Witness Statement Ref. No. 008/1

NAME OF CHILD: Adam Strain

Name: Robert Taylor

Title: Consultant Paediatric Anaesthetist

Present position and institution:

Consultant Paediatric Anaesthetist, Royal Belfast Hospital for Sick Children

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

Membership of Advisory Panels and Committees:
[Identify by date and title all of those between January 1995-December 2004]

1997-98, Provision of Paediatric Surgical Services Working Party,
30th September 1997. Regional Working Group on the care of Acutely Ill Children; Sub-Group on Paediatric Intensive Care
1997-2005, Local Advisory Paramedic Steering Committee,
1997-98, EH&SSB Working Party on Meningococcal Disease,
1999-2005, Sick Child Liaison Group,
Sept 2001-Jan 2002, Hyponatraemia Working Party,
2002, Paediatric Long-Term Ventilation Working Party,
Jun 2003-Feb 2004, Neonatal/Paediatric Interhospital Transport Working Party,
2003-2005, Chairman Clinical Audit Committee, RGH Trust
2002-2005, Member Clinical Ethics Committee, RGH Trust

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

011-005-035,036	Statement to Coroner 30.11.95	(same as 059-067-155/156)
011-017-108-121	Deposition at Inquest 21.06.96	
059-004-007	Note to Mr Brangam	
059-009-028	Note to Mr Brangam 07.06.96	
059-036-071,072	Letter to Dr Murnaghan 08.05.96	
059-053-108	Letter to Dr G Murnaghan 02.02.96	
059-012-031,032	Fax to Mr Brangam 07.06.96	

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

Ref:	Date:	
011-005-035	30.11.95	Statement
011-017-108	21.06.96	Deposition at the Inquest on Adam Strain
		Transcript of oral evidence at the Inquest on Adam Strain

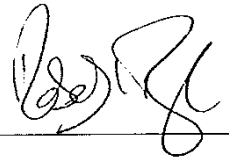
Particular areas of interest
[Please attach additional sheets if more space is required]

1. **Describe in detail your role in the preparation for the transplant surgery on Adam, including:**
   (i) meetings with other medical personnel
   (ii) information sought and provided to other medical personnel; and
   (iii) calculations made.

(i) I was on call for RBHSC – Friday, Saturday & Sunday, which was a typical busy weekend. Prof Maurice Savage phoned me on Sunday night 26th November 1995, to inform me that a Renal Transplant was scheduled on Adam Strain for early next morning. I was informed that Adam retained his native kidneys. I suggested coming in to assess him, but we concluded that relevant information could be given by phone and that I would be required to start case at 06.00 hrs next morning (058-003-005). This meant leaving home at 05.15 hrs on the 27th November 1995, to prepare the patient, drugs and perform my pre-anaesthetic equipment checks.

During this phone call pre-transplant information was given and my many questions were answered (058-002-002). However I knew I would have to make a more detailed examination of the medical records and Adam before embarking on the transplant anaesthetic. It was agreed that this would be best done early the following morning. I asked for 4 units of blood and to check FBC/U&E, etc, fasting instructions, and a request to erect IV fluids at the usual maintenance rate. The next morning, on 27th November 1995 I was told by a ward nurse that blood tests and IV fluids were not done because of poor venous access and repeated attempts had caused Adam to be upset. At about 05.45 hrs I met with Adam and his mother and reviewed all available information pre-operatively. I now discussed the effect of having no post-dialysis, U&E results and the impact of no intravenous fluids for the fasting period of the previous two hours since his night feeds were stopped with Dr Montague. I reviewed his fluid balance sheet (057-010-013) and noted that he was to have received 200 ml/hour of oral fluids (I think this was by artificial feeding tube). In actual fact Adam had received in excess of this 200 ml/hr which suggested to Dr Montague and myself that he was capable of tolerating rates of fluid in excess of the normal amounts because of his underlying high-output renal failure.

This meant that we had to make several unusual fluid calculations (see below). I also checked his most recent blood test results from 23.00 on the 26th November which indicated a sodium value of 139 mmol/l and a Haemoglobin of 10.5 (058-035-144). Although I noted that he did have a sodium of 124 mmol/l on one occasion without apparent ill-effects I was informed that it was usual for Adam's electrolytes to remain stable following dialysis for 24 hours as demonstrated in a summary of his biochemistry results in 1995 (058-041-187-224). It was clear that Adam produced very dilute urine with a sodium content of 29-52 mmol/litre as seen in a summary of his urine biochemistry results from 28th November 1991-5th December 1991 (050-018-055) and again confirmed in a test done on the 14th December 1991 (050-018-051) which meant that he was unable to cope with a high sodium load.



Particular areas of interest (Contd.)

(ii) I then sought information on Adam's previous anaesthetic management. He had undergone a shorter procedure on 18th October 1995. I examined the anaesthetic record (058-025-069 to 074). This indicated a brief summary of significant medical history and of note he was distressed on arrival in theatre. The anaesthetist (Dr Loan) recorded that "much better co-operation when IV induction offered". Otherwise there were no difficulties noted with his anaesthetic management. I noted the size of the endotrachael tube (4.5mm) and that a butterfly needle was used to induce anaesthesia in the left ante cubital fossa. Although there were no fluid calculations performed on this, I noted that 300mls of "1/5 NSaline/4%" were given over approximately 1hr.

No other fluids were administered and no blood loss was recorded. Adam appeared to have recovered well and uneventfully from this surgery. His heart rate and blood pressure appeared to follow a "standard course". I checked recent medical history, drug history, whether he was allergic or sensitive to any medications, and his most recent evaluation of fluid and electrolyte status. I therefore had to make a decision about further delaying surgery to gain IV access and blood tests against prolonging the "cold ischaemic time" of the donor kidney.

The decision to delay surgery to the morning was to ensure that the operating room staff were not too exhausted, that new day staff would be coming on duty, that a Paediatric Intensive Care bed would be available. Also, that an emergency theatre would not be "blocked" by a semi-elective case. In our hospital, only one operating theatre is available at nights and weekends. There were therefore many complex, inter-dependent factors that made it difficult to determine when the optimum conditions existed for Adam's transplant to take place. In close discussion with the nursing staff in PICU, Theatres, Nephrology Ward and Mr Keane, a "team" decision was made to go ahead with the kidney transplant on Adam at about 0700hrs on 27th November 1995.

