Witness Statement Ref. No. 350/1

NAME OF CHILD: CONOR MITCHELL

Name: Darrell Lowry

Title: Dr

Present position and institution:

Consultant Anaesthetist, Southern Health & Social Care Trust

Previous position and institution:
[As at the time of the child's death]

Consultant Anaesthetist, Craigavon Area Hospital

Membership of Advisory Panels and Committees:
[Identify by date and title all of those between January 1995-August 2013]

NI Sick Child Liaison Group 2000 – 2005
NI Paediatric Anaesthesia Group 2000 – present
NI Working group on hyponatraemia in children 2001
NI Paediatric Neonatal retrieval service working party 2003- 2004
Paediatric Resuscitation Committee Craigavon Area Hospital 2000 – 2012
Chair Medical Staff Committee Craigavon Area Hospital 2009 -2012
NIMDTA Anaesthetic Training Committee 2002 – present
Southern Trust Local Negotiating Committee 2007 - present
BMA Northern Ireland Consultants Committee 2009 – present
RCoA e Portfolio working group 2009 – 2012
RCoA Assessment working group 2009 – present
RCoA National Recruitment Committee 2012 – present
RCoA NI Advisory Board 2009 - present

Previous Statements, Depositions and Reports:
[Identify by date and title all those made in relation to the child's death]

None

OFFICIAL USE:
List of previous statements, depositions and reports attached:

Ref:	Date:	

IMPORTANT INSTRUCTIONS FOR ANSWERING:

Please attach additional sheets if more space is required. Please identify clearly any document to which you refer or rely upon for your answer. If the document has an Inquiry reference number, e.g. Ref: 049-001-001 which is 'Chart No.1 Old Notes', then please provide that number.

If the document does not have an Inquiry reference number, then please provide a copy of the document attached

(1) Please address the following,

(a) As of the 26 September 2001, state your medical qualifications and the date you qualified as a medical doctor.

MB BCh BAO FCARCSI. June 1990

(b) State the date of your appointment to Craigavon Area Hospital, and the role to which you were appointed.

Appointed as a Consultant Anaesthetist in August 1999

(c) Describe your career history before you were appointed to Craigavon Area Hospital.

I graduated in Medicine from the Queen's University of Belfast in June 1990. I worked as a pre-registration JHO in the Belfast City Hospital from August 1990 until August 1991. I was appointed to the NI Anaesthetic Training Scheme in August 1991 and rotated round various NI hospitals until gaining my CCST in July 1999. Of note I worked twice in the RBHSC - as a SHO in anaesthetics from August – October 1994 and as a Specialist Registrar in anaesthetics from November 1998 – January 1999. I also worked as a QUB Tutor in the Department of Anaesthetics QUB from 1996-7 and did a DHSS research Fellowship post in this Department from 1997-8.

(d) What post did you hold as of the 26 September 2001?

Lead Consultant Paediatric Anaesthetist, Craigavon Area Hospital

(e) Describe your work commitments to the Craigavon Area Hospital from the date of your appointment, stating the locations in which you worked and the periods of time in each department/location.

I worked as a Consultant Anaesthetist in main theatres (anaesthesia for general surgery, gynaecology, ENT, urology and emergency anaesthesia), maternity unit (obstetric anaesthesia and analgesia), Day Surgery Unit and the psychiatric unit (ECT anaesthesia). I covered the Intensive Care Unit on call as part of my duties until the rota separated (around 2001). I also anaesthetised occasionally in South Tyrone Hospital, Dungannon when they became part of our Department. Since the formation of the Southern Trust I have occasionally anaesthetised for theatre sessions in Daisy Hill Hospital, Newry.

(2) Describe in detail the education and training you have received in fluid management, the prevention of hyponatraemia and record keeping in relation to fluid balance, to include any particular training relating to fluid management in children, and provide dates and names of the relevant institutions/bodies, by reference to the following:

(a) Undergraduate level.

I have no recollection of the exact training received but as an undergraduate in QUB Medical School I would have had some training in the above.

(b) Postgraduate level.

The above was covered as part of the curriculum during my training in the anaesthetic training rotation. I have no direct recall of the specific training. I have attached the report of the Southern Area Medical Audit group which notes that a teaching session on hyponatraemia took place in 1993-94. At this time I worked as an anaesthetic SHO in Craigavon Area Hospital. I do not recall where this teaching took place nor who delivered it.

(c) Hospital induction programmes.

I have no recollection of specific training but I had inductions in all the hospitals in which I worked.

(d) Continuous professional development.

I regularly attended meetings and courses relevant to paediatric anaesthesia. Many of these had updates on paediatric fluid management (see attached documents). I have completed the BMJ e learning module on hyponatraemia. I taught regularly as an instructor on the Paediatric Advanced Life Support courses (later EPLS) in Northern Ireland.

(3) On the 26 September 2001, you were identified as having been present at a meeting on acute hyponatraemia in children which took place at Castle Buildings (Ref: 007-048-094). Please address the following:

(a) In what capacity did you attend that meeting?

As the lead Consultant Paediatric Anaesthetist in Craigavon Area Hospital

(b) Explain the circumstances in which you were asked to attend that meeting.

I do not recall exactly but I found in my files the letter from Dr Darragh asking me to attend the meeting.

(c) Who asked you to attend the meeting?

Dr Paul Darragh

(d) What was your understanding of the purpose of the meeting before attending there?

I cannot recall but the letter is self explanatory

(e) What was your state of knowledge about the incidence of hyponatraemia related deaths in Northern Ireland before attending the meeting?

I was aware only of the death in Altnagelvin (Raychel Ferguson) because Dr Geoff Nesbitt had telephoned me about it.

(f) At the meeting were you made aware of the deaths of any of the following children:

(i) Adam Strain;

(ii) Claire Roberts;

(iii) Lucy Crawford;

(iv) Raychel Ferguson?

I have no recollection of being made aware of any of the deaths. From the minutes it appears that the death of Raychel Ferguson was discussed but I have no direct memory of this.

(g) If you were made aware of any of those deaths, please address the following:

(i) In each case, who told you about the death?

(ii) What were you told about each death?

(h) To the best of your recollection, does the document at Ref; 007-048-094, 095 & 096 represent an accurate record of the meeting? If not, please clarify the respects in which the record is inaccurate.

