needs to accumulate a sufficiently large secretion bolus to trigger a swallow.

NNS is observed in utero by 15 to 18 weeks of gestation (Ianniruberto & Tajani, 1981), with a developmental progression in the establishment of NNS patterns noted in early premature infants (Hack, Estabrook, & Robertson, 1985). Single sucks of NNS activity between long pauses can be observed beginning at 27 to 28 weeks of gestation. Between 30 and 33 weeks' gestation, an organized burst–pause pattern begins to emerge. The sucking bursts are short but stable with long or irregular pauses.

By 34 weeks' gestation, the burst–pause pattern begins to approximate the mature pattern of a term infant. There are a greater number of sucks per sucking burst with fewer and shorter pauses.

During evaluation of NNS, having the infant suck on the examiner's gloved finger allows evaluation of the strength of the suck and the relative amounts of suction and compression. A pacifier can be used, but observations of sucking strength, pressure, and coordination are not as clear. The timing within the sucking cycle of any noises or breaks in suction should be noted. There should be a stable, rhythmic quality to the bursts and pauses.

Nutritive sucking. NS occurs during active feeding in the presence of liquid flow from the breast or bottle. NS has a more complex sucking pattern than NNS, although it varies predictably over the course of a feeding. Initially there is a continuous sucking pattern that lasts 30 to 80 sec or more and consists of long sucking bursts, with few or brief sucking pauses. The infant gradually shifts to an intermittent sucking pattern, characterized by a decreasing length of sucking bursts with increasing length of sucking pauses. By the end of the feeding, the infant is having frequent and lengthy pauses, occasionally interrupted by short sucking bursts (Mathew, Clark, Prongske, Luna-Solarzano, & Peterson, 1985; Shivpuri et al., 1985).

During NS the sucking rate is one suck per second and is stable over the course of the feeding. The suck–swallow ratio is 1:1 although it may increase to 2:3:1 toward the end of the feeding or in older infants. The rate of NS is slower than that of NNS due to the swallowing that occurs during active feeding (Daniels, Devlieger, Csaer, & Eggermont, 1986; Mathew & Bhattacharya, 1989).

Coordination of sucking and swallowing is reported to occur in preterm infants as early as 32 weeks' gestation (Hack et al., 1985), though breathing is not well integrated. Thus, the introduction of bottle-feeding is generally more successful between 34 and 35 weeks' gestation (Brake, Fifer, Alfasi, & Fleischman, 1988; Csaer, Daniels, Devlieger, DeCock, & Eggermont, 1982). Beyond 34 weeks' gestation, the healthy preterm infant generally demonstrates some temporal organization to the sucking pattern on the bottle, having both continuous and intermittent sucking phases. This behavior is similar to that of the term infant, suggesting increased feeding readiness (Mathew, 1988a). Meier (1993) suggested that coordination of sucking with swallowing and breathing on the breast may emerge earlier in the healthy preterm infant and be observable at 32 to 33 weeks' gestation.

When sucking during bottle-feeding is evaluated, the return of bubbles into the bottle is a reflection of the liquid flow out of the bottle. The strength of the infant's suck is reflected in both the resistance to pulling the nipple out of the infant's mouth and the rate of liquid flow.
Problem in sucking mechanics. Difficulties in the initiation of sucking may reflect depressed state control or can result from an inability to inhibit the rooting reflex to allow the infant to latch on to the nipple. A weak suck can be observed, or a suck that is so strong that the nipple collapses or that fluid flow is too great. Poorly coordinated or inefficient sucking may result from inadequate control of one or more of the oral structures. For example, if the tongue does not form an appropriate central groove, tongue movement is often abnormal and cannot create sufficient negative pressure suction. Poor lip control can result in loss of liquid. When differences are noted in the quality of sucking between NS and NNS, however, it is suggestive of problems with some aspect of suck—swallow—breath coordination, rather than oral motor dysfunction.