(iii)From about 0630 or 0640 I spent some time with my experienced senior registrar, Dr Terence Montague, calculating the dose of anaesthetic drugs and fluids. We double checked the syringes and fluid bags with each other and agreed on their accuracy. The drug calculations were made on standard text-book dosing schedules. The need to replace fluid deficit is calculated on the known urine and insensible losses and it was agreed that there was an urgency to replace this deficit so that Adam did not become dehydrated or suffer from low blood circulation prior to transplant. We knew that Adam was unable to concentrate urine by the natural hormonal influences, Anti-Diuretic Hormone (ADH) and Renin-angiotensin. Therefore we needed to provide at least 200mls per hour of similar fluid to his renal losses. The concentration of sodium in his urine was low, 29-52 mmol/l (050-018-055) and replacement for this was most closely represented by the 0.18 NaCl/ 4% Glucose fluid (sodium = 30 mmol/l). This then required 400mls to replace his 2hr fasting deficit and a further 200mls for his first hour of surgery or 600mls in the first hour. There was also the need to replace any ongoing losses of blood initially with crystalloid. We agreed that we would keep a close watch on blood loss and replace such losses with a ratio of 3mls crystalloid to 1ml blood loss. This was a well established ratio used by anaesthetists worldwide at that time. We also recognised that there would be the need to replace the type of fluid lost by the body by that type of fluid which it most closely resembled, i.e. replace water with water, salt with salt and blood with blood.

Particular areas of interest (Cont'd)

In summary, pre-operative fluid calculations were:-

1. Replace fluid deficit (mainly dilute urine) 2hrs @ 200mls = 400mls total
2. Provide fluid maintenance requirements each hour in theatre, i.e. 200mls = 200mls/hr
3. Replace any blood loss by monitoring swabs and suction and replace blood with crystalloid in a ratio of 3mls crystalloid to 1ml blood loss. This would also include blood products when indicated in a ratio of 1ml for each ml of loss.
4. Further fluid management would depend on BP, HR, CVP and organ perfusion
5. The need to ensure that Adam's blood volume was certainly not deficient BUT with careful monitoring was actually increased in order to adequately perfuse the new, adult sized donor kidney.

2. Describe in detail the course of the transplant surgery, including:
(i) your own actions;
(ii) tests requested and results received;
(iii) results received from monitoring; and
(iv) condition of Adam at the completion of the surgery.

(i) In a long case lasting over four hours, it is not possible to provide patient safety with a single anaesthetist. I only agreed to provide general anaesthesia for Adam with an experienced senior registrar, Dr T Montague, experienced theatre nursing staff and the ready access to experienced surgeons, and nephrologists who were in theatre dress and present beside me in theatre for large parts of the procedure.

Therefore, my actions are as a team member and a team leader (for anaesthesia). Dr T Montague and/or myself were present with Adam in theatre at all times. The degree of vigilance and personal comfort cannot be provided by a single individual.

I cannot remember the exact reasons why Adam's surgery did not start at 06.00 as originally planned. I can only speculate that it took a considerable amount of time to work out an agreed management plan and review previous notes despite my very early attendance at the hospital that morning. At 07.00 I worked closely with Dr T Montague and the anaesthetic nurse to induce anaesthesia and provide all the technical skills necessary to secure the airway, breathing, access to intravenous lines, arterial access, central venous access and epidural catheter placement. I am dependent on my statement (011-005-035,036) when I report that Adam was anaesthetised "without undue difficulty". We continued to record the anaesthetic drugs and procedures on the appropriate chart (058-003-005).

(ii) The IV fluids were reassessed several times during the first hour. The total fluid now needed & during the 1st hr was 400ml (deficit) + 200 ml current hrs maintenance giving an total of 600 mls.
(iii) Therefore the first 500mls (being 1 bag) of 0.18NaCl/4% Glucose was increased to be completed in the first half hour and a second bag (500mls) to make up that volume and type of fluid lost by the kidneys ie approximately 600-700 mls given in the first hour.
During the second hour ie 08.00-09.00 of surgery the blood loss from Adam's swab count (058-007-020,021) became the crucial factor in relation to his fluid management. The computerised record (058-008-023) indicated that the Central Venous Pressure (CVP) was being recorded from 08.00. This means that the anaesthetic tasks were complete and the operation could begin from that time.

Particular areas of interest (Cont'd)

No time-line was present on the swab count form (058-007-020,021) nor was there a time-line of blood volume lost in the suction or spilled on to towels. We noted that initially the swabs were light, i.e. 6-10gms (net wt recorded) but this increased with several heavier swabs including one of 67gms (equivalent to 67mls). It was becoming clear that about 200 mls of blood was lost in the swabs in the first hour plus a similar amount in the suction bottle and on the towels; about 600 mls in total. We were concerned about this loss and together with others present, decided to commence a second fluid infusion of Human Plasma Protein Fraction (HPPF) which had a similar electrolyte profile to the type and quality of fluid being lost. HPPF contains 130-150 mmol/litre of sodium as well as albumin which is retained in the blood circulation and is used as a blood volume replacement.

This HPPF, 400mls was administered over the second hour of surgery. Towards the end of the second hour of surgery, we had therefore given 1000mls of 0.18NaCl/4% Glucose and 400mls HPPF, giving a total input of 1400mls and a loss exceeding 500mls of blood and urine lost by Adam's native kidneys. We were reasonably satisfied toward the end of the 2nd hour of surgery that the renal losses were now adequately replaced and therefore erected a 3rd bag (500 mls) of 0.18NaCl/4% Glucose to be given at a much reduced rate, over the following two hours twenty minutes to maintain the loss of dilute urine by Adam's native kidneys. This infusion of glucose containing fluid was also needed to provide sufficient sugar for Adam's metabolic requirements. It is well recognised that epidural anaesthesia reduces the "stress-response" to surgery. This can limit the increased blood sugar normally seen in patients undergoing general anaesthesia and surgery. All aspects of the anaesthetic were reassessed throughout the 2nd hr and in respect of fluids another type of fluid, Hartmann's solution (Sodium content 130 mmol/litre) was commenced near the end of the 2nd hour of surgery. This is a much more usual type of fluid given to patients under anaesthetic for maintenance of fluid and electrolyte requirements but does not provide glucose needs. Hartmann's solution was given over the remaining two hours fifteen minutes of surgery. This fluid was provided to "preload" the new kidney so that there would be sufficient fluid for its function. A review of his BP and HR at the end of the 2nd hr of surgery indicated a stable BP 90-95 mmHg systolic, and a HR initially of 140 settling to 110 associated with the initial dose of atropine wearing off.