I do not remember what was said but I have no reason to believe that the minutes are inaccurate.

(i) Did you attend any follow-up meetings in relation to the incidence of acute hyponatraemia in children? If so, fully describe the follow up meetings you attended, who organized them, who attended, when they occurred and what was discussed.

I do not recall any subsequent meetings.

(j) Based on the information which you received at the meeting on the 26 September 2001 or at subsequent meetings, did you take any action in terms of the practice of fluid management in Craigavon Area Hospital, or did you communicate the need to do so to anyone else at Craigavon Area Hospital?

I cannot recall exactly what happened. I remember meeting informally with Dr Mike Smith, Consultant Paediatrician in Craigavon and between us we developed the paediatric IV fluid guidelines.

(k) Please outline any steps which you or others at Craigavon Area Hospital took in order to address the issue of hyponatraemia in children or the fluid management of children at Craigavon Area Hospital.

I wrote a chapter for the induction manual for trainee anaesthetists on paediatric anaesthesia (including guidance on fluid management) and included handouts on hyponatraemia in their induction pack. I also gave regular talks on paediatric anaesthesia to theatre and recovery nurses in Craigavon.

(4) With reference to the *Guidance on the Prevention of Hyponatraemia* (Ref: 007-003-004) which was issued by the Chief Medical Officer in March 2002, please provide clarification and/or further information in respect of the following:

(a) Was the Guidance brought to your attention,? If so, state:

(i) Who brought the Guidance to your attention?

I cannot remember but I presume that it was sent to me.

(ii) When was it brought to your attention?

I do not recall.

(iii) In what way was the Guidance brought to your attention?

I do not recall.

(iv) Did you have any role in implementing the Guidance at Craigavon Area Hospital, or in bringing it to the attention of clinicians? If so, fully describe your role and the steps which you took.

I do not recall.

(5) Have you ever received training in the use or application of the Guidance? If so, state,

(a) Who provided you with training?

(b) When and on how many occasions have you been provided with such training?

(c) What form did the training take?

(d) What did you learn from the training?

(e) Was the training of an adequate quality or standard for the work that you do?

I do not recall any such training.

(6) Have you ever received written information in relation to the use or application of the Guidance? If so, please provide a copy and state,

(a) Who provided you with the written information?

(b) When did you receive it?

(c) What did you learn from the written information?

(d) Was the written information which was given to you of an adequate quality or standard for the work that you do?

I do not recall any such information.

(7) Identify the locations at which the Guidance was displayed within Craigavon Area Hospital as of the 8 May 2003.

I remember seeing it displayed in main theatres, theatre recovery and the Day Surgery Unit.

(8) After the death of Conor Mitchell in the Royal Belfast Hospital for Sick Children on the 12 May 2003 (following his treatment in the Craigavon Area Hospital) were you asked to take part in any process designed to learn lessons in relation to any issue relating to his fluid management? If so,

(a) Describe the process which you participated in.

(b) Who conducted it?

(c) When was it conducted?

(d) What contribution did you make to it?

(e) Were you advised of the conclusions that were reached, and if so, what were they?

I have no recollection of any such process. I was unaware of the death of Conor Mitchell until the inquiry started.

(9) Provide any further points and comments that you wish to make, together with any documents, in relation to:

(a) The care and treatment of Conor on 8th May 2003.

(b) The Guidance on the Prevention of Hyponatraemia.

(c) Fluid management.

Record keeping in association with fluid management

I was not involved with the care and treatment of Conor.

I have attached further documents regarding hyponatraemia:

THIS STATEMENT IS TRUE TO THE BEST OF MY KNOWLEDGE AND BELIEF

Signed:  Dated: 19.9.13

Education Meetings for Theatre, Recovery Ward and DPU Staff.

These meetings will take place in the ICU tutorial room every second Thursday at 8.15 am. The first meeting is scheduled on 28th September 2000.

Date	Topic
28/09/00	New drugs in anaesthesia
13/10/00	Problems in Obstetric Anaesthesia
27/10/00	Blood Products
09/11/00	Monitoring in anaesthesia — Paed. anaesthesia
23/11/00	Ventilation
07/12/00	Arrests and Crises
21/12/00	Anaesthesia in A&E.
11/01/01	Difficult/Failed Intubation
25/01/01	Perioperative warming
08/02/01	~~Paediatric Anaesthesia~~ monitoring
22/02/01	Postoperative pain management
08/03/01	Spinal and epidural anaesthesia
22/03/01	Use of the Nerve Stimulator
05/04/01	Anaesthetic Emergencies
19/04/01	Neurolytic Blocks
03/05/01	Dental Anaesthesia

Junior Anaesthetists and Medical Students are encouraged to attend.

If a speaker is unable to give his/her talk on any particular date please swap with a colleague rather than canceling.

? Laser

piercing

? video biopsy

FRIDAY SEMINARS 2001 / 2002

September	7	Difficult airway.
	14	Learning & teaching styles I.
	21	Learning & teaching styles II.
	28	Practice vivas.
October	5	Acute Renal failure.
	12	Anaesthesia for the cardiac patient for non cardiac surgery.
	19	Anaesthesia for vascular surgery.
	26	Problem based training / OSCE practice.
November	2	Obstetric anaesthesia.
	9	Electrolytes.
	16	Novel therapies for sepsis.
	23	Regional anaesthesia.
	30	Anaesthesia for ENT procedures.
December	7	Allergy / Malignant hyperpyrexia.
	14	Practise vivas.
	21	
	28	
January	4	Ventilation. CPAP / PEEP + Modes of ventilation. NIV + Home ventilation. ECMO + Sleep apnoea.
	11	Written examination practice.
	18	X rays.
	25	Paediatric anaesthesia.
February	1	Advanced life support - adults.
	8	Chronic pain.
	15	Heart failure.
	22	Practice vivas.

March	1	Nutrition. Laparoscopic surgery / gas embolism.
	8	Anaesthetic emergencies.
	15	Acute pain.
	22	Problem based training / OSCE practice.
	29	Hyperbaric oxygen therapy.
April	5	
	12	Advanced life support-paediatric.
	19	Introduction to research.
	26	Liver failure.
May	3	Problem based training / OSCE practice.
	10	Obstetric anaesthesia.
	17	Anaesthesia for day case surgery.
	24	Obesity / endocrine disease. Sress response.
	31	Problem based training / OSCE practice.
June	7	Neurological diseases. Head injury.
	14	Anaesthesia in the presence of renal or hepatic failure.
	21	Anaesthesia for patients with unusual diseases.
	28	Case presentations

Southern Health and Social Services Board

The fourth annual report of the

AREA MEDICAL AUDIT COMMITTEE

1993 / 94

emetic therapy. The five patients had undergone laparoscopic surgery.

