Despite such selection, nine unsuspected cases of liver disease occurred in the whole group, five of them among the 68 patients with untreated supradiaphragmatic disease. Most of these cases were asymptomatic. Like others, we found no liver disease without concomitant splenic and nodal involvement.

Similar selection to exclude patients with bone-marrow disease was exercised by preoperative trephine biopsy on all patients. Only one case of bone-marrow disease was subsequently discovered by Stryker-saw biopsy.

Clinical assessment of spleen size as an indication of involvement by Hodgkin's disease proved to be totally unreliable unless massive splenomegaly was present. Impalpable spleens contained disease and palpable spleens were disease-free often enough to make the assessment meaningless. We could not define characteristics at presentation which would exempt surgical staging on the grounds of a negligible risk of abdominal disease. The presence or absence of symptoms of Hodgkin's disease was not a reliable indication of the extent of disease.

An incidental finding at five laparotomies was non-caseating miliary granulomata in spleen, nodes, or liver.¹⁵⁻²⁴ Comparison of clinical assessment and subsequent laparotomy findings indicates that over a third of the patients had clinically unsuspected abdominal disease. This disease would have been unaffected if treatment had been planned according to clinical assessment of the extent of disease.⁶⁻¹⁴⁻¹⁵ This error is reflected in the disease-free survival figures for our patients treated with radiotherapy after clinical or pathological (post-laparotomy) assessment of disease extent. At 36 months the figures were 60% and 82% respectively.

These results confirm the failure to define the extent of disease solely by clinical means and indicate that when either mantle or inverted Y radiotherapy fields are used, the absence of Hodgkin's disease in the untreated areas must be established beyond doubt. In this context the disclosure of disease by surgical staging outweighs any upset caused by the procedure. The application of total nodal and splenic irradiation would obviate

the need for such scrupulous staging. But this would result in overtreating most patients presenting with localised disease and would be inappropriate in the 10% of patients in whom disseminated disease is established by operative means.

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Requests for reprints should be addressed to Dr S B J Sutcliffe, ICRF Department of Medical Oncology, St Bartholomew's Hospital, London EC1A 7BE.

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Increased insensible water loss in newborn infants nursed under radiant heaters

R W A JONES, M J ROCHEFORT, J D BAUM

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Summary

Urine osmolality was studied in 38 babies nursed in conventional incubators or cots and 18 nursed under an overhead radiant heat shield. Among 50 babies receiving a similar fluid intake in the first 48 hours of life mean urinary osmolality was significantly higher in the radiant heater group. In babies weighing less than 1500 g a trend towards higher urinary osmolalities was recorded in those nursed under radiant heaters even though they had received al-

most double the fluid intake of the incubator group. Severe hypernatraemia occurred in four of the five babies weighing less than 1000 g who were nursed under radiant heaters but in none of the seven babies of similar birth weight nursed in incubators.

These findings are consistent with previous observations of an increase in insensible water loss in babies nursed under radiant heaters and emphasise the importance of providing enough extra water for these infants and the need for close monitoring of their fluid balance. The latter may be done at the bedside by measuring urinary specific gravity with a hand refractometer.

Introduction

Recent estimations of insensible water loss in the newborn period have suggested that infants of low birth weight may lose over 60 ml/kg/24 hours.¹⁻² These values are much higher than those found by others.³⁻⁴ An increase in insensible water loss in babies nursed under radiant heaters compared with that in

Department of Paediatrics, University of Oxford, John Radcliffe Hospital, Headington, Oxford OX3 9DU

R W A JONES, MRCP, DCH, research fellow (present address: Hospital for Sick Children, Great Ormond Street, London WC1)

M J ROCHEFORT, BSc, medical student

J D BAUM, MD, MRCP, clinical reader in paediatrics

babies nursed in conventional incubators has also been reported.²⁻⁵ Since insensible water loss increases with decreasing birth weight,³ babies of low birth weight and short gestation are likely to be at risk of dehydration when nursed under radiant heaters.⁶

We attempted to monitor insensible water loss by measuring urinary osmolalities in babies nursed either in conventional incubators, cots, or under a radiant heat shield. We also compared the plasma sodium concentrations in babies of very low birth weight (less than 1000 g) nursed in incubators and under radiant heaters.

Methods

Babies admitted at birth to the special care baby unit of the John Radcliffe Hospital, Oxford, over three months were studied during their routine clinical management. Those admitted from other hospitals, those discharged from the special care baby unit before 48 hours of age, and one infant with severe hyponatraemia secondary to maternal water intoxication during labour were excluded.