The computerised record (058-008-023) indicated that Adam's Central Venous Pressure CVP was initially 17 mmHg at 08.00hrs and had risen to 20 mmHg at 0900 hrs a modest rise of 3 mmHg after 2 hours of surgery. Although the initial CVP of 17 is higher than normally expected (8-12 normal range), we concluded that the tip had curved upward into the neck vessels as confirmed by compression. Therefore, as indicated in my statement (011-005-035,036), we accepted the 17 mmHg as a marker to look for a relative change rather than an absolute level. It is usual practice to increase the CVP by 5-10 cms above the initial level to ensure adequate blood flow to the new or donor kidney. We concluded that the CVP was of value as a relative measure of venous pressure rather than an absolute measure. When continuously re-assessing Adam's fluid replacement we used all the information available from the anaesthetic monitors as well as visualising the impact on the surgical field.

By the third hour , 0900 – 1000hrs (058-003-005), the blood loss was continuing and Adam's blood pressure, CVP and general status indicated that we may still require further fluid to be administered. We were moving to a stage when more blood products were now appropriate. During the third hour 0900 – 1000hrs, the blood loss continued in all three areas, swabs, suction

Particular areas of interest (Cont'd)

and towels. A blood gas analysis was taken at 09.32hrs which confirmed, good gas exchange and acid base balance, an estimated haemoglobin of 6.1 and a sodium of 123mmol/L(058-003-003).

This result led to an immediate re-appraisal of the blood loss and a unit of packed red blood cells was given over the following hour to replace the measured blood loss. This blood test suggested that the fluids administered so far had maintained the blood volume necessary to tolerate the imminent connection of the donor kidney. The saline/glucose infusion was further reduced following this blood test to stop any further reduction in the serum sodium and only fluids containing sodium at 130 mmol/l or greater were administered in addition. We were aware that Adam had sodium levels as low as this previously without any ill effects (058-041-187 to 224).

The new kidney was in place toward the end of the 3rd hour of surgery. This can be interpreted from the anaesthetic record (058-003-005) as being the time when Prednisone and Azothiaprone were given under the direction of Dr O'Connor. This was another opportunity for the team to review the fluid management, blood loss and general status of the new kidney. In that review it was clear that the appropriate amount of fluid was being delivered ie;

1. 1100 mls of 0.18NaCl/4% Glucose had been given to replace the amount lost by Adam's native kidneys and provide maintenance sugar requirements (5 hrs@200 ml/hr=1000mls).

2. 800 mls of HPPF and 250 mls of Blood had been given to replace that lost in swabs, suction and towels and to help to restore the low Haemoglobin.

3. Hartmann's solution was commenced to maintain the CVP and provide the new kidney with sufficient preload to ensure its function. The sodium and electrolyte content of this fluid is physiological and therefore appropriate for the function of the donor kidney.

The fluids were again reassessed during the 4th hour of surgery. They included 0.18 NaCl /4% glucose at 200 ml/hour for renal losses, HPPF and Packed red blood cells for replacement of blood loss and Hartmann's solution at 200 mls/hour to support preload for the new donor kidney. The estimated losses from Adam's circulation were noted in his swab count record (058-007-021);

1. Swabs weighed 411 mls
2. Suction bottle 500 mls
3. Towels "heavily soaked" 500 mls

My anaesthetic record finishes at 11.00 indicating that the surgery was completed. However there was a further 30-40 minutes when Adam was being prepared for transfer to PICU. The computerized record clearly shows that HR and BP monitoring continued until after 11.30 (058-008-023). Thus the total anaesthetic time was 4 hours 30 minutes.

(iv) It was therefore a terrible shock to me and all those present when Adam did not wake-up when his anaesthetic was switched off. Throughout the kidney transplant there had been no episodes of instability in his breathing or circulation or neurological state. In fact when his anaesthetic record was reviewed immediately after surgery it appeared very stable with no unexplained episode of low heart rate or blood pressure or oxygen levels. I printed off a computerised record of his actual recordings to re-examine in greater detail any possible adverse episodes which may have been overlooked (058-008-023).

Particular areas of interest (Cont'd)

I also re-examined his losses from the surgery and took account of the measurements taken (swabs and suction) as well as an estimate of that lost in the towels and on the floor. In particular there was no sign that inappropriate or excessive fluids had been given for Adam's complex surgery and pre-existing medical problems. The blood sugar test performed at the end of surgery was 4 mmol/l. This is a low normal level. If I had not provided the same quantity of glucose as I had done then there would have been a serious risk of Adam developing hypoglycaemia.

To assist the Inquiry I have summarised the total fluids given to Adam (058-003-005) with reasons;

1. 1500 mls of 0.18NaCl/4% Glucose had been given to replace the amount lost by Adam's native kidneys and provide basic sugar needs (61/2 hrs@200 ml/hr=1300mls).

2. 1000 mls of HPPF and 500 mls of Blood had been given to replace that lost in swabs, suction and
towels and to help to restore the low Haemoglobin. (Estimate of losses 1411 mls)

3. 500 mls of Hartmann's solution to maintain the CVP and provide the new kidney with sufficient preload to ensure its function.

In my previous experience of anaesthesia for renal transplantation there has always been the option to institute renal dialysis after surgery if there is evidence of fluid overload. This gives anaesthetists and nephrologists an opportunity to give generous intravenous fluids provided careful and continuous monitoring is provided to ensure the function of the donor kidney. In most of the cases I have been involved with there has been evidence of pulmonary oedema following renal transplants. Often the patient needs oxygen therapy or even mechanical ventilation to manage this complication. Therefore we were administering fluids to Adam with the express purpose of increasing his blood volume to ensure that the donor kidney (with a long cold ischaemic time) would have sufficient preload and be given the best possible chance of working. All our calculations confirmed that this was the case.

At 1140 I transferred Adam to the Paediatric Intensive Care unit for further evaluation. A short time later I accompanied Dr Savage to speak to Adam's mother. We passed on our concerns on why Adam hadn't woken up at the end of surgery. Unfortunately Adam never regained consciousness following the transplant surgery and was declared dead on the 28th November 1995. I worked closely with other medical staff to determine the cause of his death so that his mother could be given as much information as possible. It was also important to investigate the cause of his death so that other patients could benefit from knowledge learned by Adam's tragic death during renal transplantation.