- In total, 19 patients (6%) had either nausea or vomiting post-operatively, 11 of whom had undergone laparoscopic surgery. The remaining eight procedures ranged from repair of hernia, oral surgery to orchidopexy.

- None of the patients were admitted to hospital overnight as a result of PONV.

In summary, a protocol for the prevention of nausea and vomiting was implemented. Although compliance with the protocol was low, the overall incidence of PONV was 6%. These findings would suggest that prophylactic anti-emetic therapy is not indicated on a routine basis, except for patients undergoing laparoscopic surgery. It was recommended that only those patients who complain of significant nausea or vomiting should be treated according to the protocol. These findings have been disseminated to medical and nursing staff in the Day Procedure Unit.

An audit is also underway to assess the incidence of and treatment of PONV in patients using PCAS.

Audit on post-operative pain relief following major surgery

A review of the effectiveness of PCAS and epidural infusions on patients admitted to the High Dependency Unit following major surgery was undertaken. The results showed that epidural infusions using 0.25% Bupivacaine solution combined with Diamorphine provided the most satisfactory analgesia, with fewer side-effects such as hypotension. This change in practice has been implemented and the effectiveness of epidurals and PCAS will be audited in 1994/95.

Educational meetings

Educational meetings are held on a weekly basis. The contents of the CEPOD, Confidential Enquiries Into Maternal Deaths and relevant CREST reports have been reviewed. Discussions have also been held on individual reports which were identified using the computerised database in theatre. Other topics of educational interest which have been discussed include neuromuscular disorders, hyponatraemia and MAOIs and anaesthesia, transfer of patients, organ donation and epidurals in obstetrics.

University Department of Anaesthesia
Manchester Children's Hospitals

Ninth Annual Paediatric Anaesthesia Update

The Manchester Conference Centre
Weston Building

Friday 15th February 2002

NINTH ANNUAL PAEDIATRIC ANAESTHESIA UPDATE

PROGRAMME

9.00 -9.55	**Registration and coffee**
9.55 - 10.00	**Introduction** *Dr George Meakin, Manchester*
10.00 - 10.45	**Anaesthesia for laser surgery in children** Dr Tanya Howell, Manchester
10.45 - 11.30	**Principles of paediatric anaesthesia** *Dr Peter Crean, Belfast*
11.30 - 12.00	**Coffee**
12.00 - 12.45	**Fluid and electrolyte management in children** *Dr Mary Cunliffe, Liverpool*
12.45 - 13.30	**Analgesia for paediatric day-case surgery** *Denise Jonas MSc RSCN, Manchester*
13.30 - 14.30	**Lunch**
14.30 - 15. 15	**HIV/AIDS and the paediatric anaesthetist** *Professor Adrian Bösenberg, Cape Town*
15.15 - 16.00	**Resuscitation in infants and children** *Dr Russell Perkins, Manchester*
16.00 - 16.45	**Infant Anaesthesia in a DGH** *Dr Kathy Wilkinson, Norwich*
16.45 - 17.15	**Tea and depart**

Fluid and electrolyte management in children

Dr Mary Cunliffe
Alder Hey Children's Hospital, Liverpool

The body manages to maintain fluid and electrolyte homeostasis despite large variations in the daily intake of fluids. This is an essential requirement for normal cellular and organ function. Fluid and electrolyte disturbances are very common in the perioperative period. Intravenous fluid therapy is often required to correct fluid deficits and losses associated with surgery. In children, the physiological capacity to cope with inappropriate fluid and electrolyte therapy is more limited than in adults.

Normal losses and requirements

Maintenance requirements consist of –

(i)	insensible water loss (through skin and lungs)	45 ml.100cal^{-1} expended
(ii)	obligatory water loss (via kidneys)	50-55 ml.100cal^{-1} expended
(iii)	stool water	0-5 ml.100^{-1} expended
	TOTAL	100 ml.100cal^{-1} expended or 1 ml.cal^{-1} expended

Daily caloric expenditure is estimated at:

100 cal.kg^{-1} up to 10kg
+50 cal.kg^{-1} for 10-20kg
+20 cal.kg^{-1} for over 20kg

As water requirement can be related to energy expenditure, and energy expenditure can be related to body weight, then water requirement can be related to body weight.

Total daily water or fluid requirement –

3-10 kg	100 ml.kg^{-1}
10-20 kg	1000 ml + 50 ml.kg^{-1} for each kg over 10
Over 20 kg	1500 ml + 20 ml.kg^{-1} for each kg over 20

This approximates to an hourly rate of -

First 10 kg	4 ml.kg^{-1}.hr^{-1}
10-20 kg	40 ml +2 ml.kg^{-1}.hr^{-1}
Over 20 kg	60 ml +1 ml.kg^{-1}.hr^{-1}

Normal fluid requirements vary considerably between low birth weight (LBW) and full term neonates as well as between older infants and children. The main factors determining fluid requirements are –

(i) metabolic rate
(ii) ratio of evaporative losses to body surface area (BSA)
(iii) maturity of renal function
(iv) total body water (TBW)

Important changes in body fluid compartments occur during infancy and childhood.

	Preterm neonate	neonate	1 year	3 years	adult
Weight (kg)	1.5	3	10	15	70
Surface area (m^2)	0.15	0.2	0.5	0.6	1.7
BSA/wt	0.1	0.07	0.05	0.04	0.02
TBW(%)	80	78	65	60	60
ECF(%)	50	45	25	20	20
ICF(%)	30	35	40	40	40

Fluid requirements in infants are greater than in adults or older children because of their metabolic rate, their greater surface to weight ratio which results in higher insensible water loss, and their reduced renal concentrating capacity, which results in increased obligatory water loss. Preterm infants have an even greater rate of insensible loss due to thinner, more permeable, vascularised skin. Total body water is greater due to an expanded ECF. This extra fluid is excreted in the first 3 days of life, actually reducing requirements in this period. Fluid management may be complicated by low ambient humidity, used of radiant heaters and phototherapy. Body temperature is a major factor affecting caloric expenditure. Fever increases caloric needs by 10-12% for each degree Celsius above normal. Patients who are hypothermic have decreased caloric needs by the same amount.