The babies were nursed in incubators (Air Shields Isolette or Vickers 59), in cots, or under an overhead radiant heater (IMI Infant Care Centre, Becton & Dickinson Ltd, Runcorn, Cheshire). These three groups of infants were not matched for sex, birth weight, or gestational age. All the infants weighing under 2000 g were initially nursed in incubators or under radiant heaters. Allocation was otherwise randomised but influenced by the availability of radiant heaters. Incubator temperatures were adjusted manually to maintain rectal temperature at 37°C. Radiant heater babies were servocontrolled via a skin probe to maintain abdominal skin temperature at 36.7°C.

Urine bags were applied immediately on arrival in the baby unit, usually within a few minutes of birth. The bags were emptied whenever the infant was seen to have voided, and urinary osmolality (Advanced Osmometer, MSE Scientific Instruments Ltd, Crawley,

FIG 1—Urine osmolality, plasma sodium, and fluid intake in an 870-g girl born at 27 weeks' gestation and nursed under radiant heater.

Conversion: SI to traditional units—Sodium: 1 nmol/l = 1 mEq/l.

TABLE 1—Group 1. Clinical data on 50 babies receiving similar fluid intake in the first 48 hours of life. Ranges are given in parentheses

	Incubator	Cot	Radiant heater
No of babies	31	7	12
Mean birthweight (g)	2343 (980–4190)	2501 (2005–3135)	2108 (870–2870)
Mean gestational age (weeks)	35.4 (27–40)	37 (36–40)	33.3 (27–40)
No with assisted ventilation	3		
No of deaths			1
No who had sodium bicarbonate therapy			
No receiving part of intake by intravenous infusion	9		3
Mean fluid intake (ml/kg/1 st 48 hours)	145 (93–180)	140 (125–153)	158 (135–175)

FIG 2—Mean urine osmolalities for the first 48 hours of life in 50 babies receiving similar fluid intake (group 1). Open symbols show babies receiving part of this intake intravenously.

TABLE 2—Clinical data on 14 babies with a birth weight less than 1500 g (group 2) and on 12 babies with a birth weight less than 1000 g (group 3). Ranges are given in parentheses

	Group 2		Group 3	
	Incubator	Radiant heater	Incubator	Radiant heater
No of babies	5	9	7	5
Mean birthweight (g)	1128 (900–1500)	1056 (650–1470)	912 (720–980)	808 (650–940)
Mean gestational age (weeks)	29.4 (27–34)	29.3 (26–33)	28.6 (27–32)	26.7 (26–27)
No with assisted ventilation	3	3	3	4
No of deaths	2	3	3	4
No who had sodium bicarbonate treatment		3*	3†	4‡
No receiving part of fluid intake intravenously	4	7	7	5
Mean fluid intake (ml/kg/1st 48 h)				
(ml/kg/24 h during 1st 96 h of life)	120 (93–144)	210 (159–384)	81 (44–109)	111 (59–192)

*Mean dose (and range): 4 (3–5) mmol.

† " " " " 6 (2–13) mmol.

‡ " " " " 9 (3–15) mmol.

FIG 3—Mean urine osmolalities for the first 48 hours of life in 14 babies with birth weight of less than 1500 g (group 2). Open symbols show babies receiving part of this intake intravenously.

Sussex) and specific gravity (AO hand refractometer, British American Optical Co, Slough, Berkshire) were measured. Samples were analysed as soon as possible after collection, or stored at 4°C until analysis. Cloudy or contaminated specimens were discarded.

Incubator- and cot-nursed infants were fed by mouth or nasogastric tube. According to routine nursery practice they were given 60 ml/kg in the first 24 hours and 90 ml/kg in the second 24 hours of life. Radiant heater babies were initially randomly allocated to groups either with, or without, extra fluid. Early in the study, however, we encountered an infant of low birth weight who developed hypernatraemic dehydration under the radiant heater (see fig 1). We therefore decided to provide extra fluid for all babies weighing less than 1500 g and nursed under the radiant heater; this was given as water by mouth or as 5% dextrose intravenously. All infants studied started taking fluids within four hours of birth.

