Original Article

Neonatal hypernatremia and dehydration in infants receiving inadequate breastfeeding

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Introduction: Neonatal hypernatermic dehydration (NHD) is a potentially very serious condition, which has been reported to occur in infants who have breast feeding problems in the first week of the life. This study looked at the incidence, risk factors, clinical symptoms and complications of NHD in healthy breastfed term neonates. Methods: A prospective case-control study was conducted on 53 neonates with serum sodium concentrations of ≥ 150 mmol/L (as the case group) who were recruited between June 2006 and June 2007 from the Ghaem hospital (Mashhad, Iran) to investigate the relationship between NHD and breastfeeding. Fifty-three healthy breastfed full-term neonates (serum sodium <150 mmol/L) from the same hospital were also recruited as the control group. Result: The results showed an average weight loss of 1.6% in the healthy neonates vs. 16.2% in infants with NHD (p<0.001). The frequency of feeds received per day was 10.2 for the healthy neonates vs. 7.6 in the NHD group (p<0.001). The NHD group had mothers who had a higher frequency of breast problems (23 vs. 7, p<0.001). Mean serum sodium concentration was significantly lower in the control group compared with the cases (137.80 vs.160.06 mmol/L, p<0.001). The main presenting features of the infants with NHD were fever, lethargy and jaundice. Conclusion: Breastfeeding problems are associated with the presence of NHD. Therefore, more breast examination during prenatal and postnatal periods and careful neonatal weight watch during the first week of life could decrease the incidence of NHD.

Key Words: hypernatremia, dehydration, neonates, risk factor, breastfeeding

INTRODUCTION

Breastfeeding, as opposed to formula feeding, is considered the better option and undoubtedly provides health advantages to both infant and mother. Adequate breast milk intake depends on several interdependent processes: normal mammogenesis, lactogenesis, and galactopoiesis as well as effective milk delivery to the infant. The latter depends on effective maternal breast feeding techniques, combined with an intact milk-ejection reflex. The volume of human milk consumed daily by a neonate depends on the frequency and duration of feeds and the pattern of breast use. Normal neonatal feeding is usually on demand every 2-4 hours, with a range of 10-70 ml per feed over a period of 5-20 minute.[1-3]

It is normal over the first week of life for the neonate to lose as much as 5-7% of its birth weight. Neonates should regain their birth weight by the tenth day of life.[1,2] Many underlying factors can interfere with lactation and breastfeeding, and thus contribute to inadequate breastfeeding and complications, for example hypernatremic dehydration.[2] It has been reported that some normal healthy newborns developed Neonatal hypernatermic dehydration (NHD), even while being exclusively breast fed. Inadequate breast milk production appears to be the most important factor in the development of NHD.[3] NHD is a potentially lethal condition and is associated with cerebral edema, intracranial hemorrhage, seizures, and disseminated intravascular coagulation prior to death.[4,5] To investigate the factors contributing to this problem, its incidence, maternal and neonatal risk factors, clinical

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symptom, its management and complications, a comparison was made between NHD patients and an equal number of healthy breastfed term neonates from the local neonatal clinic local, Mashhad, Iran.

MATERIALS AND METHODS

This study was conducted from June 2006 to June 2007. From 1816 term neonates who were admitted to the Pediatric Emergency and Neonatal Intensive Care Unit (NICU) wards of the Ghaem hospital (Mashhad, Iran) during the course of this study, 57 were selected as the case group based on the following criteria: 1) rehospitalization within 27 days of discharge from the birth hospitalization; 2) being normal in the first examination in the delivery service; and 3) serum sodium ≥150 mmol/L. Of these 57 neonates, four were excluded due to Cleft palate malformations and sucking problems (n = 2), Down's syndrome (n = 1) and neuromuscular disorder (n = 1), with 53 neonates entering the study. Fifty-three healthy newborns with serum sodium concentrations less than 150 mmol/L, who were referred to the Outpatient clinic for screening, were also selected as the control group. This study was conducted with the approval of the ethical committee of Mashhad university of Medical Sciences (MUMS) and parental informed consent was obtained for every patient before admission to the study.

