Pediatric theme

Physiology of nutritive sucking in newborns and infants

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ABSTRACT

Nutritive sucking is the process by which infants obtain their feeding, which may be sucking by breastfeeding or through a bottle. This article summarizes the physiological basis of nutritive sucking in order to establish the normal conditions of this process. In this context it is known that the nutritive sucking consists of three phases: expression/suction, swallowing and breathing. Coordination of the first two phases can provide an adequate supply of food and direct it to the digestive tract without the risk of it passing to the airways. The sequence in which these phases are given varies with the age of the child. Under normal conditions, nutritive sucking is an aerobic process and is accomplished with jaw and tongue movements, which are capable of generating the necessary pressure from a reservoir for the suction and extraction of milk. Thus, lack of coordination of these phases explains the changes in the rate of suction and the appearance of abnormal clinical signs such as low consumption of food, choking, regurgitation, vomiting or respiratory disorders. The construction of clinical scales has been possible by determining the sequence of the different phases of suction. These scales can detect problems with newborns or infants who do not achieve adequate nutritive sucking either by the identification of abnormal clinical signs or because milk consumption is <80% of the recommended volume.

Key words: nutritive sucking, infants, physiology.

INTRODUCTION

From birth throughout the first 6 months of life, infants will obtain their primary food (milk) through nutritive sucking. During the last months of embryonic development, the fetus acquires reflexes and skills required to achieve an independent and effective sucking. This is a physiological process that allows infant to ensure sufficient food intake, which is easy to assimilate, ìsafeî and with low energy requirements.[1-3]

To achieve this, a newborn should present no congenital malformations in the mouth or the respiratory or nervous systems and be free of medication effects and lesions that alter normal functions in involved organs and systems (digestive, respiratory, cardiovascular and nervous).[4,5]

Healthcare personnel should determine during clinical evaluation of any newborn or infant if feeding is efficient to guarantee an appropriate development. Nutritive sucking should be part of the clinical evaluation; however, this is not always carried out objectively. Here we summarize the current knowledge on normal sucking physiology in newborns and infants. First we describe anatomic characteristics that ease the process and physiological phases involved. We also include data on variations of each phase in order to define normal limits. Finally, we describe criteria to differentiate normal from abnormal nutritive sucking.

Nutritive Sucking Process

The process that allows an infant to obtain food, either maternal milk or infant formula, is known as nutritive sucking (NS).[6-8] Although suction can be triggered through oral stimulation (non-nutritive sucking), this has other physiological characteristics and will not be covered in this report. Sucking is a process integrated by three highly correlated phases: a) expression-suction, b) swallow and c) breathing, accompanied by other body stability factors such as cardiovascular and nervous systems.[9]

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There are variations in NS physiology according to how food is offered to the infant; however, most show a homogeneous behavior during the process. Therefore, NS can be classified as breastfeeding nutrition (BS) and bottle-feeding nutrition (BNS).

Anatomic Aspects of Nutritive Sucking

It is important to remember that newborns and infants <6 months of life have a 1:5 head-body ratio. This condition and their neural immaturity produce a lack of neck and torso control, which prevents them from feeding in a vertical posture. Although such conditions ease their horizontal or inclined position feeding, the latter is usually recommended. They also present a 1:4 nose-mouth/face ratio and the jaw is proportionally shorter than in children and during adulthood. Both conditions favor NS by preventing food from accidentally passing to airways. Even when the nose is smaller, because the nostrils have a more horizontal position this allows infants to breath, considering the mouth position that is essential to maintain constant breathing while feeding.[10-12] Even though the jaw of a newborn is smaller, it presents greater antero-posterior and elevation mobilities that ease ondulation instead of vertical movements (Figure 1).

The oral cavity is proportionally smaller than in children and during adulthood because of buccal fat pads. This reduced space helps control ingested milk volume, eases food towards the posterior cavity and retains liquid at the end of the suction. Although the hard palate has a more pronounced curve, it generates a longitudinal crease that eases a directed flow of liquids. On the other hand, a newborn's tongue is proportionally larger than in adults and its upward-downward movement during suction initiates a propulsion wave towards the back of the oral cavity that almost completely occupies the oral cavity and, therefore, eases milk flow towards the oropharynx.[11-13] Incorrectly situated food in the oral cavity will be expelled from the mouth by the tongue. The larynx is short and moves forward easily towards the epiglottis. This movement is eased by the ascending movement of the tongue, which provides a greater protection of the lower airways from complete obstruction by glottis closure and overlap of epiglottis and vallecules. This closure is so efficient that it allows the newborn to be fed even in horizontal and tilted positions.