Particular areas of interest (Cont'd)

3. Explain the reasons for the actions that you took in the operating theatre, including:
(i) when and why tests were requested; and
(ii) what fluids were administered and when and why they were changed

(i) arterial blood gas 09.32 (058-003-003) This test was done primarily to confirm adequate respiratory function. It also provided a estimate for the haemoglobin since there was a continued blood loss and active bleeding. It also provided an estimate of sodium levels. (Na 123 mmol/l).

(ii) Fluid administration was described in Q2 (i). This was a continuous assessment of fluid deficits, losses and projected needs to adequately perfuse a donated adult kidney. Fluids were changed in response to on-going blood loss and metabolic requirements. This was based on preoperative fluid plan (Question 1 (i)):

Fluid Plan; Replace fluid deficit in the first hour and provide ongoing renal losses associated with Adam's native kidneys with a type of fluid low in sodium content (0.18 NaCl/4%Glucose). This fluid, Saline & Glucose mixture is recommended for dehydration in the British National Formulary (BNF) Number 29, March 1995 **(Ref BNF 29, copy enclosed)**. There is no advice on the problems associated with Anti-diuretic Hormone with this mixture of fluid until March 2003 **(Ref BNF 45, copy enclosed)**. The remainder of the fluid plan was to replace surgical losses as measured by swab weight, suction volume and estimated as the amount soaked in towels in conjunction with the patient's overall status with invasive monitoring of his vital signs.

4. Describe in detail, including providing dates, the actions that you took to educate the medical profession on hyponatraemia in child surgical cases following Adam's death on 28th November 1995

I worked with all those involved in the days and weeks following Adam's death to investigate all the possible reasons for that tragic event. This included multiple reviews of all aspects of the anaesthetic and pre-operative management. It also involved a detailed literature search by me for publications relevant to the case. We knew that a complete understanding of the reasons for his death would be essential before asking others to change their medical practice. During the Coroners Inquest clear recommendations were drafted. On the 19th June 1996 I worked in co-operation with Drs Murnaghan, Savage and Gaston to develop Draft Recommendations for Paediatric surgery (060-018-036). This was shared and discussed with my Paediatric Anaesthetic colleagues, Drs Crean and McKaigue (060-014-025 – redacted).

As a consultant in the Royal Belfast Hospital for Sick Children, with my colleagues, I have had the opportunity since 1995 to teach and train junior anaesthetic and paediatric trainee doctors in all aspects of fluid management in children undergoing major surgery. I have maintained my professional knowledge of all aspects of such cases by reading widely on the subject of fluid management and passed on such knowledge in formal and informal teaching sessions.

I became an active instructor on the Advanced Paediatric Life Support (APLS) course in 1997. On this course I have taught all of the many aspects of life support. In relation to the Inquiry I have taught many doctors and nurses about the type and volume of fluids to be administered to infants and children with serious life-threatening conditions eg, shock, dehydration, diabetes, trauma etc. This teaching follows national and international guidelines. In 1999 I became the APLS course

Particular areas of interest (Cont'd)

director on two Belfast courses annually and was invited to initiate the APLS course in Dublin in 2001 and Jersey in 2003. I have also taught on the APLS course in Walsall, Manchester and Leicester. Overall I have assisted in the instruction of over 400 doctors and nurses, mainly in Northern Ireland.

I founded a group of Paediatric, Anaesthetic and Accident and Emergency Consultants who met 2-3 times per year at Antrim Area Hospital (**reference SCLG, copy enclosed**). This group called itself the Sick Child Liaison Group (SCLG). Its main purpose was to improve the quality of care to critically ill infants and children being transferred to the Paediatric ICU mainly by better communication. I chaired these meetings and kept my Clinical Director, Dr Hicks at the RBHSC, and Dr M. McCarthy, DHSS informed of our discussions. One of the outcomes from this SCLG was the production of an agreed "Meningococcal Guideline" to be used in all hospitals in Northern Ireland. This guideline included advice on the fluid management of children presenting with Meningococcal disease. At another meeting of the SCLG on 26th June 2001 the issue of dilutional hyponatraemia was presented by me in relation to children receiving intravenous fluids on paediatric wards (**reference SCLG2, copy enclosed**). Unfortunately these meetings became poorly attended probably because they were held in the evenings. I have recently introduced the use of Tele-medicine to link with other doctors who transfer sick children to PICU. This has been well received but at the moment has only been piloted between the PICU and Craigavon Area Hospital.

I was a founder member along with Dr Brendan O'Hare of the Paediatric Anaesthetic Travelling Society of Ireland (P.A.T.S.I.) in 1997. This is a group of paediatric anaesthetists from RBHSC, Temple Street Children's Hospital and Our Lady's Hospital for Sick Children who meet annually. We have a very close academic and social relationship. At our meetings we discuss areas of common interest and invite respected doctors from overseas to help in our education. Dr Des Bohn was invited to one of our meetings in 2000 to discuss intravenous fluids. I continue to provide leadership in the teaching of fluids and other important matters to other doctors involved in major paediatric surgery in Ireland.

From 1991 I met twice a year with other Consultants in Paediatric Intensive Care at organized conferences of the UK Paediatric Intensive Care Society (PICS) . At these conferences fluid management of critically ill children was discussed on several occasions. At a meeting in Great Ormond Street in October 1999 a whole session was devoted to the subject of the optimum fluid for such children. Dr Des Bohn who has published several papers on hyponatraemia spoke at this meeting. I had worked for Dr Bohn as a Paediatric Critical care Fellow in the Hospital for Sick Children, Toronto in 1988-1989. These PICS meetings also provided an opportunity to discuss paediatric fluid management on an informal manner. In 2002 I was asked to sit on the PICS Council as the co-opted member for Ireland.

In 2001 I was invited to be a member of the Working Party on Prevention of Hyponatraemia by Dr Darragh (007-050-099). As a member of this committee I helped to draft guidelines to be used by all hospital departments where children are given intravenous fluids. I was asked to report the death of a child to the Medicines Control Agency using the "yellow card" system (007-048-094 to 096 and **reference CSM, copy enclosed**) of adverse incident reporting. Correspondence from the MCA is available on the Inquiry

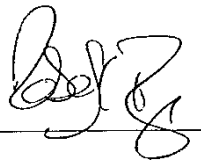
Particular areas of interest (Cont'd)

website (007-017-034). I provided a teaching aid for this committee in the form of a power-point presentation that included an audit of children admitted to PICU with hyponatraemia and recent publications (007-051-100 to111).