Complete blood count (CBC), blood culture, cerebrospinal fluid culture, total and direct serum bilirubin, blood urea, creatinine, sodium, potassium and blood sugar were measured in both groups, whenever it was clinically indicated. Arterial gas (in 64% of cases), brain axial CT scan (in 47% of cases) and ultrasonography (in 58.5% of cases) were done whenever it was clinically indicated. Maternal factors (age, weight, education, parity, pregnancy complications, mode of delivery, duration of delivery, breast size before, during and after delivery and feeding, breast problems, breastfeeding technique (position), let-down reflex, time of first breastfeeding, frequency of breastfeeding and hospital stay after delivery), as well as neonatal factors (age, birth weight, new weight, hospital stay, 5-minute APGAR score, gestational age, sex, cause of admission, heart rate, feeding duration, number of urinations and defecations per day) were recorded for all controls and cases. Pregnancy complications included hypertension, diabetes mellitus, anemia, vaginal bleeding, preeclampsia, infections, malignancy, endocrine disorders, epilepsy, and collagen vascular disorder. A breast problem was defined as the presence of one of the following: inverted nipple, cracked nipple or mastitis identified during the physical examination. The classic breastfeeding position was considered as the normal position. In the classic position, the mother's same sided arm supports the infant at the breast on which the infant is nursing and whose head is cradled near the mother's elbow while the arm supports the infant along the back, facing the mother, chest to chest. The let-down reflex was defined as the milk-ejection reflex in response to suckling. All breastfeeding data were collected using a questionnaire which was filled in by an interviewer. All babies were examined by a neonatologist. Hospitalized babies were treated for sepsis and dehydration if necessary and NHD complications were also recorded and fully managed. Clinical symptoms and signs of successful mammogenesis included prenatal breast tenderness and growth. Clinical symptoms and signs of successful lactogenesis included a sensation of "milk coming in," postpartum breast enlargement or engorgement and the production of colostrum.

Statistical analysis

All statistical analyses were performed using SPSS 13.5 for Windows software (SPSS Inc., 444 N Michigan Avenue, Chicago, Illinois 60611, USA). Values were expressed as mean ± SD. The group comparisons were assessed by Student's *t*-test (in case of normally distributed data) or Mann-Whitney U test (in case of non-normally distributed data). Categorical variables were compared using chi-square test. Regression analysis was performed using binary logistic regression model with the forward conditional method. A two-tailed *p*-value of <0.05 was considered statistically significant.

RESULTS

Maternal findings

A total of 106 mothers and their neonates participated in this study (either as a member of the control or the case groups). No significant difference was observed in age, parity, education, gestational age, duration of labour and the mode of delivery between mothers in the control and case groups ($p>0.05$, Table 1). However, the rates of breast problem, breast feeding position problem, absence of milk let-down reflexes and absence of soft breast after feeding, were significantly higher in the cases compared with the controls: ($p<0.001$, Table 1).

Three mothers of neonates with NHD (5.6%) had a failure of mammogenesis without enough prenatal breast growth, two of them had experienced the same problem with their previous babies. In eight other mothers (15%) with normal mammogenesis, no postpartum breast growth was seen (two of them showed severe postpartum hemorrhages). Twenty three mothers (43.4%) showed absence or delay in the milk let-down reflex with inadequate milk release, seventeen (32%) improper latching of baby to breast, twenty three (43.4%) maternal breast problems (9 mother with inverted nipple, 9 with cleft nipple and 5 with mastitis) and finally in 23 mothers (43.4%) unsuitable breast feeding techniques were observed (Table 1). Ninety-two percent of mothers (49 of 53 mothers) were discharged with their infants 48 hours after birth and it should be mentioned that for the neonates with NHD, 54.3% of their mothers were primiparous.