Finally, the newborn's breathing is fundamentally nasal and is associated with a more direct respiratory pathway from the nasal cavity to the trachea and shorter airways,[13] which helps to have a laminar air flow with less resistance towards the alveolus and vice versa.

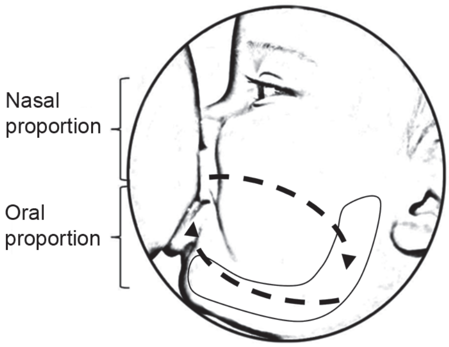

Figure 1. Anatomic and mobility aspects of jaw during nutritive suction.

Nutritive Suction Physiology

NS process includes three closely related phases: expression/suction (E/S),[7,13-15] swallow (S) and breathing (B).[7,16,17] During E/S, the infant generates extraction pressure over a fluid contained in an external reservoir towards the oral cavity. Once a bolus has formed, liquid is directed towards the digestive system (swallow) without passing through airways.[1,14,16] E/S and S phases must be coordinated with breathing.[17-20]

Suction effectiveness depends on an appropriate integration and synchronization of the structures in lips, cheeks, tongue and palate to form a bolus and move it towards the back of the oral cavity for swallowing.[7] This process needs to be rhythmic and continuous in healthy full-term newborns to ensure sufficient food ingestion and comply with metabolic requirements. It is necessary to coordinate suction with breathing to keep the process aerobic. This will allow the infant to obtain the highest possible amount of food with the lowest energetic expense while protecting the airways.[21,22]

Nutritive sucking begins with compression of the mother's nipple or baby bottle teat. Compression is achieved by contraction of orbicularis oris muscle in the newborn's lips plus gum chewing by moving the jaw in an anterosuperior direction. This compression generates a positive pressure (30-60 cm H_2O) over nipple or teat and produces the initial expression of food flow towards the mouth. Particularly in BNS, this pressure may generate higher volumes than BS, although the latter is a strong stimulus to keep producing maternal milk. For both suction types, it is essential that the infant creates a hermetic seal to avoid food leakage through the oral commissures, which would cause the NS to be inefficient.[13,14,23] The second phase of E/S generates a negative suction pressure when the infant retracts the jaw by contracting the suprahyoid muscles, a backwards movement of tongue[7,13,14] and stability of buccal cheeks. Backward movement of the tongue generates an intraoral cavity using palate, cheeks and soft palate.[13]

Tongue movements required to generate suction differ according to feeding type. In BS, the tongue forms a longitudinal crease with two peripheral borders and a central fold, which resembles a milking movement. In this phase, descent of the tongue's base generates a negative pressure that favors milk extraction.[24] In BNS, tongue movements mimic a piston with alternating movements of the tip and base.[13-15] These tongue movements can change according to the infant's maturity and they are more evident after the newborn has reached 2 months of life.[25,26] For both BS and BNS, jaw descent and tongue movement are the most important factors to generate suction pressure.[13,15,16,23] Pressure varies between -60 and -100 mmHg and is closely associated with the weight of the child.[21,27] During BS, suction pressure starts with sealing of the nipple using -50 mmHg alternated with cyclic fluctuations between -110 and -170 mmHg.[24]

Swallow phase includes bolus transit from the oral cavity to the esophagus.[13-16] Food initially contained in the crease of the tongue is moved by a peristaltic wave to the pharynx, which moves forward and upwards, coming closer to the base of the tongue. The laryngeal abductors contract and the upper esophageal sphincter is relaxed. Contraction of the upper constrictor of the pharynx favors palate veil elevation that closes the upper airways while the tongue pushes the bolus towards the hypopharynx. At that moment, breathing is inhibited causing a brief apnea from swallowing.[13,14,16] This apnea lasts 530 msec (350-850 msec) on average (Figure 2).[28-30]

