A Neurobehavioral Approach to Breastfeeding

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www.kangaroomothercare.com
THE "OLD" BRAIN HAS 3 PROGRAMMES

- DEFENCE
- NUTRITION
- REPRODUCTION
The neurobehavioural programmes originate in the **Limbic System**

Expressed through
- hypothalamus (autonomic nervous system)
- hypophysis (endocrine system, hormones)
- cerebellum etc (somatic system)
HIGHLY CONSERVED NEURO-ENDOCRINE BEHAVIOR

DEFENCE    NUTRITION    REPRODUCTION

HORMONES    NERVES    MUSCLES

endocrine    autonomic NS    somatic
HIGHLY CONSERVED NEURO-ENDOCRINE BEHAVIOR

DEFENCE  NUTRITION  REPRODUCTION

HORMONES  NERVES  MUSCLES
HIGHLY CONSERVED NEURO-ENDOCRINE BEHAVIOR

DEFENCE  

X  

NUTRITION  

X  

REPRODUCTION  

HORMONES  

NERVES  

MUSCLES
HIGHLY CONSERVED NEURO-ENDOCRINE BEHAVIOR

DEFENCE  NUTRITION  REPRODUCTION

HORMONES  NERVES  MUSCLES
“It is a serious mistake to assume that the principles derived from careful animal studies do not apply to human infants. The risk of suppression or disruption of needed neural processes ... is very significant and potentially lasts a life time.
All mammals have set sequence of behaviours at birth .............

...... All with a single purpose : to

BREASTFEED
After birth, events are determined … … by the neonate stimulating the mother!

(Rosenblatt 1994)
Breast-feeding is “established through a set of mutual, complex sensory stimulations in mother and child.”

(Kjellmer & Winberg 1994)
HABITAT DETERMINES BEHAVIOUR
The "habitat-niche" concept BEHAVIOUR ENSURES BIOLOGICAL NEEDS
Warming, feeding and protection behaviours are intricately, inseparably linked to the right place.  
(Alberts 1994)
In all mammals ......

...... the **newborn** is responsible for initiating breastfeeding, **not the mother**!!
In all mammals .......

..... the **newborn** is responsible for initiating breastfeeding,

not the mother !!

**EXCEPT IN HUMAN ??**
Sequence human newborn breast-feeding

Pre-requisite = habitat

hand to mouth
tongue moves
mouth moves
eye focuses nipple
crawls to nipple
latches to nipple
suckles

(Widstrom et al 1994)
**Conclusion:** Inborn breastfeeding reflexes were depressed at birth, possibly because of a depressed sensory system. It is hypothesized that when the infant is given the option to peacefully go through the nine behavioural phases birth cry, relaxation, awakening, activity, crawling, resting, familiarization, suckling and sleeping when skin-to-skin with its mother this results in early optimal self-regulation.

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>Closed or opened&lt;br&gt;Looks mainly at mother’s breast&lt;br&gt;Looks mainly in the direction of the mother’s face</td>
</tr>
<tr>
<td>Soliciting sounds</td>
<td>An affirmative, short, ringing so sound</td>
</tr>
<tr>
<td>Hand-to-mouth</td>
<td>Hand in/or touching the mouth</td>
</tr>
<tr>
<td>Hand-breast-mouth</td>
<td>Infant moves hand across mother’s breast and brushes the nipple/areola and brings hand to mouth</td>
</tr>
<tr>
<td>Rooting</td>
<td>Twisting movement where face is brought across or lifted above mother’s chest and turned to side or hand</td>
</tr>
<tr>
<td>Rocking/pushing</td>
<td>Rocking activity without shifting position</td>
</tr>
<tr>
<td>Phases</td>
<td>Behaviours</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Birth cry</td>
<td>Intense crying just after birth</td>
</tr>
<tr>
<td>Relaxation phase</td>
<td>Infant resting/recovering. No activity of mouth, head, arms, legs or body</td>
</tr>
<tr>
<td>Awakening phase</td>
<td>Infant begins to show signs of activity. Small thrusts of head: up, down, from side-to-side. Small movements of limbs and shoulders</td>
</tr>
<tr>
<td>Active phase</td>
<td>Infant moves limbs and head, is more determined in movements. Rooting activity, ‘pushing’ with limbs without shifting body</td>
</tr>
<tr>
<td>Crawling phase</td>
<td>‘Pushing’ which results in shifting body</td>
</tr>
<tr>
<td>Resting phase</td>
<td>Infant rests, with some activity, such as mouth activity, sucks on hand</td>
</tr>
<tr>
<td>Familiarization</td>
<td>Infant has reached areola/nipple with mouth positioned to brush and lick areola/nipple</td>
</tr>
<tr>
<td>Suckling phase</td>
<td>Infant has taken nipple in mouth and commences suckling</td>
</tr>
<tr>
<td>Sleeping phase</td>
<td>The baby has closed its eyes</td>
</tr>
</tbody>
</table>
“The newborn may appear helpless, but displays an impressive and purposeful motor activity which, \textit{without maternal assistance}, brings the baby to the nipple.