Neonatal findings

There was no statistically significant differences between the two groups regarding gender, gestational age, and leukocyte count ($p>0.05$, Table 2). Incidence of breast feeding-associated NHD among hospitalized term neonates was 3.1% (57 of 1816 patients admitted to Ghaem Hospital with serum sodium concentrations of ≥150 mmol/L), though four of these individuals were eventually excluded from the study (two with cleft palate, one with neuromuscular disorder and one with the Down's syndrome). They were admitted to the hospital 3 to 21 days postpartum (average 9) with mean hospital stay of 6.1±3.5 days and duration before full correction of hyper-

Table 1. Maternal characteristics of case and control groups

Maternal characteristics	Cases (n = 53)	Control (n = 53)	*p*-value
Age (year)	27.0±5.9	27.6±6.6	0.391
Parity	2.0±1.6	1.9±0.9	0.473
NVD† /CS ‡	26/20	31/22	0.843
Education (year)	10.3±4	10.6±3.5	0.590
Weight (Kg)	64.1±13	69.9±11	0.033
Breast problem	23 (43.3)	7 (13)	<0.001
Breastfeeding problem	14 (26.4)	1 (1.9)	<0.001
Maternal technical difficulties	23 (43.3)	0 (0.0)	<0.001
Absence of let-down reflex	29 (54.7)	2 (3.8)	<0.001
Failure breast growth in pregnancy	4 (7.5)	0 (0.0)	0.002
Absence of postpartum breast enlargement	8 (15.0)	0 (0.0)	0.001
Absence of Soft breast after feeding	23 (43.4)	0 (0.0)	<0.001
pregnancy complication	9 (16.9)	3 (5.6)	0.098

Values are expressed as mean ± SD or number (%). Comparisons between control and case groups were made using the Student's *t*-test (in case of normally distributed data), Mann-Whitney U test (in case of non-normally distributed data) or chi-square test (in case of categorical variables). †NVD: normal vaginal delivery; ‡C/S: caesarean section.

Table2. Characteristics of case and control infants

Neonatal Characteristics	Cases (n = 53)	Control (n = 53)	*p*-value
Age (day)	9.0±4.5	8.8±4.1	0.859
Birth weight (kg)	3.145±0.555	3.31±0.441	0.137
New weight (kg)	2.63±0.450	3.38±0.522	<0.001
weight loss (%)	16.2±5.9	1.6±2.7	<0.001
Five minute-APGAR Score	9.0±0.9	9.4±0.5	0.004
Gestational age (week)	39.4±1.4	39.7±0.6	0.357
Sex (male/female)	30/23	32/21	0.844
Time of first breast-feeding (hour)	5.2±3.6	1.8±1.4	<0.001
Number of feedings/day	7.6±3.5	10.3±1.8	<0.001
Duration of feeding (minute)	14.3±4.3	13.9±6.4	0.166
Number of urination/day	2.9±0.9	5.4±0.9	<0.001
Number of defecation/day	3.5±2.4	3.1±1.2	0.755
Time of first defecation (hour)	20.2±16.1	11.6±4.3	<0.001

Values are expressed as mean±SD, number or percentage. Comparisons between control and case groups were made using the Student's *t*-test (in case of normally distributed data), Mann-Whitney U test (in case of non-normally distributed data) or chi-square test (in case of categorical variables).

natremia of 3±1.8 day (range: 1-6 days). The average time to the first feed postpartum was 5.2 hours, the average number of feeds per day was 7.6±3.6, with an average duration of feeding of 14.3±4.3 minute, the number of urination episodes was 2.7±0.9 per day and the time to first defecation postpartum was 20.2±16.8 hours (Table 2). The duration of breastfeeding was less than 5 minutes for 16 infants and more than 30 minute for 12 other infants (Table 2). The main reasons for admission were noted to be fever (50%), lethargy (45.3%), jaundice (39.6%), irritability (26.4%), seizure (22.6%) and excessive weight loss (7.5%). Major signs in primary examination and evaluation were weight loss of more than 10 percent of birth weight (88.6%) and excessive drowsiness (15.1%) (Figure 1). No significant difference in birth weight was found between cases and controls, but weight on presentation was significantly different between the two groups ($p<0.001$) and the percentage of weight loss was also significantly different between the groups, 16.2± 5.9 vs. 1.6±2.7 for the NHD and control group respectively (Table 2).

The median peak serum sodium concentration was 160 mmol/L in the NHD neonates (range: 150-182 mmol/L) and the peak serum sodium concentration was strongly correlated with percentage weight loss on admission ($p<0.001$, Figure 2).