As already mentioned, breathing does not stop during NS. Infants do not suction, they "suckle." Liquid extraction is caused by movements of the oral structures, not by suction force generated by the stomach as an adult does. This cyclic movement of the buccal apparatus allows breathing to integrate at its own rhythm without interrupting either process. Therefore, NS maintains an aerobic component. During NS, newborns demonstrate these patterns: inspire–swallow (pause)–exhale [ISE], exhale–swallow–inspire [ESI], inspire–swallow–inspire [ISI] and exhale–swallow–exhale [ESE].[17,19] These patterns are known as type I [ISE and ESI] and type II [ISI or ESE]. A third pattern (type III) occurs when there is an apnea between two or more swallows; this pattern has been defined as "apnea from multiple swallow" (AMS) (Figure 3). In full-term newborns, type I pattern is more common (35%-50% of cycles) followed by type II.[17] However, pattern type can be modified by the type of liquid. Mizuno et al. found that BNS in breastfed children, when compared with infant formula or distilled water, demonstrated type I pattern and presented a higher rate (36.4% vs. 28.4% and 24.6%, respectively).[19]

These authors also found that full-term babies present type III patterns in 20%-25% of swallows (AMS).[29] In general, AMS does not produce abnormal clinical data but may reduce regular respiratory volume and explain behavioral changes during NS. AMS is more frequent in infants fed through a bottle feeding.[14,26]

In newborns, sequence of elements during the E/S-S-B process presents a 1:1 ratio, i.e., one suck per each swallow and breathing. However, this ratio can change to 2:1:1 or 3:1:1 from the sixth week of life. These changes have been explained by an increasing brain size and voluntary control over NS (Figure 3).[14,26]

Breathing pattern partially explains NS behavior during feeding.[1,29,30] Initially, suction is very intense and frequent, but as minutes pass the activity changes, becoming intermittent and less vigorous. Changes are associated with modifications in respiratory pattern during suction.[1,18,20,30] A shorter inspiration time and longer expiration time has been observed in the infant's breathing.[20] Also, volume/minute during suction decreases at the expense of breathing frequency, although tidal volume may be preserved.[20,22,30] Also, descent in ventilation is modified by food flow speed and amount of liquid.[19,22] This phenomenon has been observed both in bottle-fed infants as well as in breastfed infants, the latter present a less intense phenomenon because of their ability to better manage liquid flow.[18,30]