(Michelson et al 1996)
“The newborn may appear helpless, but raises its own temperature, has a higher blood glucose, metabolic adaptation faster.

(Widstrom 1987)
**METABOLIC ADAPTATION**

SSC started in the first 20 minutes after birth

<table>
<thead>
<tr>
<th></th>
<th>SSC</th>
<th>Cot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood glucose (1 hr)</td>
<td>3.17</td>
<td>2.56</td>
</tr>
<tr>
<td>Base excess drop</td>
<td>3.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

(Christenson 1992)
Warming, feeding and protection behaviours are intricately, inseparably linked to the right place. (Alberts 1994)
Animal literature does not talk about mammalian lactation, it talks about mammalian birth.

Ruin the birth - and there is no lactation
With a good birth, lactation follows

Diane Weissinger
PSN envisions a community that embraces its mothers and babies, and values the unique opportunity at birth to impact the physical and emotional well-being of the newborn.
Target #1 for 2005:

Report that 65% of infants are placed and remain in direct skin to skin contact with their mothers for at least one hour during the first 3 hours after birth.
Skin-to-skin and breastfeeding (4)

0
10
20
30
40
50
60
70
80
90
100

3Q05 4Q05 1Q06 2Q06 3Q06 4Q06 1Q07 2Q07

Breastfeeding intention
Skin-to-skin one hour
Breastfeeding at discharge

Babies breastfeeding
Mothers intending to breastfeed

Used with permission: Ruth Stanhiser, MD
Effect of Early Skin-to-Skin Mother Infant Contact During the First 3 Hours Following Birth on Exclusive Breastfeeding During the Maternity Hospital Stay

Leslie Bramson, Jerry W. Lee, Elizabeth Moore, Susanne Montgomery, Christine Neish, Khaled Bahjri and Carolyn Lopez

More skin-to-skin $\Rightarrow$ more breastfeeding
... highly conserved neuro-endocrine behaviors

DEFENCE

NUTRITION

REPRODUCTION

HORMONES

NERVES

MUSCLES

endocrine

autonomic NS

somatic
BREASTFEEDING IS A BEHAVIOUR OF THE NEWBORN

Not the mother !!
... highly conserved neuro-endocrine behaviors

DEFENCE

NUTRITION

REPRODUCTION

HORMONES

NERVES

MUSCLES

docrine

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somatic
Animal literature does not talk about mammalian lactation, it talks about mammalian birth.

Ruin the birth - and there is no lactation
With a good birth, lactation follows

Diane Weissinger
Premature babies will need help.

BERLITH PERSSON has provided that help …

PERSSON’S WHEEL !
KERSTIN HEDBERG-NYQVIST:
(Early Human Dev 55 (1999) 247 -264.)

PIBBS
Preterm Infant Breastfeeding Behaviour Scale

- rooting 0 - 2
- areolar grasp 0 - 3
- latch (and fixation) time 0 - 3
- sucking 0 - 4
- longest sucking burst 1 - 6
- swallowing 0 - 2
KERSTIN HEDBERG-NYQVIST:

PIBBS
Preterm Infant Breastfeeding Behaviour Scale

Nutritive sucking = >5ml swallowed

Full breastfeeding = exclusive Brf
Preterm Infant Breastfeeding Behaviour Scale

**EARLIEST OBSERVATION:**
(weeks PMA) 28 29 30 31 32 33 34 35 36

- **rooting**: 90%
- **grasp**: 50%
- **latch**: 95%
- **sucking**: 90%
- **swallow**
- **burst**

**Nutritive**
- Effective
- >30 sucks

**Full breastfeeding** 33w
Step 1  SKIN-TO-SKIN

Continuous skin contact

The newborn must be in the right environment for the behaviours that it is capable of to be expressed. It requires protection from stress and provision of warmth.

KMC provides the “maternal nest”

Ideally this should be done on prematures AT BIRTH. However it can be done later, even with nasogastric tube providing expressed breast milk in the meantime.
Step 2 and 3  Olfactory

The first steps in sequence require smell of the nipple which may take longer in the premature,

and then the smelling of milk.

Babies can identify smells and tastes from their time in the uterus in the mother’s milk!
Step 4    Taste

This is re-inforcing the smell. Fullterm seems to skip this!

Step 5    Rooting

These are mouth movements the normal sequence described in the full-terms.

Here the premature requires help, with position and “sipping” = feeling milk in mouth
Step 6  First suckling.

Key step, builds on steps 1 to 5. Must be awake and alert. Alert period is maximal at birth, and lasts 45 - 90 minutes. If missed then, will require feeding, and several hours delay.
Step 6  First suckling.

Note difference suckling vs sucking!