Swallowing

The most comprehensive evaluation of swallowing occurs radiologically during the videofluoroscopic swallowing study (VFSS) or modified barium swallow (Logemann, 1983). The goal of the VFSS is to assess the specific functional characteristics and safety of the swallowing mechanism, and to identify treatment strategies that may be effective in improving swallowing performance. The clinical evaluation of feeding, however, also plays an important role in determining whether there is swallowing dysfunction. Doing a clinical feeding evaluation before a VFSS may enhance use of this radiographic study. Not only can the clinical observation of feeding help determine whether a VFSS is necessary (Tuchman, 1988), it can also establish a baseline for feeding performance and behavior. Such baseline information helps the therapist plan for positioning and food presentation during the VFSS and can help determine the validity of the study. Clinical indications of swallowing dysfunction, as described below, suggest the need for a VFSS.

Coughing or choking during swallowing can indicate that liquid is impinging on the airway (Mathew & Sant'Ambrogio, 1988). This can be liquid that is actually aspirated into the airway or that merely penetrates the airway and then is expelled. Aspiration can result from a primary swallowing dysfunction or from incoordination between sucking, swallowing, and breathing.

In some cases, a history of frequent upper respiratory infection or pneumonia is the only clinical indication that aspiration is occurring (Logemann, 1983; Terry & Fuller, 1989). This silent aspiration can be only be confirmed with a VFSS. Aspiration can be descending (during feeding), but can also be ascending (during gastroesophageal reflux). When there are frequent and unexplained exacerbations of respiratory illness, as in infants with bronchopulmonary dysplasia, evaluation of both the swallowing mechanism and gastroesophageal reflux might be considered (Orenstein & Orenstein, 1988).

The inability to handle secretions is another indication of potential swallowing dysfunction. The infant may need frequent oral suctioning, or may have pooling of secretions, leading to airway obstruction or vagal stimulation and ultimately resulting in apnea or bradycardia or both. The infant is clearly not swallowing appropriately. This difficulty may be due to primary swallowing dysfunction, inadequate oral motor control, or poor sensory receptivity to trigger the swallow.

The presence of noisy or wet-sounding breathing may also be a sign of swallowing dysfunction (Logemann, 1983). These sounds can occur after feeding or can slowly increase over the course of the feeding. The therapist should consider the potential location of the wet sounds. Noises arising from the nasopharynx may indicate nasal reflux during swallowing, whereas noises in the pharynx may indicate residue left in the pharynx after swallowing.

Poor pharyngeal clearance may be inferred when the infant needs multiple swallows to clear a single bolus. This problem may result from the poorly timed initiation of swallowing, inadequate pharyngeal peristalsis, or an inability to develop appropriate pharyngeal pressure gradients to propel the bolus through the pharynx (Kennedy & Kent, 1988).

Breathing

During feeding, the infant makes adjustments in the respiratory system to accommodate to the demands of the work of feeding. How well the infant makes these adjustments during feeding depends on the basic functioning of the respiratory system. When a disease state is present, such as infant respiratory distress syndrome, the baseline function of the respiratory system may interfere with efficient or safe feeding. Several parameters need to be considered when evaluating respiratory function during feeding. These include respiratory effort, changes in respiratory pattern, and the sound of respirations.

Respiratory effort. The amount of respiratory effort or work of breathing needs to be evaluated before, during, and after feeding. Increased respiratory effort, often called respiratory distress, can be observed throughout the body. Retractions at the neck, trunk, or rib cage are indications of respiratory distress. Head bobbing, grunting, or forced exhalation are signs of increased work to breathe (Redding et al., 1987).

If there is increased work of breathing, the infant...
may fatigue early and stop feeding before ingesting adequate calories. Or the infant may ingest adequate calories, but expend so much effort working to breathe during feeding that there is a net caloric loss. By observing the timing and magnitude of the increased respiratory effort during feeding, the therapist will be able to decide when and how long to feed a particular infant.

Changes in respiratory pattern: Normally the infant has a smooth rhythmic breathing pattern. Some variation in the length of inspiration and exhalation and pauses between the two is normal, but excessive pauses or irregularities in breathing pattern are noteworthy.

The cessation of airflow of any duration is called apnea. Short respiratory pauses or short apneas of less than 15 sec can be considered normal at any age. Longer periods of apnea, or apnea of any length that is associated with cyanosis, pallor, or bradycardia is pathologic (National Institutes of Health, 1986). When the infant does not make any attempt to breathe during active sucking and swallowing, it suggests inhibition of respiratory drive by a central mechanism, or central apnea. Obstructive apnea results when the infant is making efforts to breathe, but is not able to move air because the airway is blocked (National Institutes of Health, 1986). Such blockage can occur from the bolus itself, or from laryngeal adduction triggered by a vagally mediated reflex response, such as from microaspiration. Although an infant may recover spontaneously from either type of apneic event, the infant may develop oxygen desaturation or bradycardia or both. During feeding, it is often difficult to differentiate between these two types of apnea. A multichannel pneumogram, measuring chest wall expansion and nasal airflow, may be needed to make this differentiation.