I have continued to phone and email other doctors and pharmacists in different parts of the world to gain some insight into the use or prohibition of saline/glucose fluids (007-041-082). This has led me to conclude that there is no consensus on the optimum type of fluids to use in children for major surgery. There is a wide spectrum of opinion on the use of saline/glucose mixtures with some individuals who wish to see these fluids restricted, eg Dr Stephen Playfor, Royal Manchester Children's Hospital (007-061-130).

In 2003 I was invited to edit the Fluids chapter for the second edition of the reference book "Medicines for Children". There was a deficiency in the text regarding the risks of hyponatraemia. I included a paragraph on dilutional hyponatraemia that reflected the CMO's guidance for the "Prevention of Hyponatraemia" which was accepted by the editors. **(reference MFC, copy enclosed)**

I do not believe that individual doctors like me can have any impact on the prescribing of fluids by doctors in the various hospitals in Northern Ireland. The implementation of the guideline on the Prevention of Hyponatraemia by the Chief Medical Officer in 2002 has made a major impact in NI. However it will take a determined effort by a powerful body such as the National Patient Safety Agency to introduce a change to clinical practice in all UK regions.



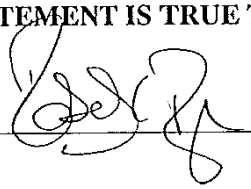
Other points you wish to make including additions to any previous Statements, Depositions and or Reports
[Please attach additional sheets if more space is required]

In my letter to Dr Murnaghan on the 2nd February 1996 (059-053-108) I draw attention to a factual error as reported by Dr Sumner in his report (059-054-109to 120). He reports that the Human Plasma Protein Factor (HPPF) administered to Adam did not contain sodium (059-054-116 and 119). In actual fact this solution contains 130-150 mmol/l of sodium, similar to that present in blood. It is crucial to the understanding of the type and volume of fluids given to Adam to be absolutely accurate. I have outlined in Question 1 the reasons why each type and volume of fluid was given. It was the agreed intention of the transplant team to ensure that water would be given to replace water, salt to replace salt and blood to replace blood and that sufficient sugar be given to provide Adam's essential metabolic requirements.

Also I draw attention to other concerns with Dr Sumners report such as the reasons why 0.18 NaCl/4% Glucose was chosen as a fluid type are as outlined in correspondence to Mr Brangam prior to the inquest. (059-004-007, 059-009-028, 059-053-108)

Unlike drugs, intravenous fluids are not required to undergo rigorous licensing procedures such as evidence of their safety and efficacy. The product information as supplied by the BNF Number 29 in 1995 listed no specific hazards or contra-indications with saline/glucose mixtures. Also despite my request in 2001 for the regulating body for intravenous fluids and drugs, the Medicines Control Agency, to issue a warning about dilutional hyponatraemia (007-029-056) their response was that there should be "no amendments to product information"(007-017-034). In March 2003 a specific warning is supplied by the BNF, Number 45 for intravenous saline and glucose mixtures and the issue of ADH. **(reference BNF, copy enclosed)**

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

Signed:  **Dated:** 18/7/05

BNF Number 29 (March 1995)

WATER

The term water used without qualification means either potable water freshly drawn direct from the public supply and suitable for drinking or freshly boiled and cooled purified water. The latter should be used if the public supply is from a local storage tank or if the potable water is unsuitable for a particular preparation. (Water for injections, section 9.2.2.1)

9.2.2 Intravenous administration

Solutions of electrolytes are given intravenously, to meet normal fluid and electrolyte requirements or to replenish substantial deficits or continuing losses, when the patient is nauseated or vomiting and is unable to take adequate amounts by mouth.

In an individual patient the nature and severity of the electrolyte imbalance must be assessed from the history and clinical and biochemical examination. Sodium, potassium, chloride, magnesium, phosphate, and water depletion can occur singly and in combination with or without disturbances of acid-base balance; for reference to the use of magnesium and phosphates, see section 9.5.

Isotonic solutions may be infused safely into a peripheral vein. Solutions more concentrated than plasma, for example 20% glucose are best given through an indwelling catheter positioned in a large vein

INTRAVENOUS SODIUM

Sodium chloride in isotonic solution provides the most important extracellular ions in near physiological concentration and is indicated in *sodium depletion* which may arise from such conditions as gastro-enteritis, diabetic ketoacidosis, ileus, and ascites. In a severe deficit of from 4 to 8 litres, 2 to 3 litres of isotonic sodium chloride may be given over 2 to 3 hours, thereafter infusion can usually be at a slower rate.

Excessive administration should be avoided; the jugular venous pressure should be assessed, the bases of the lungs should be examined for crepitations, and in elderly or seriously ill patients it is often helpful to monitor the right atrial (central) venous pressure

Compound sodium lactate (Hartmann's solution) can be used instead of isotonic sodium chloride solution during surgery or in the initial management of the injured or wounded.

Sodium chloride and glucose solutions are indicated when there is combined *water and sodium depletion*. A 1:1 mixture of isotonic sodium chloride and 5% glucose allows some of the water (free of sodium) to enter body cells which suffer most from dehydration while the sodium salt with a volume of water determined by the normal plasma Na^+ remains extracellular. An example of combined sodium chloride and water depletion occurs in persistent vomiting

SODIUM CHLORIDE

Indications: electrolyte imbalance, also section 9.2.1.2

Cautions: restrict intake in impaired renal function, cardiac failure, hypertension, peripheral and pulmonary oedema, toxaemia of pregnancy

Side-effects: administration of large doses may give rise to sodium accumulation and oedema

Dose: see notes above

PoM Sodium Chloride Intravenous Infusion, usual strength sodium chloride 0.9% (9 g, 150 mmol each of Na^+ and Cl^-/litre), this strength being supplied when normal saline for injection is requested. Net price 2-mL amp = 28p; 5-mL amp = 31p; 10-mL amp = 33p; 20-mL amp = 69p; 50-mL amp = £1.52