“ … myographically distinct”

For late premature lactation, allow suckling to develop in successive alert periods, while feeding by tube.
Breastfeeding & Suckling

From 16 or 20 weeks gestation, the fetus is swallowing.
From 26 or 28 weeks gestation the fetus can SUCKLE.
From 36 weeks gestation the fetus is able to SUCK.

SUCKING and SUCKLING sound same, but VERY different.
Step 7  Latching & swallowing

Premature is too physically weak to crawl to nipple, but if held to nipple will at this stage latch on.

Once latched, suckling follows.

Suckling squirts a controlled dose of milk to the back of throat, which is safely swallowed without any interference of breathing.

This is INNATE.
Step 8  First breast milk meal.

Steps 1 to 7 and on take place rapidly in the fullterm. They can occur in the first alert period after birth in a premature if allowed to, but may require a longer period of defined steps in successive alert periods. For late prem lactation, step 8 is the first time milk is swallowed enough to feed the baby.
Step 9  Frequent feeding

In utero, baby is feeding Continuously. Demand feeding is NOT SUITABLE for prematures. Feeds should be at most 2 hours apart.

Step 10  Together continuously
The wheel is not round. Turns slow at first, but then picks up speed!
BREASTFEEDING A PREMATURE

STEP 1  SSC
STEP 2  ALLOW TIME
STEP 3  State organisation: alert awake
STEP 4  SMELL
STEP 5  TASTE
STEP 6  LATCH
STEP 7  SUCKLE
BABY STOHM  PREM BREASTFEED:
SEE WEBSITE

THE NEWBORN

also has a larynx that meets the uvula, designed to separate the respiratory tract from the gastrointestinal tract, enabling the newborn to feed and breathe simultaneously.
Meier 1988
BOTTLE AND BREASTFEEDING IN PREMATURE
Prematures babies weighing 1300g and 34/40 PCA, given alternating bottle and breastfeeds.

<table>
<thead>
<tr>
<th>Start feed</th>
<th>Ends feed</th>
<th>10 min later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottle</td>
<td>Sucking burst</td>
<td>Rest</td>
</tr>
<tr>
<td>Breast</td>
<td>Suckling continuous</td>
<td>Non-nutritive</td>
</tr>
</tbody>
</table>

Baseline $pO_2$

Baseline $pO_2$
There were 2 episodes of apnea and 20 episodes of oxygen desaturation during bottle-feeding and none during breastfeeding. We conclude that breastfeeding is a more physiological feeding method for the preterm infant and bottle-feeding may be more stressful.
SUCKLING uses the largest muscle in the baby's head, making the smallest movement.

SUCKING requires lots of tiny and weak muscles, making maximum effort.

... also causes hypoxia,

... and is STRESSFUL!
Bottle feeding requires SUCKING, which requires completely different muscles, and does NOT allow coordination between swallowing and breathing. Bottle feeding causes STRESS in prematures, and relative post-prandial hypoxaemia.

SUCCCKLING - in and of itself, apart from nutrition intake - has beneficial effects on both mother and baby. SENSORY STIMULATION ....
Suckling induces simultaneous endocrine effects in the gut of both mother and child. There is a physiological symbiosis between them.

Breast feeding also has psychic effects; CCK is produced, which induces sedation and sleep.
The ability to appropriately control the level of sleep and arousal.
<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified scale -</td>
<td></td>
</tr>
<tr>
<td>HARD CRYING</td>
<td>L to R shunting, IVH risk</td>
</tr>
<tr>
<td>CRYING</td>
<td>Stressful, wastes calories, ... build up to stress</td>
</tr>
<tr>
<td>FUSSING</td>
<td>This is feeding zone!</td>
</tr>
<tr>
<td>ACTIVE AWAKE</td>
<td>Time to connect - stimulation</td>
</tr>
<tr>
<td>QUIET AWAKE</td>
<td>... transition zone</td>
</tr>
<tr>
<td>ALERT INACTIVE</td>
<td>... transition zone</td>
</tr>
<tr>
<td>DROWSY</td>
<td>... transition zone</td>
</tr>
<tr>
<td>ACTIVE SLEEP</td>
<td>... activity consumes calories</td>
</tr>
<tr>
<td>IRREGULAR SLEEP</td>
<td>Good sleep - digestion zone</td>
</tr>
<tr>
<td>QUIET SLEEP</td>
<td>Apnoea zone !!</td>
</tr>
<tr>
<td>DEEP SLEEP</td>
<td></td>
</tr>
</tbody>
</table>
Simplified scale -
HARD CRYING
CRYING
FUSSING
ACTIVE AWAKE
QUIET AWAKE
ALERT INACTIVE
DROWSY
ACTIVE SLEEP
IRREGULAR SLEEP
QUIET SLEEP
DEEP SLEEP

Incubator

SSC
KMC babies oscillate slowly in safe zones

Separation babies oscillate erratically to danger zones

Simplified scale -
HARD CRYING
CRYING
FUSSING
ACTIVE AWAKE
QUIET AWAKE
ALERT INACTIVE
DROWSY
ACTIVE SLEEP
IRREGULAR SLEEP
QUIET SLEEP
DEEP SLEEP

Risk
Stress
Feeding
Stimulation
Digestion
Apnoea
rest-activity cycle is approx 60 minutes long

(Ludington 2006)
Not so much duration, or density of any sleep stage, or number of sleep stage episodes, but, **cycling between quiet sleep and active sleep** is what is important.
SLEEP CYCLING - Separation vs contact

In SSC:

- Normal cycling
- Non-chaotic pattern
“The newborn may appear helpless, but displays an impressive and purposeful motor activity which, without maternal assistance, brings the baby to the nipple.