Guidelines for fluid infusions in children are not applicable to neonates. Following a fluid load, neonates can increase their urine volume but their ability to concentrate urine is limited. Administration of sodium free fluids rapidly gives rise to hyponatraemia, which can cause neurological disturbances and poor growth, unless a relatively high intake of 2-5 $mmol.kg^{-1}.day^{-1}$ is given. Older children or term infants require approximately 1-2 $mmol.kg^{-1}.day^{-1}$ of sodium. Potassium requirements are the same as those for sodium. For the majority of children a fluid containing 2.5 mmol of Na^+, 2.5 mmol of K^+ and 5 mmol of Cl^- per 100ml of fluid is adequate. This equates to a solution of 5% dextrose and 0.18% saline with 20 mmol $KCl.l^{-1}$. However this is a hypotonic fluid and if used for long periods of time, or to replace other than maintenance requirements eg gastric losses, hyponatraemia can occur. Commercial solutions containing a higher concentration of sodium are available and are a better choice.

Although parenteral fluid administration over short periods can readily meet water and electrolyte needs, caloric requirements are not met. The rationale behind providing 5% dextrose in paediatric maintenance fluid is to prevent development of ketosis and not to provide adequate calorie intake. In preterm infants and neonates, solutions containing 10% dextrose are used to prevent hypoglycaemia. Blood glucose should be monitored during any intravenous therapy by regular estimation.

Perioperative fluid and electrolyte management

Perioperative fluid management consists of assessing the fluid requirements of the patient and providing appropriate maintenance and replacement fluids. Where there is a large deficit or continuing losses, a flexible approach with regular reassessment of the patients hydration will be required.

Preoperative deficit

The main cause of a preoperative deficit in children having elective surgery is fasting. In a healthy child assuming normal fluid and electrolyte balance, the deficit incurred is the child's hourly requirement multiplied by the number of hours fasted. Today, fasting times should be shorter due to a more lenient attitude in giving preoperative drinks of clear fluid up to 2 hours before anaesthesia. It is normal to replace 50% of the fasting deficit in the first hour of surgery and 25% in the second and third hours (2).

Assessment of dehydration

For an emergency procedure an assessment of hydration is necessary, particularly if the disease process has caused increased fluid losses. In children the compensatory response to hypovolaemia is largely by way of increased heart rate and peripheral vasoconstriction. The ability to increase stroke volume as a means of increasing cardiac output develops with age, Hypotension is a late and ominous sign of hypovolaemia, suggesting imminent decompensation and requiring immediate treatment.

Assessment of dehydration

Signs and symptoms	**Mild**	**Moderate**	**Severe**
Weight loss %	5	10	15
Deficit $ml.kg^{-1}$	50	100	150
Vital signs Pulse	Normal	Weak	Feeble
BP	Normal	Normal/low	Reduced
Respiration	Normal	Deep	Deep and rapid
Appearance	Thirsty, restless, alert	Thirsty, restless or lethargic but rousable, pale	Drowsy to comatose, limp, cold, sweaty, grey, cyanosed
Skin turgor	Normal	Decreased	Markedly decreased
Anterior fontanelle	Normal	Sunken	Markedly decreased
Mucous membranes	Moist	Dry	Very dry
Urine output $ml.kg^{-1}.hr^{-1}$	<2	<1	<0.5
Specific gravity	1,020	1,020-1,03	>1,030

Correction of dehydration should be with normal saline or Ringers lactate. A colloid solution may need to be used if the extent of the dehydration is severe.

Intraoperative glucose management

The risk of hypoglycaemia resulting from preoperative starvation in children has been extensively studied with conflicting results. However, almost all studies since 1982 have failed to demonstrate a high incidence of hypoglycaemia in children under 5years who are fasted, as was initially described by Thomas in 1976 (3). Children fasted during the daytime for afternoon surgery as opposed to those fasted overnight for morning surgery tend to have a lower glucose concentration, despite a shorter fasting period (4). This is thought to be due to

the diurnal variation in circulating cortisol, being higher in the morning than in the afternoon. As a result of all these studies it is suggested that hypoglycaemia may not be as common an occurrence in paediatric patients as was previously thought, even in infants (5).

The purpose of glucose administration is to provide sufficient energy to prevent hypoglycaemia during starvation and the perioperative period. However, administration of glucose during anaesthesia and surgery, in combination with the stress response can lead to intraoperative hyperglycaemia which is undesirable (6). Hyperglycaemia can induce an osmotic diuresis leading to dehydration and electrolyte disturbances, especially in small infants. It can increase the risk of hypoxic-ischaemic brain or spinal cord damage and can induce neurological symptoms in patients with structural cranial abnormalities as well as in patients with normal brain structure (7,8).

Children given non-glucose containing fluids have been shown to have a rise in blood sugar during the course of surgery (9). However one in five may show no change or even a fall. When the anaesthetic technique includes a regional block, the stress response can be blunted and the rise in blood sugar may not occur (10).

A commonly used replacement fluid is 5% dextrose with a quarter to half normal saline. There is currently a difference of opinion on whether dextrose should be omitted from replacement fluid altogether in view of the risk of producing hyperglycaemia, and many studies have been done looking at less concentrated dextrose solutions (11,12). All studies confirm that 5% dextrose is likely to cause hyperglycaemia whereas solutions containing 1% and 2.5% dextrose seem to be more appropriate. Infusion of glucose free solutions can reduce or abolish the risk of postoperative hyperglycaemia, but would not correct a low preoperative blood glucose value, and consequently lipid mobilisation and ketosis may develop (13).

Intraoperative losses

In addition to providing normal maintenance fluid requirement during surgery, specific intraoperative losses relating to third space loss and blood loss also occur and require replacement.

Third space loss is an isotonic transfer of fluid from the ECF to a non-functional interstitial compartment. Surgical trauma, infection and burns are some of the causes. If such sequestration of fluid continues without replacement, the plasma volume will become depleted. The volume lost is impossible to measure and is estimated by the extent of the surgery and the clinical response to appropriate fluid replacement. Third space loss is usually highest in infants undergoing intra-abdominal procedures and least in superficial surgery or neurosurgery.