In hospitals, 500- and 1000-mL packs, and sometimes other sizes, are available

Note. The term 'normal saline' should not be used to describe sodium chloride intravenous infusion 0.9%; the term 'physiological saline' is acceptable but it is preferable to give the composition (i.e. sodium chloride intravenous infusion 0.9%)

With other ingredients

PoM Sodium Chloride and Glucose Intravenous Infusion, usual strength sodium chloride 0.18% (1.8 g, 30 mmol each of Na^+ and Cl^-/litre) and 4% of anhydrous glucose

In hospitals, 500- and 1000-mL packs, and sometimes other sizes are available

PoM Ringer's Solution for Injection, calcium chloride (dihydrate) 322 micrograms, potassium chloride 300 micrograms, sodium chloride 8.6 mg/mL, providing the following ions (in mmol/litre), Ca^{2+} 2.2, K^+ 4, Na^+ 147, Cl^- 156

In hospitals, 500- and 1000-mL packs, and sometimes other sizes, are available

PoM Sodium Lactate Intravenous Infusion, Compound (Hartmann's Solution for Injection, Ringer-Lactate Solution for Injection), sodium chloride 0.6%, sodium lactate 0.25%, potassium chloride 0.04%, calcium chloride 0.027% (containing Na^+ 131 mmol, K^+ 5 mmol, Ca^{2+} 2 mmol, HCO_3^- (as lactate) 29 mmol, Cl^- 111 mmol/litre)

In hospitals, 500- and 1000-mL packs, and sometimes other sizes, are available

INTRAVENOUS GLUCOSE

Glucose solutions (5%) are mainly used to replace water deficits and should be given alone when there is no significant loss of electrolytes. Average water requirements in a healthy adult are 1.5 to 2.5 litres daily and this is needed to balance unavoidable losses of water through the skin and lungs and to provide sufficient for urinary excretion. Water depletion (dehydration) tends to occur when these losses are not matched by a comparable intake, as for example may occur in coma or dysphagia or in the aged or apathetic who may not drink water in sufficient amount on their own initiative

Excessive loss of water without loss of electrolytes is uncommon, occurring in fevers, hyperthyroidism, and in uncommon water-losing renal

Dose: see notes above

Sodium Bicarbonate (Non-proprietary)
Capsules, sodium bicarbonate 500 mg (approx 6 mmol each of Na^+ and HCO_3^-). Net price 20 = £6.08
Available from Generics, IVAX
Tablets, sodium bicarbonate 600 mg, net price 20 tabs = 50p
IMPORTANT Oral solutions of sodium bicarbonate are required occasionally, these need to be obtained on special order and the strength of sodium bicarbonate should be stated on the prescription

POTASSIUM BICARBONATE

Indications: see notes above
Cautions: cardiac disease, renal impairment, interactions: Appendix 1 (potassium salts)
Contra-indications: hypochloraemia, plasma potassium concentration above 5 mmol/litre
Side-effects: nausea and vomiting
Dose: see notes above

Potassium Tablets, Effervescent (Non-proprietary)
Effervescent tablets, potassium bicarbonate 500 mg, potassium acid tartrate 300 mg, each tablet providing 6.5 mmol of K^+. To be dissolved in water before administration. Net price 100 = £4.29
Label: 13, 21
Available from Alpharma, Hillcross
NOTE These tablets do not contain chloride, for effervescent tablets containing potassium and chloride, see under Potassium Chloride, section 9.2.1.1

9.2.2 Parenteral preparations for fluid and electrolyte imbalance

9.2.2.1 Electrolytes and water

Solutions of electrolytes are given intravenously, to meet normal fluid and electrolyte requirements or to replenish substantial deficits or continuing losses, when the patient is nauseated or vomiting and is unable to take adequate amounts by mouth. When intravenous administration is not possible large volumes of fluid can also be given subcutaneously by hypodermoclysis.

In an individual patient the nature and severity of the electrolyte imbalance must be assessed from the history and clinical and biochemical examination. Sodium, potassium, chloride, magnesium, phosphate, and water depletion can occur singly and in combination with or without disturbances of acid-base balance, for reference to the use of magnesium and phosphates, see section 9.5.

Isotonic solutions may be infused safely into a peripheral vein. Solutions more concentrated than plasma, for example 20% glucose are best given through an indwelling catheter positioned in a large vein.

Intravenous sodium

Sodium chloride in isotonic solution provides the most important extracellular ions in near physiological concentration and is indicated in *sodium depletion* which may arise from such conditions as gastro-enteritis, diabetic ketoacidosis, ileus, and ascites. In a severe deficit of from 4 to 8 litres, 2 to 3 litres of isotonic sodium chloride may be given over 2 to 3 hours, thereafter infusion can usually be at a slower rate. Excessive administration should be avoided; the jugular venous pressure should be assessed, the bases of the lungs should be examined for crepitations, and in elderly or seriously ill patients it is often helpful to monitor the right atrial (central) venous pressure.

Chronic hyponatraemia should ideally be corrected by fluid restriction. However, if sodium chloride is required, the deficit should be corrected slowly to avoid the risk of osmotic demyelination syndrome, the rise in plasma-sodium concentration should be limited to no more than 10 mmol/litre in 24 hours.

Compound sodium lactate (Hartmann's solution) can be used instead of isotonic sodium chloride solution during surgery or in the initial management of the injured or wounded.

Sodium chloride and glucose solutions are indicated when there is combined *water and sodium depletion*. A 1:1 mixture of isotonic sodium chloride and 5% glucose allows some of the water (free of sodium) to enter body cells which suffer most from dehydration while the sodium salt with a volume of water determined by the normal plasma Na^+ remains extracellular. Maintenance fluid should accurately reflect daily requirements and close monitoring is required to avoid fluid and electrolyte imbalance. Illness or injury increase the secretion of anti-diuretic hormone and therefore the ability to excrete excess water may be impaired. Injudicious use of solutions such as sodium chloride 0.18% and glucose 4% may also cause dilutional hyponatraemia especially in children and the elderly; if necessary, guidance should be sought from a clinician experienced in the management of fluid and electrolytes.

Combined sodium, potassium, chloride, and water depletion may occur, for example, with severe diarrhoea or persistent vomiting, replacement is carried out with sodium chloride intravenous infusion 0.9% and glucose intravenous infusion 5% with potassium as appropriate.