(Michelson et al 1996)
Gut hormones.

(Uvnas-Moberg 1989)

20 different hormones work in the gut - regulated by the vagal nerve.

Each has a specific function.
Gut hormones.

"Bad guy" - SOMATOSTATIN:
(produced by fetus, rise 10-fold under stress)

inhibits gastrointestinal secretion,
inhibits motility,
reduces blood flow to gut and absorption,
causes gastric retention,
vomiting, constipation.
SOMATOSTATIN:

inhibits the good hormones, contributes to slow weight gain. At high levels also inhibits release of growth hormone.
It takes 30 to 60 minutes to lower somatostatin and other stress hormones.

SLEEP
VITAL !!!
DISSOCIATED INFANT WILL NOT SHOW FEEDING CUES
TRIGLYCERIDE
Left: glycerol,
Right: palmitic acid,
oleic acid, alpha-linolenic acid

In phosphoglycerides, glycerol molecule same:
two fatty acids esterified

Phospholipids are a major component of all biological membranes,

Sphingomyelin particularly concentrated in BRAIN major part of MYELIN.
Dendirification and myelinisation peaks occur at 2 and 6 months is maximal at one year ....

At one year: human milk has less protein, but MORE TRIGLYCERIDE !!!
Up to 6 months, milk is 7.4% fat, but after 12 months it is 10.7%
CC homozygote for "FADS2", "missing"

<table>
<thead>
<tr>
<th></th>
<th>NOT Brf</th>
<th>DID Brf</th>
<th>DID Brf</th>
</tr>
</thead>
<tbody>
<tr>
<td>NZ</td>
<td>98.4</td>
<td>103.2</td>
<td>98.9</td>
</tr>
<tr>
<td>UK</td>
<td>97.3</td>
<td>104.0</td>
<td>100.7</td>
</tr>
</tbody>
</table>
Evidence on the long-term effects of breastfeeding

SYSTEMATIC REVIEWS AND META-ANALYSES

Bernardo L. Horta, MD, PhD
Universidade Federal de Pelotas, Pelotas, Brazil

Rajiv Bahl, MD, PhD
Department of Child and Adolescent Health and Development, World Health Organization, Geneva, Switzerland

José C. Martines, MD, PhD
Department of Child and Adolescent Health and Development, World Health Organization, Geneva, Switzerland

Cesar G. Victora, MD, PhD
Universidade Federal de Pelotas, Pelotas, Brazil

World Health Organization
Figure 5.1. Mean difference in cognitive development scores and its 95% confidence interval between breastfed and non-breastfed subjects in different studies. Whether the estimate was for males (M), females (F) and all (A) is indicated in parenthesis.
BREASTFEEDING AND BREAST MILK INCREASE IQ
BOTTLE FEEDING & FORMULA DECREASE IQ
Be sure the wet nurse has plenty of milk ... because if she lacks it she may give the baby milk of a goat or sheep or some other animal, because the child ... nourished on animal milk does not have perfect wits like one fed on woman’s milk and always looks stupid and vacant and not right in the head.

14th century Tuscan text
PEDIATRICS Volume 129, Number 3, March 2012

POLICY STATEMENT

Breastfeeding and the Use of Human Milk

abstract

Breastfeeding and human milk are the normative standards for infant feeding and nutrition. Given the documented health and neurodevelopmental advantages of breastfeeding, infant nutrition should be considered a public health issue and not only a lifestyle choice. The American Academy of Pediatrics reaffirms its recommendation of exclusive breastfeeding for about 6 months, followed by continued breastfeeding as complementary foods are introduced, with continuation of breastfeeding for 1 year or longer as mutually desired by mother and infant. Medical contraindications to
BOTTLE FEEDING & FORMULA DECREASE IQ
Human Milk Banking Association of North America
• Setting the Standards for Human Milk Banking
• Meeting the Milk Banking Needs for North America

• A Safe Alternative in the Absence of Infant's Own Mother's

This website is designed to provide information on milk banking and how to contact a milk bank to donate milk or to order donor human milk. This site is also a resource for health care providers and others who are looking for information on HMBANA's resources and services.

http://www.hmbana.org/
"Where it is not possible for the biological mother to breastfeed, the first alternative, if available, should be the use of human breast milk from other sources. Human milk banks should be made available in appropriate situations."