Approximate losses are –

Intra-abdominal surgery	6-10 $ml.kg^{-1}.hr^{-1}$
Intrathoracic surgery	4-7 $ml.kg^{-1}.hr^{-1}$
Eye surgery/superficial/neurosurgery	1-2 $ml.kg^{-1}.hr^{-1}$

Ringers lactate or normal saline are appropriate replacement fluids as we are replacing sequestered plasma volume. The clinical response to replacement should be sustained and

consist of an adequate blood pressure and heart rate, adequate tissue perfusion and a urine output of 1-2 $ml.kg^{-1}.hr^{-1}$.

Blood loss in children undergoing major surgery invariably requires replacement. All blood loss in children should be replaced – the main question is with what? The lowest acceptable haematocrit in children is controversial, however 25% in infants and children and 30-35% in neonates is recommended. Blood losses are replaced with either a 1:1 ratio of blood or colloid, or a 3:1 ratio for crystalloid. The administration of a large volume of normal saline can cause dilutional acidosis or hyperchloraemic acidosis, whereas a large volume of balanced salt solution such as Ringers lactate can decrease serum osmolality, which is not beneficial in patients with decreased intracranial compliance. Artificial colloids such as gelatin and starch solutions may be used. There is evidence that in neonates albumin solution is a superior plasma expander (14). Pure glucose solution should never be used for plasma volume expansion. It is rapidly metabolised and behaves as free water, quickly equilibrating between the intracellular fluid and ECF compartments. For every 100 ml infused only 7.5 ml remains in the intravascular space.

It is important that the anaesthetist has a preoperative plan for blood loss replacement, based on the patient's preoperative condition, haematocrit and the nature of the surgery, The concept of an allowable blood loss (ABL) is a useful approach to planning when blood products need to be given(15). In determining ABL, an estimate of blood volume (EBV) need to be made first.

Preterm infant	90-100 $ml.kg^{-1}$
Term neonate	80-90 $ml.kg^{-1}$
3m to 1 yr	75-80 $ml.kg^{-1}$
Older children	70-75 $ml.kg^{-1}$

Using the EBV and the patient's original haematocrit H_0, the ABL can be calculated using the lowest acceptable haematocrit H_1 and the average haematocrit H_a where $H_a = (H_0 + H_1)/2$.

$$ABL = \text{weight} \times EBV \times (H_0 - H_1)/H_a$$

Initial blood loss can be replaced with colloid or crystalloid until the ABL is reached when blood should be given.

Fluid therapy is based on the knowledge of fluid and electrolyte needs in healthy children. Formulas for fluid therapy are guidelines and should be used alongside a process of re-evaluation of the child's response.

References

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The ROYAL HOSPITALS

THE ROYAL GROUP OF HOSPITAL AND DENTAL HOSPITALS
HEALTH AND SOCIAL SERVICES TRUST

Human Resources
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Dr D W Lowry
Consultant Anaesthetist
2nd Floor Main Block
The Royal Hospitals

29 October 2004

THIS COPY TO BE RETAINED BY YOU

Dear Dr Lowry

HONORARY APPOINTMENT

It is with pleasure that I write to inform you that, under the powers delegated to me by the Trust Board, I am conferring on you the title of **Honorary Clinical Observer** in the **The Royal Hospital** for the period: **24 November 2004** to **25 November 2004** subject to the following conditions:

a) any relevant provisions of the Health and Personal Social Services (Northern Ireland) Order 1972 and the Health and Personal Social Services (Northern Ireland) Order 1991 and any rules, orders or regulations made thereunder;

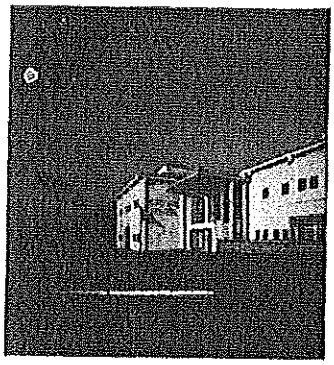
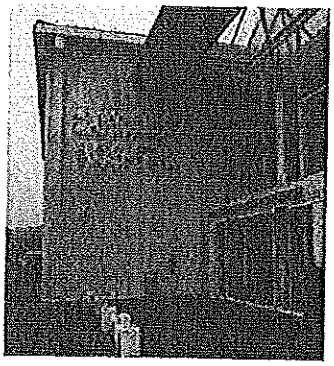
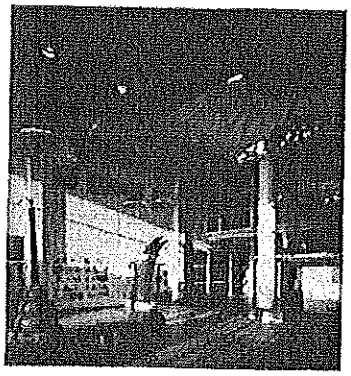
b) the Terms and Conditions of Service of Hospital Medical and Dental Staff and Doctors in Public Health Medicine and the Community Health Service (Northern Ireland) 2003 (revised) in so far as they are applicable to Honorary Appointments: and

1. HEALTH AND SAFETY AT WORK

Whilst at work you must take reasonable care for the health and safety of both yourself and others with whom you come into contact and who could be affected by your work. You must also comply with the health and safety rules and procedures appertaining to your job and undergo training provided. You must also comply with the Royal Hospitals' No Smoking Policy. The Health and Safety Policy Statement is enclosed.