SODIUM CHLORIDE

Indications: electrolyte imbalance, also section 9.2.1.2

Cautions: restrict intake in impaired renal function, cardiac failure, hypertension, peripheral and pulmonary oedema, toxaemia of pregnancy

Side-effects: administration of large doses may give rise to sodium accumulation and oedema

Dose: see notes above

Sodium Chloride Intravenous Infusion (Non-proprietary) [FGH]
Intravenous infusion usual strength sodium chloride 0.9% (9 g, 150 mmol each of Na^+ and Cl^- /litre), this strength being supplied when normal saline for

First appears this edition. NOT in BNF no. 44

BNF No. 45 (March 2003)

SCL5

ROYAL BELFAST HOSPITAL FOR SICK CHILDREN
PAEDIATRIC INTENSIVE CARE UNIT

MEMORANDUM

TO: The Undernoted **DATE:** 9 February 1999

FROM: Dr R Taylor **REF:** RT/AB

Following recent correspondence with Paediatricians and Anaesthetists in various Hospitals I would like to invite you, or a suitable deputy, to convene meetings regarding the CLINICAL IMPLICATIONS and implementation of the recent "Framework for the Future" document for Paediatric ICU. In particular I would like to consult widely on agreed guidelines for admission, initial management and transfer of critically ill infants and children.

Could you please indicate preference for the following date:-

March 2nd 1830-2000 yes
March 3rd 1830-2000 NO
March 9th 1830-2000 yes

A Beh

Suggested venue is Antrim Area Hospital.

DR R TAYLOR
CONSULTANT ANAESTHETIST

CC Dr N McLeod Consultant Anaesthetist ICU Antrim Area Hospital
Dr J McAloon Consultant Paediatrician Antrim Area Hospital
Dr B Bell Consultant Paediatrician Craigavon Area Hospital
Dr C McAllister Consultant Anaesthetist ICU Craigavon Area Hospital
Dr B Morron Consultant Anaesthetist ICU Altnagelvin Area Hopsital
Dr N Corrigan Consultant Paediatrician Altnagelvin Area Hospital
Dr J Trinder Consultant Anaesthetist ICU Ulster Hospital
✓Dr T Brown Consultant Paediatrician Ulster Hospital

→ Dr. Ben, Please

RT 11/2/99

SCLG2

SICK CHILD LIAISON GROUP
Minutes
Tuesday 26th June 2001 - ANTRIM AREA HOSPITAL

IN ATTENDANCE:
Dr J McAloón
Dr R Taylor
Dr H Steen
Dr D O'Donoghue

APOLOGIES:
Dr M MCCarthy
Dr B Bell
Dr A Bell
Dr B Morrow

ACTION

Matters Arising;

1.1. BRONCHIOLITIS guidelines; BT to present guidelines for infants with severe bronchiolitis available for winter 2001 (BB/BT

1.2. TRANSPORT OF CRITICALLY ILL CHILD guideline; This is a product of the Paediatric Benchmark nurses project and is currently running throughout Northern Ireland with good participation among Units. BT

1.3. Seriously Injured Child guideline; SO'R to advise. SO'R

Chairman's Business;

Long term Ventilated Patients now occupy five PICU beds. This is unacceptable as it blocks beds for acutely ill children. Much effort now taking place to educate and train other areas to take these patients. BT

Hyponatraemia; BT presented several papers which indicated the potential problems with the use of hypotonic fluids in children. Work to take place on agreed guidelines from the Department of Health on this subject.

Dr Taylor thanked Dr McAloon for organising the facilities and meals for all in attendance.

Next Meeting;
Tuesday 6 November 2001 at 6.30pm in Antrim Area Hospital

LSM

2a

COMMITTEE ON SAFETY OF MEDICINES

Market Towers • 1 Nine Elms Lane • London SW8 5NQ
Telephone 020-7273 0263 • Facsimile 020-7273 0060

MCA MEDICINES CONTROL AGENCY

IN CONFIDENCE

Dr B Taylor
Paediactric ICU
Royal Hosp for Sick Children
BELFAST
CO. ANTRIM
BT12 6BE

01 Oct 01

Dear Dr Taylor

RE: PATIENT: RF AGE: 9
PATIENT ID NUMBER: 476454
ADR Reg. No: 433167

Thank you for sending us a suspected adverse drug reaction report on the above patient. A copy is enclosed for your records. If additional information becomes available about this report it would be most helpful if you could send this to us, quoting the above reference number.

Your contribution to the UK's Adverse Drug Reactions Reporting Scheme is greatly appreciated. This provides an important early warning of previously unrecognised adverse effects which allows us to take appropriate action to improve the safe use of medicines.

Yours sincerely,

Dr J M Raine
Director - Post Licensing Division

OTHER DRUGS (including self-medication & herbal remedies)

Did the patient take any other drugs in the last 3 months prior to the reaction? (Yes) / No

If *yes*, please give the following information if known:

Drug (Brand, if known)	Route	Dosage	Date started	Date stopped	Prescribed for
CEFOTAXIME	2400mg	IV	07/6/01	10/6/01	APPENDICITIS
METRONIDAZOLE					"

Additional relevant information e.g. medical history, test results, known allergies, rechallenge (if performed), suspected drug interactions. For congenital abnormalities please state all other drugs taken during pregnancy and the date of the last menstrual period.

POST-OP APPENDICECTOMY. - URINE & ELECTROLYTES NOT MONITORED FOR 48 hours
- SYMPTOMATIC — SEIZURES
Na+ 118

433167

REPORTER DETAILS	CLINICIAN (If not the reporter)
Name and Professional Address: DR BOB TAYLOR PAEDIATRIC ICU, 180 FALLS ROAD BELFAST	Name and Professional Address:
Post code: BT12 6BE Tel No: 02890487303	Post code: Tel No: Speciality:
Speciality: PAEDIATRIC ANAESTHESIA	
Signature: Date: 25/9/01	If you would like information about other adverse reactions associated with the suspected drug, please tick this box ☑

Send to Medicines Control Agency, CSM FREEPOST, LONDON SW8 5BR or if you are in one of the following NHS regions:

to CSM Mersey, FREEPOST, Liverpool L3 3AB
or CSM Northern, FREEPOST 1085, Newcastle upon Tyne NE1 1BR
or CSM West Midlands, FREEPOST SW2991, Birmingham B18 7BR
or CSM Wales, FREEPOST, Cardiff CF4 1ZZ

COMMITTEE ON SAFETY OF MEDICINES

In Confidence

M.C.I.A.
MEDICINES CONTROL AGENCY

SUSPECTED ADVERSE DRUG REACTIONS

P2-

If you are suspicious that an adverse reaction may be [illegible] drug or combination of drugs please complete this Yellow Card. Please report all adverse reactions for black triangle (▼) drugs and only [illegible] adverse reactions for established drugs. For additional reporting advice please see page 10 of the BNF or the MCA website www.open.gov.uk/[illegible].htm. Do not be put off reporting because some details are not known.