Regression analysis

For regression analysis, neonatal parameters including infant new weight, weight loss percentage, 5-minute Ap-

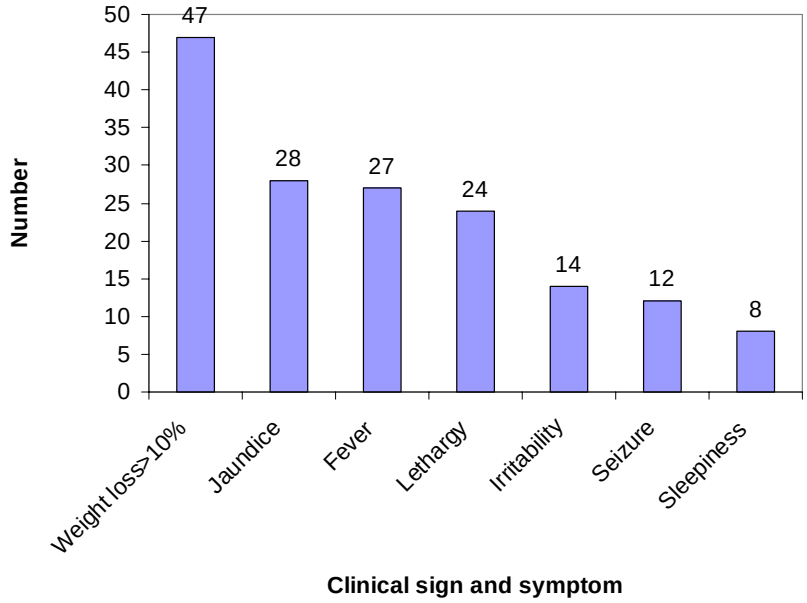

Figure 1. Presenting symptoms and signs of breastfeeding-associated NHD.

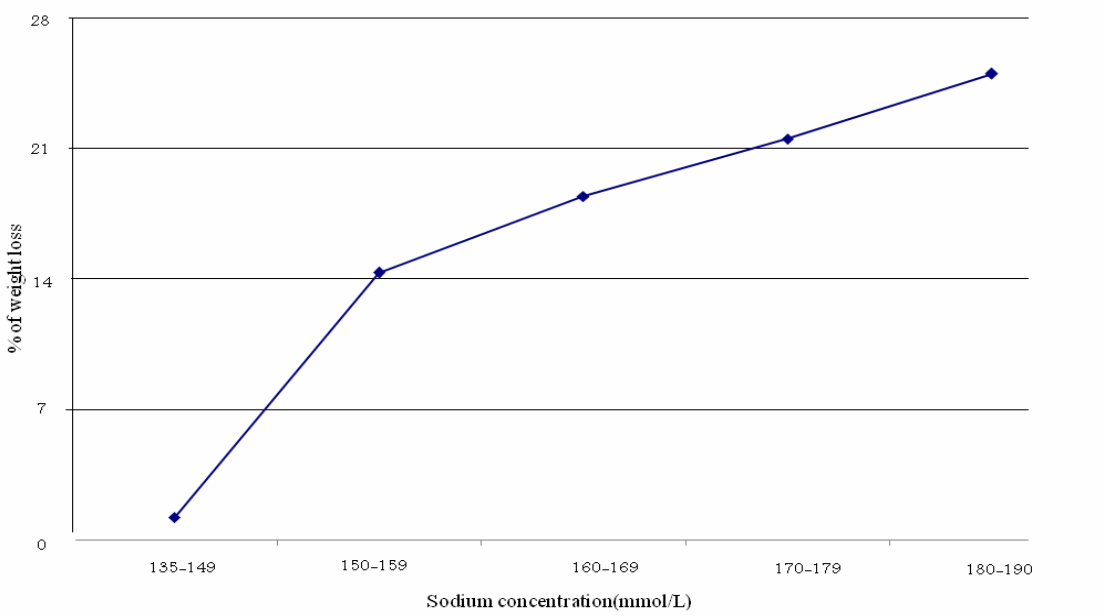

Figure 2. The relationship between serum sodium and the percentage of weight loss.