1873-1973

Seminar Handbook

The Northern Ireland Society of Anaesthetists and The Royal Belfast Hospital for Sick Children

Paediatric Anaesthesia Half Day Seminar

Friday 3rd December 2004 12.30 - 5.30pm
Lower Lecture Theatre
Education Centre
Royal Victoria Hospital

NISA/RBHSC PAEDIATRIC ANAESTHESIA
HALF DAY SEMINAR

FRIDAY 3RD DECEMBER 2004
LOWER LECTURE THEATRE, GROUND FLOOR
EDUCATION CENTRE, RVH

1230 – 1355
Registration/Lunch/Trade Exhibition
Lower Lecture Theatre, Ground Floor, Education Centre, RVH

SESSION 1

Aspects of Anaesthesia for Children
Chair: Dr J P McKaigue, Consultant Anaesthetist, RBHSC

1355 - 1400	Opening Remarks Dr I Bali - President of NISA
1400 - 1420	The Critically ill/injured Paediatric Patient - Tips on the initial management Dr R H Taylor, Consultant Anaesthetist, RBHSC
1420 - 1440	Fluid/Electrolyte Management - Revisited Dr P B Loan, Consultant Anaesthetist, RBHSC
1440 - 1500	Paediatric Anaesthesia Services in the District General Hospital Dr D Lowry, Consultant Anaesthetist, CAH
1500 - 1530	PANEL DISCUSSION

1530 - 1600 COFFEE BREAK/TRADE EXHIBITION

Perioperative Fluid Management in Children

Paul Loan
R.B.H.S.C.

Why is Perioperative Fluid Balance for Children Difficult?

- Disordered fluid balance preoperatively
  - Deficit from presenting illnesses – bleeding, dehydration, sepsis
  - Routine preoperative fasting (eg 6,4,2 hours)
- Intraoperative maintenance and deficit
  - Blood, evaporative, "3rd space" losses
- Postoperative losses
- Hormonal responses
- Dependence on others
- High "turnover"

Shifting Goalposts

- "Normal" requirements based on old data, not perioperative cases
- Perioperative IV fluids only course "recently"
- Traditional fear of "sodium load" and hypernatraemia in children

Indications for IV Fluids

- 1) Shock
- 2) Replacement of Ongoing Losses
- 3) Replacement of Existing Deficit
- 4) Maintenance (*Prevention* of dehydration)

Resuscitation from Shock

- "Salty" crystalloid or colloid
  - 20 ml/kg IV or IO asap.
    - Repeat if still shocked
    - Repeat if still shocked
- Third bolus should be blood in haemorrhagic shock

Replacement of Ongoing Loss

- Vomiting, diarrhoea, NG losses, bleeding, sweating, 3rd space losses, ….
- Volume given = volume lost
- Fluid used should "mimic" fluid lost

Electrolyte Content of Fluids Lost

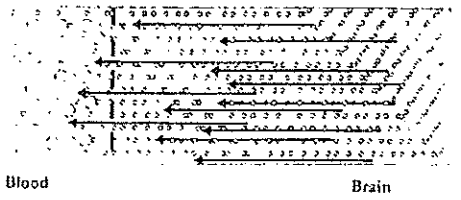
	Na	K
Gastric	20-80	5-20
Pancreatic	120-140	5-15
Biliary	120-140	5-15
Small intestinal	100-140	5-15
Diarrhoea	10-90	10-80
Urine	*0-100*	*20-100*

Replacement of Ongoing Losses

- Saline (with potassium) or Hartmann's solution suitable for most, initially
- *Measure* ongoing losses
- Measure sodium and potassium concentration in losses if volume large (esp. urine)
- Check U+E and blood sugar regularly

Replacement of Existing Deficit (Dehydration)

- Replace deficit in addition over 24hrs (48+ hrs if Na high)
  - 10 x % dehydration x wt



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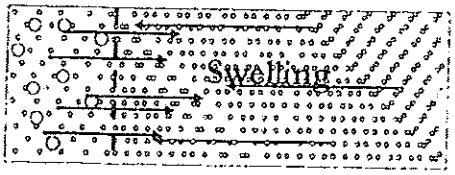


Replacement of Existing Deficit (Dehydration)

- Perioperatively:
  - Why?

Maintenance

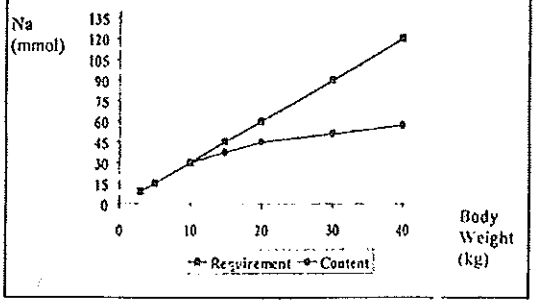
- To prevent dehydration in "well" child
- Water: 4, 2, 1 ml/kg/hour or 100, 50, 20 ml/kg/day
- Sodium: 3 mmol/kg/day
- Potassium: 2 mmol/kg/day
- Sugar: 2.4-4.8 g/kg/day

Holliday & Seger *

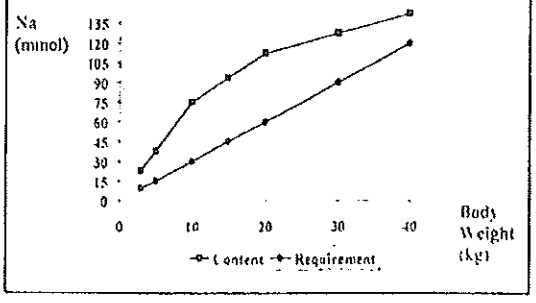
- Based on metabolic water requirements for energy expenditure
- Expenditure calculated by BSA
- BSA related mathematically to weight
- Hospital patient's energy expenditure "roughly midway between basal and normal levels"
- Electrolyte needs based on "normal" daily intake of human milk

*Pediatrics 1957; 19:823-825

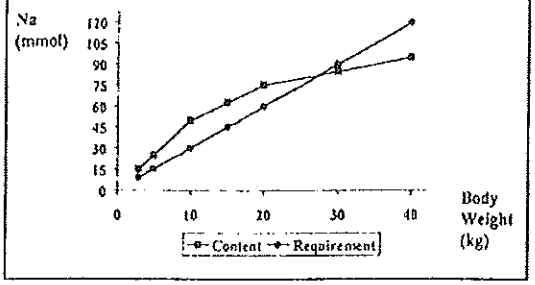
Na^+ - Daily needs *vs* "No 18" content



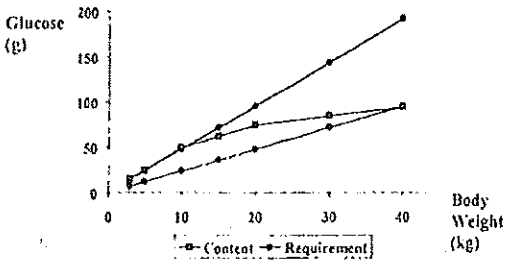
Na^+ - Daily needs *vs* "Half-Normal" content



Na^+ - Daily needs *vs* "1/3 Normal" content



Glucose - Daily needs *vs* 5% Dextrose content



Hypernatraemia *vs* Hyponatraemia

- Thirst
- Hypercoagulability
- Complications of treatment
- Convulsions
- Lethargy / malaise / Coma
- Cerebral oedema
- Complications of treatment (myelinolysis)
- Coning / Death

Dilutional Hyponatraemia in Children

Arieff AI, Ayus JC, Fraser CL.
BMJ 1992; 304:1218-1222.