Group 1: babies receiving similar fluid intake—Fifty of the infants studied (table I) received a similar fluid intake (less than 180 ml/kg in the first 48 hours). Incubator and radiant heater groups did not differ significantly in birth weight or gestational age (*t* test), but

FIG 4—Plasma sodium values for first 96 hours of life in 12 babies with birth weight of less than 1000 g (group 3). Shaded area represents normal range for plasma sodium in term babies in our laboratory. Discontinuation of line indicates death of baby, which in all cases (three incubator, four radiant heater) was due to intraventricular haemorrhage.

gestational age was significantly greater in the cot-nursed group than in those nursed under the radiant heater ($P < 0.02$). Twenty-eight of the 31 incubator babies and 11 of the radiant heater babies were fed on expressed breast milk. The remainder, including all cot-nursed infants, received formulated milk (Cow and Gate V formula or Barmilk No 1). Nine of the incubator babies and three of the radiant heater babies received part of their fluid intake as 5% dextrose intravenously.

Group 2: babies with birth weights under 1500 g—Fourteen of the infants studied had a birth weight under 1500 g (eight of these were also included in group 1). Clinical data on these infants are shown in table II. There was no significant difference between the birth weights or gestational ages of the two groups. All were fed on expressed breast milk. Four of the five incubator babies and seven of the nine radiant heater babies received part of their fluid intake as 5% dextrose intravenously.

Group 3: babies with birth weights under 1000 g—During the three months six babies were born weighing less than 1000 g (these were all included in group 2, and four were included in group 1). The plasma sodium concentrations of these babies were reviewed together with data available on a further six babies who weighed less than 1000 g who were born in the preceding six months. Plasma sodium rather than urinary osmolality was chosen, since this information was available for the retrospective group. Clinical data on the 12 babies (seven nursed in incubators, five nursed under the radiant heater) are shown in table II. The two groups did not differ significantly in birth weight or gestational age. There were seven deaths (three in the incubator group, four in the radiant heater group), all due to intraventricular haemorrhage.

Results

The low birth weight infant who developed hypernatraemic dehydration under the radiant heater early in the study (fig 1) weighed 870 g at 27 weeks' gestation, was free of respiratory distress, and received no alkali treatment. Her fluid intake was 64 ml/kg in the first 24 hours and 101 ml/kg in the second 24 hours of life (half expressed breast milk, half intravenous 5% dextrose). By the third day her urinary osmolality was approaching 600 mmol (mosmol)/kg, and the plasma sodium had risen from 140 mmol (mEq)/l on the first day to 161 mmol/l. She had become clinically dehydrated. The introduction of extra fluid from the third day onwards resulted in a return of the urinary osmolality and plasma sodium values to normal.

In many of the infants studied the urine bag leaked, and we could not therefore accurately measure urine output. The mean number of urine samples analysed for each infant was 12 (range 7-19) for those nursed in incubators, eight (range 4-15) for those nursed in cots, and

FIG 5—Comparison of urinary specific gravity and urinary osmolality in 1000 urine samples. Third order regression line is shown: $r = 0.97$.

13 (range 7-22) for those nursed under radiant heaters. These values do not accurately reflect the number of voids for each infant in the first 48 hours of life, since some samples were contaminated and therefore discarded, and the frequency with which the urine bags were emptied depended on the intensity of care given to each infant. To compare the values in babies nursed in incubators, cots, and radiant heaters urinary osmolalities were therefore expressed as the mean of the osmolalities of all collected urine samples in the first 48 hours of life. The unpaired *t* test was used for statistical analysis.

Group 1: urinary osmolalities—Mean urinary osmolalities for these 50 babies are shown in fig 2. Clinical data are shown in table I. Urinary osmolalities were significantly higher in radiant heater babies than in both incubator- ($P < 0.005$) and cot-nursed ($P < 0.05$) babies.

Group 2: urinary osmolalities—Mean osmolalities for these 14 babies are shown in fig 3. Clinical data are shown in table II. The radiant heater babies received, on average, nearly twice the fluid intake of the incubator group. Despite this the radiant heater group tended to have higher urinary osmolalities, although this difference was not significant ($P > 0.05$).

Group 3: plasma sodium concentrations—For the first 96 hours of life (fig 4) plasma sodium levels for the seven nursed in incubators were within or below the normal range for all but two estimations. All those nursed under radiant heaters, however, developed plasma sodium levels greater than 145 mmol/l, and in four out of five cases levels of over 160 mmol/l were encountered. Clinical data on these 12 infants are shown in table II.

Urinary osmolality v specific gravity—Paired measurements on 1000 urine samples from the infants studied (fig 5) showed a high correlation ($r = 0.97$). A urinary osmolality of 200 mmol/kg corresponded to a urinary specific gravity of 1.006 ± 0.002 .