gar score, time of first breastfeeding, time of first defecation, number of feedings per day and number of urinations per day, together with maternal factors including presence of breast problems, breastfeeding problem, let-down reflex, breast growth in pregnancy, postpartum breast enlargement and soft breast after feeding were entered into a binary logistic model with the forward conditional method to assess their impact on the presence of NHD as the dependent variable. Among the aforementioned neonatal and maternal parameters, number of feedings/day (p=0.007; odds ratio: 0.332; 95% confidence interval: 0.150-0.735) and let-down reflex (p=0.010; odds ratio: 0.052; 95% confidence interval: 0.005-0.498) had significant impacts on the presence of NHD.

DISCUSSION

Breastfeeding is universally considered to be the best and the safest way to feed neonates. Human breast milk is normally low in sodium,[1] which mitigates against the possible development of hypernatremia in breastfed neonates.[6] Studies of the electrolyte composition of colostrum have shown a mean sodium concentration of 64.8±4.4 mmol/L after delivery, dropping to 21.4±2.3 mmol/L by the third postpartum day (colostrums), and leveling off at a value of 7.0±2.0 mmol/L by week two in mature milk.[7] Compared with cow's milk, mature human milk contains considerably less sodium, potassium, and chloride.[8]

Higher levels of sodium in breast milk are associated with lactation failure, and a reduction in feeding frequency is associated with a marked rise in milk sodium

concentrations.[9] This association might be related to reduced breast milk production, which could in turn be secondary to maternal factors or neonatal factors.[1,4] It has been shown that insufficient breast milk production is the most important factor in the induction of NHD[3] which is a potentially lethal condition through induction of cerebral edema, intracranial hemorrhage, seizures, disseminated intravascular coagulation and finally death.[4,5]

In this study, we observed that nearly half of the mothers of neonates with NHD had either technical difficulties (positioning and latching) or breast problems (17% inverted nipple, 17% cracked nipple and 9% had mastitis). A similar percentage of maternal technical difficulties has been reported previously,[2] which clearly shows the importance of the maternal aspects of breastfeeding. Although failure of mammogenesis was observed in less than 6% of mothers, more than 60% of them had history of NHD in their previous baby. The reliability of the clinical evaluation of mammogenesis depends on the identification of clinical symptoms and signs which include prenatal breast tenderness and growth.[2] It is highly recommended that breast examination during pregnancy (nipple shape and breast growth) and after delivery (breast engorgement, inverted or cracked nipples and mastitis) should be considered as a routine clinical practice to lower the risk of breastfeeding problems. Moreover, education on the most appropriate procedure for breastfeeding for new mothers seems to be necessary.

Milk production is controlled by the lactogenic hormones prolactin and growth hormone during lactogenesis and galactopoiesis.[2,10] Clinical symptoms and the signs of successful lactogenesis include a sensation of "milk coming in", postpartum breast enlargement or engorgement and the production of colostrum. Eight mothers (15%) in this study experienced prenatal breast tenderness and enlargement, but no postpartum breast growth was subsequently recorded during clinical examination. A quarter of them had postpartum hemorrhages. Therefore, normal lactogenesis should be checked either by midwives or physicians after delivery.

It was noted that for >50% of mothers with NHD neonates there was a delay in the let-down reflex which was due to inadequate ongoing breast stimulation and drainage. Several factors contribute to inadequate breast stimulation and drainage including difficulty in latching onto the breast, maternal technical difficulties,[2] and breast problems.