World Health Organization/United Nations Children's Fund

http://www.breastmilkproject.org/
INFANT FEEDING FREQUENCY:
available evidence & neuroscience

OVERVIEW:
New section this background

Neuroscience
Anatomy & physiology
Available evidence
Proposal feeding frequency
Implications

References in this format
konklusion
that a good reliable set ov bowels
iz worth more to a man than enny quantity of brains."

http://www.vivo.colostate.edu/hbooks/pathphys/digestion/stomach/anatomy.html
CNS: cortical / subcortical
(also to PNS)

ANS: emotional / limbic brain
(incl SNS)

ANS: myelinated vagus (NA)

ANS: unmyelinated vagus (DMC)
sub-diaphragmatic

ENS: submucous plexus
myenteric plexus
The digestive system is endowed with its own, local nervous system referred to as the enteric or intrinsic nervous system.

The magnitude and complexity of the enteric nervous system is immense - it contains as many neurons as the spinal cord.
CEPHALIC PHASE
GASTRIC PHASE
INTESTINAL PHASE

FEEDBACK LOOPS

CNS
ENS
ANS

Internal Somatic environment
SMELL

“Olfaction in the fetal and premature infant: functional status and clinical implications”

Functional at end of first trimester, begins very early, experience dependent “effective from 29w GA” → significant

Schaal 2004
SMELL

modulates state organisation
elicits emotional behaviours
activates pre-feeding actions
anticipatory digestive physiology
regulates pace of ingestive behaviour

Schaal 2004
Perinatal brains show orientations towards "neonatal olfactory expectations"

When provided:
calming, autonomic orientation, active approach, metabolic conservation.

When not fulfilled:
withdrawal, autonomic defense & distress behaviours, metabolic expenditure
The secretion of Areolar (Montgomery’s) Glands from Lactating Women Elicits Selective, Unconditional Responses in Neonates

“... breast chemosignals activate oral activity on the nipple that releases a cascade of behavioral, neural, neuroendocrine and endocrine processes in the newborn and the mother.”

Doucet 2009
The secretion of Areolar (Montgomery’s) Glands

“In early ontogeny the sleeping brain may thus remain sentient of an organism’s odor environment.”

Doucet 2009
INFANT FEEDING FREQUENCY: available evidence & neuroscience

OVERVIEW:

Neuroscience

Anatomy & physiology

Available evidence

Proposal feeding frequency

Implications
Fetal stomach appears 4 weeks GA. By 11 weeks, wall capable of muscular contraction.

“Patterns of antropyloric motility in fed healthy preterm infants”

... the neuroregulatory mechanisms responsible for the coordination of antropyloric motility and gastric emptying are well developed by 30 weeks of PMA.

Hassan 2002
**Hydrochloric acid**

important for activation of pepsinogen, inactivation of microorganisms such as bacteria.

**Pepsinogen**

activated by acid into active pepsin, responsible for the stomach's ability to initiate digestion of proteins.

**Chymosin**

is an enzyme whose role is to curdle or coagulate milk in the stomach, a process of considerable importance in the very young animal.
Chymosin makes the milk into "cheese" halfway between liquid and solid. Stomach empties in 60 minutes.
Gut hormones.

20 different hormones work in the gut – regulated by the vagal nerve.

Each has a specific function.

Uvnas-Moberg 1989
CEPHALIC PHASE
GASTRIC PHASE
INTESTINAL PHASE

FEEDBACK LOOPS
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inhibits the good hormones, contributes to slow weight gain.

At high levels also inhibits release of growth hormone.

Uvnas-Moberg 1989
It takes 30 to 60 minutes of SSC to lower somatostatin and other stress hormones.

SSC & SLEEP

VITAL !!!
The “niche” (occupation) of a neonate (Alberts)

Alberts 1994
Enteric Nervous System

The “niche” (occupation) of a neonate (Alberts)

BOND $\rightarrow$ FEED

SLEEP $\rightarrow$ SLEEP

PLAY $\rightarrow$ FEED
EVIDENCE
FOR
FEEDING
FREQUENCY
???

Edmond 2006
Findings of the review

What to feed
Choice of milk

Breastfeeding or mother’s own expressed milk. There is strong and consistent evidence that feeding mother’s own milk to pre-term infants of any gestation is associated with a lower incidence of infections and necrotising enterocolitis, and improved neurodevelopmental outcome as compared with formula feeding. Feeding unsupplemented mother’s own milk to pre-term infants <1500 g resulted in slower weight and length gains, but the implications of this slower growth are unclear and there is not enough evidence to assess if it increased the risk of malnutrition. Long-term beneficial effects of breastfeeding on blood pressure, serum lipid profile or pro-insulin levels have also been reported for pre-term infants. There are limited data on most outcomes in term LBW infants; the available data suggest that improved infection and neurodevelopmental outcomes associated with feeding mother’s milk in pre-term infants are also seen in this group.
How to feed