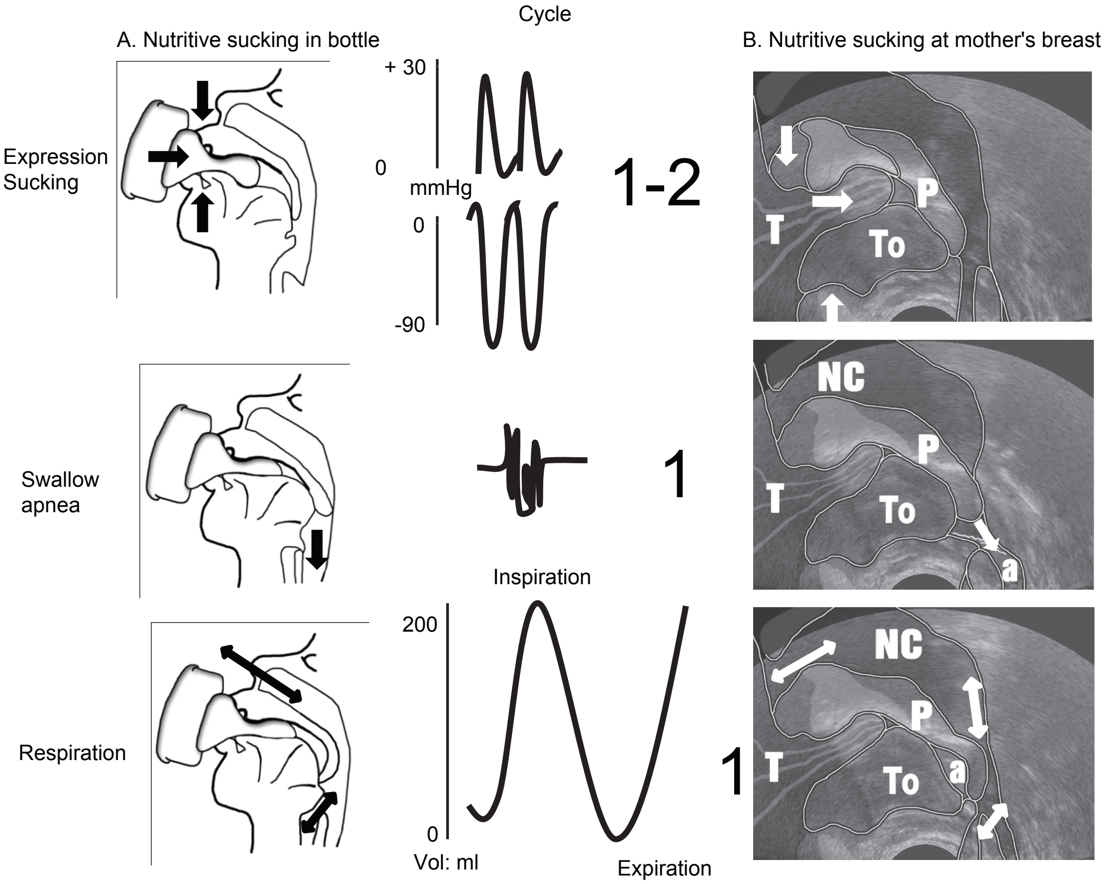

Figure 2. Expression/suction-swallow-breathing cycle. (A) Nutritive sucking schema using bottle (adapted with permission from Mathew OP. Breathing patterns of preterm infants during bottle feeding: role of milk flow. J Pediatr 1991;119:960-965). (B) Ultrasonography of breast-feeding (adapted from Geddes DT, Kent JC, Mitoulas LR, Hartman PE. Tongue movement and intra-oral vacuum in breastfeeding infants. Early Hum Dev adapted with permission from 2008;84:471-477). During expression of nipple (T) (either from bottle or mother), a positive pressure is created. A backwards tongue movement (L) generates a negative pressure. Swallow is recorded using cervical phonometry as the sign when bolus passes from the oral cavity into the esophagus. During swallow, the palate (P) elevates and the lower airway is closed (a). Breathing is recorded using nasal flow measured in vol/min when air passes through the nasal cavity (NC).

Normal Quantitative Values in NS

NS is a changing process with three accepted stages: continuous, intermittent and with pauses (Figure 4). Their duration depends chiefly on infant's hunger and changes during the first months of life.

A full-term newborn presents an E/S pattern with 20-30 burst of sucks[2,6-8] followed by 2- to 15-sec pauses. These movements occur at a rate of 1-2 E/S per second, which results in an average frequency of 55 suck/min with variations ranging between 18 and 100.[2,3,7,27]

In continuous or initial phase, sucking burst last between 30 and 120 sec for 3-5 min. Ten minutes later, sucking burst last for 10-20 sec with 30- to 50-sec pauses between each cluster, which manifests as an intermittent suction. Ten minutes after feeding is initiated, the infant presents more infrequent sucking burst and pauses that may last several minutes.[22,26,30] Sometimes, feeding ends with the infant falling asleep.

In general terms, a bottle-fed infant ingests between 0.8 and 1.2 mL per suction, so in 1 min the infant will ingest about one fluid ounce. Therefore, during the first 5 min infants will ingest 30% of their volume requirement.[31] This volume may be higher if the infant is breastfed because of the effect if breast ejection; therefore, the infant completes the meal in a maximum of 15 min. We suggest that when breastfeeding begins, the mother alternates breasts every