Sound of respirations. Generally, respiration is smooth and quiet with little sound heard on inhalation or exhalation. Noise heard during any part of the respiratory cycle may indicate airway obstruction or an alteration in airway patency. Dynamic airway problems, such as tracheomalacia, or a fixed problem such as subglottic stenosis, can result in stridor on inspiration. Wheezing as a result of bronchospasm can be heard during exhalation (Tunnessen, 1987). Any mechanism that alters airflow or compromises pulmonary efficiency, such as those underlying stridor or wheezing, can greatly increase the infant’s work of breathing and thus adversely affect the infant’s feeding (Guyton, 1991).

Coordination of Sucking, Swallowing, and Breathing

The integration of sucking, swallowing, and breathing allows the infant to feed efficiently without undue effort. Normally, these three components come together in the well orchestrated, rhythmic process of nutritive sucking.

Although watching the infant feed is a part of this evaluation, listening to the ratio of sucks to swallows and the timing and adequacy of the respiratory efforts during the sucking bursts is the best way to evaluate the coordination of sucking, swallowing, and breathing.

The normal rhythmic sucking pattern during bottle feeding consists of a series of bursts and pauses that begins as a continuous sucking pattern and changes to an intermittent sucking pattern over the course of the feeding. In addition, the ratio of sucks to swallows may change over the course of the feeding or with increasing maturative stages (Weber et al., 1986). During breast-feeding, changes in the burst-pause pattern and ratio of sucks to swallows also vary over the course of the feeding, but these changes may be related to the variable rate of milk flow throughout a breast-feeding session (Bowen-Jones, Thompson, & Drewett, 1982). Sucking rate is faster and suck-swallow ratio higher before and after let-down. Sucking rate is slower and suck-swallow ratio is lower during active let-down when the milk is flowing rapidly. During sucking bursts, respiration is suppressed when swallowing occurs. This suppression of breathing can decrease overall respiratory rate and minute ventilation. Normally recovery in all respiratory parameters occurs within the sucking pauses. Several patterns of suck-swallow-breath incoordination can be observed.

Feeding-Induced Apnea

In this abnormal sucking pattern, the infant has a lengthy sucking burst of greater than 5 to 7 suck-swallows without interspersing breaths at the appropriate interval. The episode can end in several ways. The infant may finally terminate the sucking burst and pant to recover during the sucking pause. Alternatively, the infant may be unable to terminate the sucking burst independently and the episode ends as the infant becomes increasingly apneic, with oxygen desaturation, cyanosis, or bradycardia developing (Shivpuri et al., 1983).

Some maturational factors appear to be involved in this type of suck-swallow-breath incoordination. It is seen frequently in preterm infants, especially those between 34 and 38 weeks’ gestation (Mathew, 1988a), although it can be observed in full-term infants (Mathew, Clark, & Pronske, 1985). Feeding-induced apnea is more frequently observed at the beginning of a feeding when the infant is sucking and swallowing rapidly. The suck-swallow rate and flow of liquid may be so high that the infant physically does not have time to intersperse breaths within the sucking burst. Mathew (1991) suggested that the soft, high-flow nipples often used to feed preterm infants might exacerbate the difficulties premature infants have in coordinating sucking, swallowing, and breathing, thus contributing to the high incidence of feeding-induced apnea in this group.
Appendix

Evaluation of Oral Structures

**Tongue**

**Key Functions**

- Assist in sealing oral cavity anteriorly and posteriorly
- Change configuration to provide compression to nipple and palate
- Provide a stable base for movements of the tongue
- Help in forming anterior seal
- Aid in bolus formation
- Hard palate: helps compress nipple, maintains nipple position
- Soft palate: assists in creating posterior seal, elevates during swallowing
- Hard and soft palate should be intact with smooth contours
- Clefts of any portion of palate, high arched hard palate, bifid uvula, decreased movement of soft palate

References


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