In the present study, the incidence of breastfeeding associated hypernatremia among all hospitalized term neonates was 3.1%, significantly higher than the reported incidence of hypernatremia attributable to all causes among hospitalized children, adults, and elderly subjects (1.1-1.9%).[4,11] It is unclear why the incidence of breastfeeding-associated hypernatremia is so high, but it does not seem to be attributable to early discharge from the hospital or to a higher incidence of breastfeeding in the studied population.[11,12] Some reports have demonstrated the importance of early initiation of breastfeeding post-delivery for successful lactation.[13] It is possible for a suckling infant to get a volume of less than 100 ml/day on the first day of life with milk production rapidly increasing to an average of 500 ml/day by the fourth day.[14] Therefore, the recovery of weight loss is expected to occur by the end of the first week and it has already been stated that the median durations for maximum weight loss and recovery are 2.7 and 8.3 days, respectively.[1,14] The infant with hypernatremic dehydration secondary to breastfeeding is typically encountered somewhere between the first and the third weeks of life with the presentation of NHD at around day 10 postpartum (range 3–21 days).[12,15] In this study the average day of hospital admission was at approximately day 9 (range 3-21 days).

More than half of the NHD patients in this study were from primiparous mothers, and this has been reported as one of the most important risk factor for NHD.[16] Therefore, primiparous mothers should receive more reassurance and practical advice in the breastfeeding techniques.[17] Although newborn weight loss during the first week of breastfeeding has been regarded as a physiological process, severe weight loss may lead to the development of a profound state of hypernatremic dehydration with potentially very serious consequences. It has been estimated that 31.8% of breastfed infants with weight loss exceeding 10% have hypernatremia.[3,12,18,19] In our study, although 88.6% of infants had >10% weight loss, dehydration was noted rarely (10.1%) in the medical examination before laboratory evaluation. This is not surprising because infants with hypernatremic dehydration have better-preserved extra cellular volume, and therefore have less-pronounced clinical signs of dehydration. Higher peak serum sodium concentrations were strongly correlated with greater percent weight loss at admission (p<0.001, Figure 2). Although most infants studied in this study were admitted to the hospital with fever, lethargy, jaundice and irritability, it was clear that fever and hypernatremia are often found in neonates with excessive weight loss and so fever can serve as an additional indicator of risk of NHD.

The association of hypernatremia with significant hyperbilirubinemia, which occurred for 36.9% of our patients, might contribute to long-term neurologic sequelae. Hypernatremia can cause impairment in blood-brain barrier function, which may enhance the diffusion of bilirubin across the blood-brain barrier and thereby may enhance the risk of bilirubin encephalopathy.[20]

In summary, the results of the present study indicate that breast feeding problems are the main risk factors in NHD incidence and some of them can be diagnosed and corrected before or after parturition. To prevent NHD in neonates, continuing weight watch and monitoring the number of urination per day are strongly recommended.

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AUTHOR DISCLOSURES

None declared.

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Original Article

Neonatal hypernatremia and dehydration in infants receiving inadequate breastfeeding

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母乳哺餵不足與新生兒高鈉血症和脫水

前言：新生兒高鈉血症脫水(NHD)是一種潛在的嚴重病狀，這個情形曾發生在有母乳哺餵問題的第一週新生兒。這個研究探究以母乳哺餵的健康足月新生兒，其 NHD 的發生率、危險因子、臨床症狀及併發症。方法：一個前瞻性病例對照研究，從 2006 年 6 月至 2007 年 6 月共有 53 名在 Ghaem 醫院(伊朗 Mashhad 市)的新生兒，其血清鈉濃度≥150 mmol/L(病例組)被納入 NHD 及母乳哺餵之相關性研究。另外 53 名來自於同一家醫院，有母乳哺餵且健康的足月新生兒(血清鈉<150 mmol/L)則納入當做對照組。結果：研究結果顯示在健康的新生兒及有 NHD 的嬰兒平均體重分別減輕 1.6%及 16.2% (p<0.001)。健康的新生兒每天餵食的頻率為 10.2 次，NHD 組為 7.6 次 (p<0.001)。NHD 組的媽媽有較高頻率的母乳問題(23 比 7，p<0.001)。對照組比起病例組有顯著較低的血清鈉濃度(137.80 比 160.06 mmol/L，p<0.001)。有 NHD 的嬰兒明顯症狀為發燒、嗜睡及黃疸。結論：母乳哺餵的問題與 NHD 發生有相關。因此，在孕期前後做較多的胸部檢查，且在出生後第一週關注新生兒體重的變化，可以降低 NHD 的發生率。

關鍵字：高鈉血症、脫水、新生兒、危險因子、母乳哺餵