Feeding methods

Cup feeding compared with bottle feeding. In pre-term infants, cup feeding leads to higher rates of full (exclusive or predominant) breastfeeding, compared with bottle feeding at the time of discharge from hospital. Cup feeding was also associated with greater physiological stability, e.g. lower risk of bradycardia or desaturation, than bottle feeding. No data are available for term LBW infants. When cup feeding is correctly done, i.e. with the infant upright and the milk is not poured into the mouth, there is no evidence that there is an increased risk of aspiration.
FEED FREQUENCIES AND INTERVALS

Results

Effects on mortality, serious morbidity, neurodevelopment or malnutrition

No RCTs or observational studies were located which examined the impact of feeding frequencies or intervals on mortality, serious

Effects on other important outcomes

Only case series and descriptive studies were located which examined outcomes such as feed tolerance and biochemical measures (Level IV evidence) (270, 282). These studies indicated

Conclusions and implications

Only case series and descriptive studies were located in this section. These describe the

Recommendations

No policy statements from international or national organizations were located which examined the frequency of feeding in LBW infants. Standard practice in many neonatal units is to commence feeding 4-hourly for infants >2000 g, 3-hourly for infants 1500–2000 g, 2-hourly for infants 1000–1500 g, and hourly in infants <1000 g. Feeding intervals are then extended on an individual basis depending on feed tolerance, gastric aspirates and physiological stability. It was not possible to provide additional recommendations due to insufficient evidence.

Only case series ... Insufficient evidence

No mention of stomach capacity
EVIDENCE FOR STOMACH CAPACITY

Edmond 2006
Assumption: 3kg baby, requiring 160 ml/kg/day
daily requirement = 480ml

Standard CARE:
3 hourly schedule
KEY QUESTION:
WHAT IS THE STOMACH VOLUME OF THE NEONATE ???
Length

Transverse

AP diameter

Using +2SD →

Goldstein 1987
BRADSHAW formula

Formula for calculation of stomach capacity (Charles Bradshaw, UCT)

Assumptions: the stomach can be approximated by dividing into three sections, namely a ellipsoidal hemisphere, an ellipsoidal cylinder, and a skewed ellipsoidal cone.

Variables:  
a = anteroposterior radius,  
t = transverse radius,  
l = length stomach

Relations: the height of the cone and the hemisphere are both the same as ‘a’.

Ellipsoid = \[
\frac{4}{3} \pi r_1 r_2 r_3 = \frac{4}{3} \pi a a t;
\]
therefore volume of hemisphere = \[
\frac{2}{3} \pi a a t
\]
Cylinder = Area of base * height = \[
\pi a t \cdot (l - 2a)
\]
Skewed cone = \[
\frac{1}{3} \cdot \text{base} \cdot \text{height}
\]
Total volume = \[
\frac{2}{3} \pi a a t + \pi a a t (l - 2a) + \frac{1}{3} \pi a a t
\]
\[
= \pi a t l - \pi a a t + \pi a a t (l - a)
\]

Goldstein and Sase data:
Stomach capacity at term 10 - 15 ml
Assumption: 2.5 kg baby 33w GA, requiring 150 ml/kg/day = 375 ml

45 MIN CYCLES (32 cycles/day)
12 ML PER CYCLE = 384 ml
Newborn stomach volume.

Gastric volumes at birth correlated with gastric pH, gastrin and somatostatin → "fetus drinks 10 ml portions of amniotic fluid ..."
Only recent study located: "Autopsy" capacity was determined in Indian post-mortem studies.

"An Autopsy Study of Relationship between Perinatal Stomach Capacity and Birth Weight."

100 autopsies (63 SB, 37 ENND)
Tied at cardia and pylorus, filled with water, emptied & measured, repeated,
"... obliteration of the gastric curvatures"
"due care to minimize stretch artifacts"

Naveed 1992
Infants above 2500g only:

<table>
<thead>
<tr>
<th>Category</th>
<th>Ave</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stillborn (n 11)</td>
<td>19.6 ml</td>
<td>(10-35)</td>
</tr>
<tr>
<td>Early death (n 9)</td>
<td>17.8 ml</td>
<td>(10-25)</td>
</tr>
<tr>
<td>All cases (n 20)</td>
<td>18.8 ml</td>
<td></td>
</tr>
</tbody>
</table>

Naveed 1992

"An Autopsy Study of Relationship between Perinatal Stomach Capacity and Birth Weight."
Postmortem: in situ measures
(applied Bradshaw formula)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Count (n)</th>
<th>Ave (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>11</td>
<td>15 ml</td>
</tr>
<tr>
<td>2 months</td>
<td>11</td>
<td>35 ml</td>
</tr>
<tr>
<td>2-4 m</td>
<td>10</td>
<td>50 ml</td>
</tr>
<tr>
<td>4-6 m</td>
<td>8</td>
<td>100 ml</td>
</tr>
</tbody>
</table>
Known references with data:

Scammon and Doyle 1920

“Observations of the capacity of the stomach in the first ten days of post natal life.”