1) Review of 24,412 consecutive paediatric surgical admissions (1989-91)

2) Report of 16 cases of respiratory arrest with hyponatraemia (1984-1990)

Dilutional Hyponatraemia in Children

- Na <= 128 mmol/l in 83 of 24,412 postoperative surgical cases (0.34%)
- 7 deaths (<0.03%)

Symptomatic Dilutional Hyponatraemia in 16 Children

Presentations	Outcomes
Tonsillectomy (5)	Died (10)
Tonsillitis (2)	Vegetative quadriplegia
Elbow Fracture (2)	Vegetative blind
Fractures (RTA) (2)	Vegetative (3)
VP shunt	Mental retardation
Undescended testicle	
Epistaxis	
Appendicitis	
Pneumonia	

What is Going Wrong?

- Poorly challenged, old data applied to wrong patient groups
- No account taken of illness and hormonal responses to stress.....

Anti-Diuretic Hormone

- Causes water retention, urinary sodium loss inappropriate for serum sodium concentration
- May cause severe unexpected hyponatraemia in stressed patients (even if appropriate levels of sodium are given)
- Treatment of excessive ADH production
  - Fluid restriction

Three Solutions for Maintenance.....

1. Use guidelines properly....
   Holliday, Segar, et al. Lancet 2004;363 241
2. Reduce volumes given
   Hatherill. Arch Dis Child 2004;89:414-418
3. Increase sodium content of fluids to ~ isonatraemic
   Taylor and Durward. Arch Dis Child 2004;89:414-414
   Duke and Molyneux. Lancet 2003;362 1320-23
   Halberthal, Halperin & Bohn BMJ 2001;322:780-2

Perioperative Fluids

- Most children will do well with Hartmann's postop – for maintenance and losses
- Some will need sugar added – neonates, ex-prems, diabetics, those with history of hypoglycaemia

Perioperative Fluids - Summary

- Correct shock rapidly with boluses of saline, Hartmann's or colloid
- Correct dehydration / deficit slowly (or not at all?)
- Use Hartmann's or saline with potassium; add sugar if required
- Check U+E and sugar (and results!) at least daily if on IV fluid

IV Fluid Therapy

There are **four** indications for giving IV fluids; they must be considered **separately.**

1. **Shock.**

Thirst, tachycardia, tachypnoea, hypotension (not always present), CRT>2s, cold peripheries, oliguria, etc.

Management:

High-flow 100% oxygen
Rapid bolus 20ml/kg saline or Hartmann's or colloid, IV or IO
Get senior help
Repeat if still shocked
Repeat if still shocked
(third unit is blood in haemorrhagic shock)

2. **Replacement of existing deficit.**

Replace existing deficit using formula

Deficit (mL) = 10 X estimated % dehydration (eg 5, 10, or rarely 15%) X weight in kg

given over 24 hrs, or over 48 - 72 hrs if Na high or under 5 years old.

Hartmann's or saline with potassium (once known to be making urine) is usually OK initially.
Give maintenance in addition, as below. Check U+E results 6 hrly. Adjust sodium content and rate of administration of fluid to normalise [Na] no faster than 1 mmol/L per hr.

3. **Replacement of ongoing losses.**

Replace ongoing losses mL for mL as accurately as possible.
Replacement fluid should mimic fluid being lost as best possible: eg, Hartmann's or 0.9% NaCl with KCl solution for gastric / stoma losses; diarrhoea may need Hartmann's or 0.45% NaCl / 2.5% dextrose with KCl.
Give maintenance in addition, as below.
Follow daily or twice-daily bodyweight during rehydration.

4. **Maintenance.**

Used to prevent dehydration in an otherwise well child who is unable to drink adequately.

Give 4 ml/kg/**hr** for first 10 kg	Or	Give 100 ml/kg/**day** for first 10 kg
Plus 2 ml/kg/**hr** for next 10 kg		Plus 50 ml/kg/**day** for next 10 kg
Plus 1 ml/kg/**hr** for next 10 kg		Plus 20 ml/kg/**day** for next 10 kg

(eg 18 kg child gets 4 x 10 plus 2 x 8 equals 56 ml/**hr**
or 100 x 10 plus 50 x 8 equals 1400 ml/**day**.)

Sodium needs (approx. 3 mmol/kg/day) usually met with 0.18% NaCl / 4% Dextrose ("No. 18 Soln") in children under 10 kg.
Children over 10 kg likely to need 0.45% NaCl.

Potassium maintenance (approx 2 mmol/kg/day) usually needs 5-10 mmol/L KCl. This should be given as a prepared solution; potassium should not be added to IV fluid bags outside PICU and Renal unit.

Hyponatraemic fluids **must not** be given at higher than maintenance rates.
Urea and Electrolytes must be **seen at least daily** in IV-dependent children – more often if the child becomes unwell or develops high losses. (Watch for hyponatraemia!)
These are approximate figures only, and must be revised in the light of clinical signs of under- or over-hydration, body weight changes, assessment of losses, and biochemistry.
If in doubt ask for senior help.

Fluid Calculator Weight in kg ..... (Estimated?)

Shock

High flow 100% Oxygen.

Time	HR	BP	CRT	Urine OP
	AVPU	Cold to		

Crystalloid or Colloid 20 x wt in KG = ... ml asap

Reassess need:

Time	HR	BP	CRT	Urine OP
	AVPU	Cold to		

Crystalloid or Colloid 20 x wt in KG = ... ml asap

Reassess need:

Time	HR	BP	CRT	Urine OP
	AVPU	Cold to		

Crystalloid or Colloid 20 x wt in KG = ... ml asap

(Boluses are 10 mL/kg in shocked patients with diabetic ketoacidosis.)