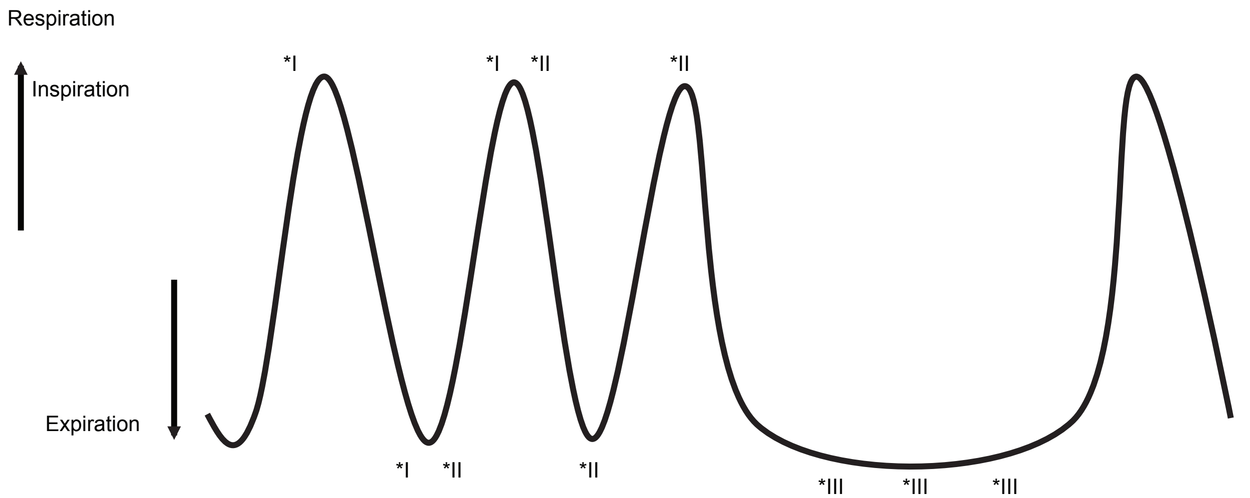

Figure 3. Swallow-breathing patterns: Type I. End of inspiration-swallow-exhalation, end by exhalation-swallow-inspiration. Type II. End by exhalation-swallow-inspiration with exhalation-swallow. End inspiration-swallow-exhalation with inspiration-swallow. Type III. Two or more swallows during one apnea. *Swallow time.

	Initial continuous phase	Intermittent phase	Paused phase
Suctions by cluster	20-30	10-20	3-10
Pauses between clusters	2-15	15-30 sec	1-10 min
Duration of the phase	5 min	5-15 min	15-25 min
Respiratory frequency	30-35 x min	40-50 x min	35-45 x min

Figure 4. Phases of nutritive sucking.

5-7 min in order to favor milk production by emptying each breast and when production reaches higher levels (from the infant's first month of life), she uses only one breast to feed the baby because late milk has shown a higher caloric content. Intermittent and paused phase can last longer, depending on the stimulation provided to the infant.[17,32]

The main factor that influences changes in suction frequency in healthy infants is speed of milk flow. Several studies have demonstrated positive correlations between an increased milk flow and suction frequency.[7,17,18] Other factors have been identified such as food consistency and flavor because if it is more pleasant, suction increases.[33] Particularly, feeding with maternal milk (even if given by bottle) seems to stimulate a more regular NS (more suctions per cluster); in addition, infants show more stable patterns than when they are fed with formula or water.[19]

From a clinical point of view, it is difficult to assess the swallow phase to determine if it is within normal levels. In general, studies have been carried out using phonometry.[16,17] Swallow apnea lasts about 530 msec. It is so brief that it does not interrupt respiratory function. Therefore, it is unusual to perceive choking or changes in breathing patterns. Swallow noises are good markers of alterations; however, the infant's short neck makes perception difficult and, therefore, its detection.[33]

The best marker for a correct coordination between swallow and breathing is to evaluate the respiratory rate of infant during feeding. The rate usually drops to 30-35 breaths per minute on the continuous phase of feeding and increases to 40-50 breaths per minute during the intermittent phase.[21] If a capillary oxygen saturation measurement is available, we should expect a descent <95%.[22,34]

Determining Normal or Abnormal NS

NS can be assessed using two approaches: clinical evaluation of coordination-safety and evaluation of effectiveness. The first approach aims to establish whether NS complies with the purpose of transferring food from the oral cavity to the digestive system without obstructing the airways. Several scales have emerged to assess this by determining position, movement and coordination of oral structures such as the Neonatal Oral-Motor Assessment scale (NOMAS).[35] This scale has been used to classify suction-swallow in infants as dysfunctional or disorganized, based on mobility of tongue and jaw. Assessment using this scale requires a properly trained observer. Concordance indexes have been reported ranging from 59% to 100%.[36] Other scales have been used for children at high risk.[37] For some authors, NOMAS is considered the gold standard to diagnose suction-swallow problems; however, it does not detect alterations of the intra-oral processes.