Zuccarelli’s method: stomach filled at autopsy to “a pressure of between 15 and 20 centimeters of water”
“Observations of the capacity of the stomach in the first ten days of post natal life.”

Anatomic capacity was determined in post-mortem studies

Main data set → Alliot 1905 (n 25)
Scammon own cases ? (n 13)

30 – 35 ml at birth – almost regardless of birth weight

Scammon 1920
Known references with data:

Scammon and Doyle 1920
quoted in Silverman 1961

"Observations of the capacity of the stomach in the first ten days of post natal life."

14571 feeding records from 323 newborns
"physiologic capacity" → all breastfed
test weighing before and after feeding

Scammon 1920
“... modern infant feeding.” →

“infants were breastfed 5 times per day”

**INFERENCE??** If fed 5 x per day and daily requirement $160 \text{ ml} \times 3\text{kg} = 480$

Required volume: $480 / 5 = 96 \text{ mls}$

Did not measure stomach capacity: Pre-determined a feeding frequency!

Scammon 1920
“... modern infant feeding.” → 5 per day

Did not measure stomach capacity: Pre-determined a feeding frequency!

“... the figures ... presented here are distinctly higher than those of earlier investigators ... not surprising considering ... (they) made their observations upon infants which were fed eight or more times per day.”

Scammon 1920
Imagine a study !!

Let us measure the stomach capacity with a balloon ... at end of NGT
Test the pressure on adults must not be uncomfortable

Once the pressure starts to rise:
→ there is risk for reflux
→ to be avoided – expected physiology

THIS SHOULD BE THE STOMACH CAPACITY
Imagined study was done!!

Zangen S et al 2001
Rapid Maturation of Gastric Relaxation in Newborn Infants

75 ml per feeding

No reference given ....

Zangen 2001
Pressures (mmHg)

Balloon inflates to 15 ml no increase

Functional capacity
"Functional capacity" equivalent to "expectation volume", for which optimal pepsin / acid is made, does not cause distention, allows adequate time for curdle, allows protein breakdown, allows controlled pyloric passage.
Zangen S et al
Rapid maturation of gastric relaxation in newborns

Pressures (mmHg)

Balloon inflates to

15 ml no increase
20 ml pressure OK

physiological capacity ...
TERMINOLOGY PROPOSALS

Physiological capacity
Maximal amount stomach can handle without undue stress.

“Receptive capacity” of STOMACH
maximal amount stretched organ holds

“Ingestive capacity” of BABY
amount baby or infant swallowed, (note, excess not in stomach)
Physiological capacity
Maximal amount stomach can handle without undue stress.

“Receptive capacity” of STOMACH
maximal amount stretched organ holds

“Ingestive capacity” of BABY
amount baby or infant swallowed,
(note, excess not in stomach)
## EVIDENCE: (NBn 111009)

<table>
<thead>
<tr>
<th>Author</th>
<th>Capacity</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sase</td>
<td>10-15 ml</td>
<td>Live, term fetus</td>
</tr>
<tr>
<td>Goldstein</td>
<td>10-15 ml</td>
<td>Live, term fetus</td>
</tr>
<tr>
<td>Widstrom</td>
<td>10 mls</td>
<td>Live, newborn</td>
</tr>
<tr>
<td>Zangen</td>
<td>20 mls</td>
<td>Live, (pressure)</td>
</tr>
<tr>
<td>Naveed</td>
<td>20 mls</td>
<td>Autopsy (SB)</td>
</tr>
<tr>
<td></td>
<td>20 mls</td>
<td>Autopsy (ENND)</td>
</tr>
<tr>
<td>Kernessuk</td>
<td>15 mls</td>
<td>Autopsy (in situ)</td>
</tr>
<tr>
<td>Scammon (Alliot)</td>
<td>30-35 ml</td>
<td>Autopsy (water pressure)</td>
</tr>
</tbody>
</table>
PROPOSAL:
The CAPACITY of a week old baby’s stomach is approx **20 ml.**
INFANT FEEDING FREQUENCY: available evidence & neuroscience

OVERVIEW:

Neuroscience
Anatomy & physiology
Available evidence
Proposal feeding frequency
Implications
Assumption: 3kg baby, requiring 160 ml/kg/day

Daily requirement = 480ml

Standard CARE: 3 hourly schedule

MOTHER NATURE:

1 hourly schedule
FUNCTIONAL CAPACITY

PHYSIOLOGICAL CAPACITY

RECEPTIVE CAPACITY of stomach

INGESTIVE CAPACITY of BABY
PROPOSAL:

The FEEDING FREQUENCY of the NEONATE is approx 60 min.
BRAIN CYCLING

CEPHALIC PHASE
GASTRIC PHASE
INTESTINAL PHASE

REM
NR1
NR2
NR3
NR4

STOMACH FILLING & EMPTYING
Normal physiology of the Enteric Nervous System

The “niche” (occupation) of a neonate (Alberts)

BOND $\rightarrow$ FEED \quad PLAY $\rightarrow$ FEED

SLEEP $\rightarrow$ SLEEP

“Small and frequent feeds, according to the sleep cycle”
INFANT FEEDING FREQUENCY: available evidence & neuroscience

OVERVIEW:

Neuroscience
Anatomy & physiology
Available evidence
Proposal feeding frequency
Implications
A balloon in stomach can fill to 76 mls

What does the stomach – without a balloon – do to 76 mls?