Replacement Estimated fluid deficit: 5% 10% 15% (rare)

10 x wt in kg x % deficit = ... ml over 24 hrs (normal/low sodium) = ... ml/hr
..... ml over 48+ hrs (high sodium or <5yrs) = ... ml/hr

To be replaced with 0.9% NaCl or Hartmann's solution initially; adjust to allow slow normalisation of [Na]; check U+E and sugar frequently (eg at least 4 hourly if sodium, potassium or sugar abnormal.)

Ongoing losses Fluid lost replaced hourly as 0.9% NaCl with potassium or Hartmann's solution initially.

Maintenance

		Per hour			Per day
Volume	First 10kg wt x 4 =	.....	or	wt x 100 =	.....
	Next 10 kg wt x 2 =	.....	or	wt x 50 =	.....
	Next 10 kg wt x 1 =	.....	or	wt x 20 =	.....
	Maintenance per Hour =	.....	or	**per Day =**	.....

Start with 10% Dextrose in first week of life
0.18% NaCl / 4% dextrose if less than 10 kg
0.45% NaCl / 2.5% dextrose in older children

Adjust fluid sodium, potassium and glucose content, and rate, according to clinical assessment and biochemistry.

NISA/RBHSC PAEDIATRIC ANAESTHESIA
HALF DAY SEMINAR

FRIDAY 3RD DECEMBER 2004
LOWER LECTURE THEATRE, GROUND FLOOR
EDUCATION CENTRE, RVH

1440 – 1500hrs

Paediatric Anaesthesia Services in the District General Hospital

Dr D Lowry, Consultant Anaesthetist, Craigavon Area Hospital

Hyponatraemia in Children

Teaching Aid

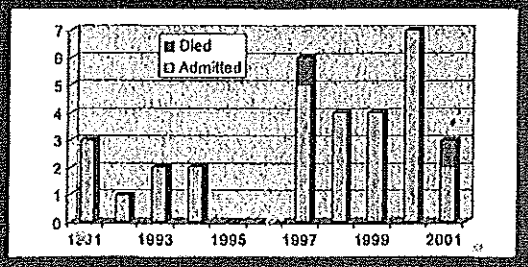
Hyponatraemia Working Party
Department of Health 2001

Background

- Dilutional Hyponatraemia has been documented in otherwise healthy children following routine elective surgery
- If unrecognised it can lead to seizures, cerebral oedema and death

Arieff AI. Paediatric Anaesthesia 1998;8:1-4
Halbenthal M et al. BMJ 2001;322:780-2

Incidence of hyponatraëmia at RBHSC



First six months of 2001

Background ...

Patients at risk

- Hypernatraemia
- Dehydration (>7%)
- Stress, Nausea, pain, anxiety
- Drugs
- Disturbances of the Central Nervous System
- Metabolic and Endocrine disorders

Arieff AI. Paediatric Anaesthesia 1998;8:1-4
Halbenthal M et al. BMJ 2001;322:780-2

Study findings

Halbenthal M et al. BMJ 2001;322:780-2

- 23 patients studied with acute hyponatraemia
- Median age = 5 years (range 1 mth-21 years)
- 13 (57%) were postoperative patients
- 18 (78%) developed seizures
- 5 (22%) Died (Brainstem death), 1 severe neurological deficit

Study findings 2

Halbenthal M et al. BMJ 2001;322:780-2

- 23 patients studied with acute hyponatraemia
- All received hypotonic fluids (plasma $Na^+ < 140$ mmol/l)
- 16 (70%) received excessive maintenance fluids (>50%)

Conclusions

Halberthal M et al. BMJ 2001;322:780-2

- Avoid hypotonic solution if plasma Na+ < 138 mmol/l
- Must measure plasma Na+ when starting an iv infusion
- Only use hypotonic solutions if plasma Na+ > 140mmol/l
- Must measure plasma if children receives > 30 mls/kg fluids

Sodium content

- 0.18 NaCl in 4% Glucose contains 30 mmol/l of sodium
- 0.45 NaCl in 2.5% Glucose contains 75 mmol/l of sodium
- 0.9% NaCl contains 154 mmol/l of sodium
- Hartmanns contains 131 mmol/l of sodium

Body weight

- Where possible the child should be weighed in Kgs
- Otherwise calculate the weight according to the formula; $(Age+4) \times 2$

ie a 2 year old will weigh 12 kgs

Plot the weight on a Centile Chart as a cross-check

Maintenance Fluids

- For the first 10 kgs body wt give 4 mls / kg / hour *(40 mls/hr for a 10 kg infant)*
- For the second 10 kgs body wt give 40 + 2 mls / kg / hour *(60 mls/hr for a 20 kg child)*
- For each subsequent 1 kg body wt give 60 + 1 ml / kg / hour *(70 mls/hr for a 30 kg child)*

Recommendations

- Body weight should be measured or carefully estimated.
- Total fluid must not exceed the calculated maintenance.
- Maintenance fluid should contain at least 0.45% NaCl in 2.5% Glucose.
- Measurement of urine output or serial body weight is mandatory and should be assessed daily.
- Baseline and regular measurement of blood biochemistry (Na+, Glucose), at least daily.
- Do not use any glucose containing solution for "Fluid Bolus" or "Fluid Challenge" above maintenance rate.

Department of Health, Social Services & Public Safety
An Roinn Sláinte, Seirbhísí Sóisialta agus Sábháilteachta Pc

From: The Deputy Chief Medical Officer
Dr Paul Darragh

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Fax: 028 90 520574
e-mail: paul.darragh@dhsspsni.gov.uk

21 August 2001

Dear Colleague

ACUTE HYPONATRAEMIA IN CHILDREN

There is increasing evidence that Acute Hyponatraemia is emerging as a significant clinical problem in sick children receiving I.V. fluids. As a result we believe we should convene a group to consider how best practice could be brought to bear on the problem and to explore whether further advice needs to be issued by the DHSS&PS at this time to the profession.

I would hope that we could achieve a broad measure of agreement on how to proceed and would hope we would only need one or two meetings to achieve a consensus. I enclose a BMJ paper and a brief resume of the problem prepared locally which should provide background reading.

I look forward to seeing you on 26 September 2001 at 9.30 am in my office (Room C.5.16, Castle Buildings).

Thank you for agreeing to participate.

Yours sincerely

DR PAUL DARRAGH
Deputy Chief Medical Officer