SAIB (Systematic Assessment of the Infant at the Breast) scale has been used to assess exclusively breastfed children and focuses its observations on the holding and approaching techniques used in the newborn: latching to nipple, areola compression and audible swallows. Its purpose is to evaluate suction movements and swallow by observation. We should mention that its reliability is yet to be demonstrated.[38] Another instrument is LATCH (breastfeeding charting system and documentation tool), which records observed data as well as cervical auditory exploration of swallow by measuring five elements (two are referred to as suction-swallow) and requires special training to be applied.[39,40]

In some studies and in daily practice, assessment of suction-swallow-breathing coordination can be carried out through clinical data observed in newborns during feeding. Infants with abnormal suction present digestive, breathing, cardiac or neurological clinical symptoms during feeding.[9,41]

Associated symptoms can be classified into four groups according to the most altered component:

- During E/S there is lack of suction initiation, problems in holding the nipple, deficient lip sealing, liquid escaping from oral commissures, excessive tongue protrusion and lack of suction clustering.[4,7,23]
- During swallowing, abnormal signs include drowning data such as choking, nausea, vomiting, cough, nasal regurgitation of milk and laryngeal noises.[33,36]
- There may be alterations in respiration rate, apnea periods, cyanosis and cardiac arrythmia.[42,43]
- Together with these clinical signs, there are some behavioral responses associated with defense mechanisms where infants attempts to preserve their integrity during suction such as spitting the nipple out, turning the head, crying, biting the nipple, stopping suction or fatigue as well as becoming distracted for long periods of time.[44]

Regarding the assessment of the effectiveness of NS, we must consider whether food intake is sufficient to comply with the infant's metabolic and growth requirements. Several authors have regarded suction as abnormal when intake volume is <80% of the recommended value.[41,42] Likewise, a decreased effectiveness of suction can be due to a slow performance with fatigue, which is common among infants with cardiac or pulmonary diseases. They suffer from a low food ingestion during the initial stage (continuous); therefore, another inefficiency criterion is the intake of <30% of the recommended volume during the first 5 min of feeding.[41] We should clarify that these measurements have been carried out based on a constant caloric intake from infant formulas; therefore, this cannot be extrapolated to breast milk because its caloric concentration varies during feeding.[42]

It is important to highlight that infants with most NS alterations are premature and especially those presenting neurological damage. They present two important alterations during NS: first, the process is disorganized because of immaturity and second, a dysfunction associated with damage of structures involved in the process. In full-term newborns, NS alterations may be associated with diseases challenging NS control. In both cases, several orosensory and motor support therapies have been developed with encouraging results.[43-48] This calls for an opportune detection of an abnormal NS.

CONCLUSIONS

NS is the process where an infant obtains nutriments for appropriate growth and development. As any complex organic function, it requires integration of different anatomic structures as well as coordination of their function to achieve a high level of efficiency.

We define NS as normal and efficient when newborns obtain food (milk) from a rhythmic process including suction, breathing and swallowing without asphyxia or choking data and with a volume that ensures a sufficient caloric ingest to comply with metabolic requirements. Assessment of NS can be carried out using clinic scales or mini-invasive instruments and it is essential to determine if food is transferred from the oral cavity to the digestive system without compromising the airways during NS. The expected relationship is 1:1:1 (expression/suction:breathing:swallowing), although it usually changes to 2:1:1 when the newborn matures.

The physiological process of NS varies from breastfeeding to bottle-feeding using formulas. In general, breastfeeding allows a more coordinated suction and, therefore, it is highly recommended from a physiological point of view. Sucking phase sequences and their variations associated with respiratory rhythm explain feeding length from continuous to paused phases.

Understanding the processes involved in NS allows the detection of abnormal conditions as well as to support therapeutic/rehabilitative actions for its correction.

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