Discussion

The radiant heater provides a convenient environment for the intensive care of newborn infants. Several studies have indicated that it compares favourably with conventional incubators, both for routine nursing care,⁷⁻⁹ and for procedures such as resuscitation in the delivery room¹⁰ or exchange transfusion.¹¹ The advantages of the radiant heater over conventional incubators include ready access to the infant for both medical and nursing staff, ease of cleaning and sterilisation, and the ease with which ventilators and monitoring equipment can be arranged close to the infant. In our experience another important advantage of the overhead radiant heater is that visiting parents feel less isolated from their baby than when a conventional incubator is used.

A disadvantage of the radiant heater is that it causes an increase in insensible water loss. Williams and Oh,⁵ measuring insensible weight loss as an approximation of insensible water loss, found that it doubled in term babies nursed under the radiant heater compared with that in babies nursed in conventional incubators, and, in a similar study, Wu and Hodgman² recorded increases of 80% in babies of over 1500 g and 50% in babies of less than 1500 g associated with the use of the IMI radiant heater. Our finding that urinary osmolalities in the first 48 hours of life, measured as an index of dehydration, were higher in babies under radiant heaters than in those nursed in incubators or cots agrees with these observations. Since total insensible water loss increases with decreasing gestational age, infants of low birth weight nursed under radiant heaters are particularly at risk of dehydration. We have not been able to show this conclusively by measuring urinary osmolalities in the few infants of low birth weight whom we studied, although there was a trend towards higher urinary osmolalities in infants of less than 1500 g nursed under the radiant heater, despite a fluid intake almost double that of the incubator group.

In babies with very low birth weights (less than 1000 g) we found that severe hypernatraemia was common under the radiant heater, confirming the suspicion expressed by Katzman.⁶ This hypernatraemia is most readily explained on the basis of an increased insensible water loss in these infants. Although babies nursed under radiant heaters in our study received marginally more sodium bicarbonate treatment than incubator babies, the absence of alkali administration in one infant who developed

severe hypernatraemia (fig 1) and the relatively small amounts used in other infants suggest that sodium bicarbonate administration was not the primary cause of the observed hypernatraemia. Any tendency to hypernatraemia produced by insensible water loss, however, might be exacerbated by sodium bicarbonate administration to infants nursed under radiant heaters or in incubators.

In view of the current debate about the relation between raised plasma sodium levels or rapid changes in plasma osmolality and intraventricular haemorrhage,¹²⁻¹³ it is important to monitor the fluid balance of very light babies nursed under the radiant heater and to provide extra fluid in an attempt to prevent hypernatraemic dehydration. From our data, we cannot comment on the possibility that hypernatraemia might have contributed to the occurrence of intraventricular haemorrhage.

The factors which predispose the short-gestation infant to an increased rate of insensible water loss have been reviewed by Fanaroff *et al.*¹ These include thinness of the epidermis and an increased skin permeability, increased skin blood flow, higher skin water content, an increased surface area to mass ratio, and, possibly, an increased loss of water from the respiratory tract associated with an increased minute volume per unit body weight. The further increase in insensible water loss that occurs under the radiant heater remains largely unexplained. The recent data of Wu and Hodgman² on insensible water loss in low birth weight babies under the radiant heater, together with our finding of severe, early hypernatraemia in these babies, indicate that infants weighing less than 1000 g should receive at least 100-120 ml/kg of fluid in the first 24 hours of life and that this should be given intravenously until it is established that oral feeds are not pooling in the stomach.

Our observations show that an increase in urinary osmolality provides an indication of dehydration, even in the first days of life in low birth weight, preterm infants. Our findings agree with those of a study¹⁴ which showed that most newborn infants, adequately hydrated, will have urinary osmolalities between 100 and 200 mmol/kg. We also confirmed that urinary specific gravity, as measured with the hand refractometer, correlates well with urinary osmolality, an osmolality of 200 mmol/kg corresponding to a urinary specific gravity of 1.006 ± 0.002 (fig 5). This provides a useful method of assessing fluid balance, particularly since accurate measurement of urine output may be technically difficult in newborn infants.

Like Jones *et al.*,¹⁴ we suggest that to protect newborn infants nursed under radiant heaters from dehydration urinary specific gravity or osmolality should be routinely monitored and should be kept below values of 1.008 or 200 mmol/kg respectively.

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