REFLUX !!!

PRESUME: each feed approximately 75 mls
WHERE IS THE MILK?

This volume is not in the stomach.
How To Do Just About Everything

How to Burp a Baby

Burping a baby can reduce spitting up and relieve bloating caused by swallowed air. Here are some tried-and-true methods.
What happens when my baby spits up?

Babies spit up when they've eaten too much or when they're burped. It can also happen when your baby is drooling.

Spitting up is not vomiting.

Babies usually don't notice when they spit up, while vomiting is forceful and painful. Spitting up is a common occurrence for most babies.
What happens when my baby spits up?

Babies spit up when they've eaten too much or when they're burped. It can also happen when your baby is drooling.

Spitting up is not vomiting.

Spitting up is reflux.

Nils Bergman, 2011
Blood sugar may fall ... after 90 minutes ...

“There is a reason behind everything in nature”  Aristotle

Would nature allow this?
HYPOGLYCAEMIA

A babies stomach empties in **60 minutes**.
Blood sugar may fall ... after 90 minutes ...
Option? **HOURLY FEEDING.**
Stettler et al
Weight Gain in the First Week of Life and Overweight in Adulthood: A Cohort Study of European American Subjects Fed Infant Formula

Large volume feeds stretched stomach = doubled absorptive capacity as adult

Figure 1. Conceptual model for hypothesized associations of infancy weight gain and feeding mode with adulthood overweight.
This finding is important, not so much to predict which infants are at risk for becoming overweight adults, but more to understand the importance of the human physiology of programming during short early-life periods on the development of chronic disease over the life course.
Gastric overfilling syndrome?

**Excessive volumes**
- reflux, aspiration, colic

**Excessive time interval**
- hypoglycaemia

**Adaptations**
- diabetic diathesis, obesity
“Small and frequent feeds, according to the sleep cycle”
WHAT IS THE STOMACH VOLUME OF THE PREMATURE??
Assume low resilience

Assume proportionality
The CAPACITY of a low birthweight prem from 20ml / 3000g

\[ = 0.007 \times BWt \ (g) \]

1kg \( \times 0.007 = 7\text{mls} \)

2kg \( \times 0.007 = 14\text{mls} \)
Standardised from 20ml capacity for 3kg baby (x 0.007)

Baby weight; freq; req’d size → actual

2kg baby: 4hrly
~ 320 ml/6 = 53ml → 14ml

1.5 baby: 3hrly
~ 240 ml/8 = 30ml → 10ml

1.0 baby: 2hrly
~ 160 ml/12 = 13ml → 7ml
Babies should be fed EVERY TIME THEY WAKE!!
Proposed Management

All babies should be fed at least once an hour!!
Proposed Management →

Unreasonable !!!

All babies should be fed at least once an hour!!
The first Milk Ejection Reflex (MER) elicited in < 2 minutes works quickly swallowed 1 minute

Feeding time (max) 3 minutes

Repeat every 1 hour

Prime 2007
The “normal” or usual and common breastfeed takes 15 minutes,
discomfort after burping time 5 minutes

Feeding time 20 min
Repeat every 3 hours
3 minute 20ml feeds x 24/d = 72 minutes
20 minute 60ml feeds x 8/d = 160 minutes

SMALL AND FREQUENT FEEDS ARE EFFICIENT !!!

FEWER NURSES NEEDED !!!
The calculated daily requirement for a 3kg baby can be given without increase in pressure ....
\[ \rightarrow \text{MINIMAL RISK} \]

20 mls x 24 feeds
\[ = 480\text{mls} / \text{day} \]

PARENTS CAN DO SAFELY !
All babies should be fed at least once an hour!!
First two days: **COLOSTRUM**
15 mls / day (Paula Meier)
“one teaspoon, three times a day”

From third day: **MILK**
small frequent feeds (on demand) between sleeps

Available from Geddes Productions
Infant feeding frequency: Proposal based on available evidence and neuroscience

“Small and frequent feeds, adjusted to the sleep cycle”
In the past, whether to breastfeed or not was a lifestyle choice. Our new knowledge of the brain makes breastfeeding a public health issue.

(Gail Storr, Fredericton, NB)
SUMMARY!!

SKIN-TO-SKIN
(Regulation)

SLEEP
(Brain)

FEEDING
(Stomach)

LOVE!
("mind")