PATIENT DETAILS Patient Initials: R.F. Sex: M / (F) Weight if known (kg): 25

Age (at time of reaction): 9 Identification (Your Practice / Hospital Ref.)*: 476454

SUSPECTED DRUG(S)

Give brand name of drug and (FLUIDS I.V. (HYPONATRAEMIA → COMA) 433167

batch Number if known	Route	Dosage/?	Date started	Date stopped	Prescribed for
0.18% NaCl/4% Gluc	I.V.	80mls/hour	7/6/01	9/6/01	Post-OP

SUSPECTED REACTION(S)

Please describe the reaction(s) and any treatment given:

HEADACHES → VOMITING → SEIZURES → COMA → BRAINSTEM DEATH (Not 118)

Date reaction(s) started: 7/6/2001 Date reaction(s) stopped: 10/6/01

Do you consider the reaction to be serious? (Yes) No

If *yes*, please indicate why the reaction is considered to be serious (please tick all that apply):

Patient died due to reaction ☑ Involved or prolonged inpatient hospitalisation ☐

Life threatening ☐ Involved persistent or significant disability or incapacity ☐

Congenital abnormality ☐ Medically significant; please give details:

COMMITTEE ON SAFETY OF MEDICINES
1 OCT 2001

Outcome

Recovered ☐
Recovering ☐
Continuing ☐
Other ☑

* This is to enable you to identify the patient in any future correspondence concerning this report

Please attach additional pages if necessary

CSM

COMMITTEE ON SAFETY OF MEDICINES

Market Towers • 1 Nine Elms Lane • London SW8 5NQ
Telephone 020-7273 0263 • Facsimile 020-7273 0060

MEDICINES CONTROL AGENCY

IN CONFIDENCE

Dr B Taylor
Paediactric ICU
Royal Hosp for Sick Children
BELFAST
CO. ANTRIM
BT12 6BE

01 Oct 01

Dear Dr Taylor

RE: PATIENT: RF AGE: 9
PATIENT ID NUMBER: 476454
ADR Reg. No: 433167

Thank you for sending us a suspected adverse drug reaction report on the above patient. A copy is enclosed for your records. If additional information becomes available about this report it would be most helpful if you could send this to us, quoting the above reference number.

Your contribution to the UK's Adverse Drug Reactions Reporting Scheme is greatly appreciated. This provides an important early warning of previously unrecognised adverse effects which allows us to take appropriate action to improve the safe use of medicines.

Yours sincerely,

Dr J M Raine
Director - Post Licensing Division

OTHER DRUGS (including self-medication & herbal remedies)

Did the patient take any other drugs in the last 3 months prior to the reaction? (Yes) / No

If *yes*, please give the following information if known:

Drug (Brand, if known)	Route	Dosage	Date started	Date stopped	Prescribed for
CEFOTAXIME	2gm	IV	07/6/01	10/6/01	APPENDICITIS
METRONIDAZOLE					"

Additional relevant information e.g. medical history, test results, known allergies, rechallenge (if performed), suspected drug interactions. For congenital abnormalities please state all other drugs taken during pregnancy and the date of the last menstrual period.

POST-OP APPENDICECTOMY. - URea + ELECTROLYTES NOT MONITORED FOR 48 hours
- SYMPTOMATIC — SEIZURES
Na^+ 118

433167

REPORTER DETAILS

Name and Professional Address: DR BOBS TAYLOR
PAEDIATRIC ICU, 180 FALLS ROAD
BELFAST

Post code: BT12 6BE Tel No: 02890487303

Speciality: PAEDIATRIC ANAESTHESIA

Signature: [signature] Date: 25/9/01

CLINICIAN (if not the reporter)

Name and Professional Address:

Post code:

Tel No: Speciality:

If you would like information about other adverse reactions associated with the suspected drug, please tick this box ☑

Send to Medicines Control Agency, CSM FREEPOST, LONDON SW8 5BR or if you are in one of the following NHS regions:

to CSM Mersey, FREEPOST, Liverpool L3 3AB
or CSM Northern, FREEPOST 1085, Newcastle upon Tyne NE1 1BR
or CSM West Midlands, FREEPOST SW2991, Birmingham B18 7BR
or CSM Wales, FREEPOST, Cardiff CF4 1ZZ

COMMITTEE ON SAFETY OF MEDICINES

In Confidence

M.C.I.A.I

MEDICINES CONTROL AGENCY

SUSPECTED ADVERSE DRUG REACTIONS

P2-

If you are suspicious that an adverse reaction may be related to a drug or combination of drugs please complete this Yellow Card. Please report all adverse reactions for black triangle (▼) drugs and only serious adverse reactions for established drugs. For additional reporting advice please see page 10 of the BNF or the MCA website www.open.gov.uk/[illegible].htm. Do not be put off reporting because some details are not known.

PATIENT DETAILS Patient Initials: R.F. Sex: M / F Weight if known (kg): 25

Age (at time of reaction): 9 Identification (Your Practice / Hospital Ref.)*: 476454

SUSPECTED DRUG(S)

Give brand name of drug and batch Number if known: (FLUIDS I.V. (HYPONATRAEMIA → COMA) 433167

Route	Dosage	Date started	Date stopped	Prescribed for
0.18% NaCl/4% Glucose I.V.	80mls/hour	7/6/01	9/6/01	Post-OP A

SUSPECTED REACTION(S)

Please describe the reaction(s) and any treatment given:

HEADACHES → VOMITING → SEIZURES → COMA → BRAINSTEM DEATH (Not IIB)

Date reaction(s) started: 7/6/2001 Date reaction(s) stopped: 10/6/01

Do you consider the reaction to be serious? (Yes) No

If *yes*, please indicate why the reaction is considered to be serious (please tick all that apply):

Patient died due to reaction	☒	Involved or prolonged inpatient hospitalisation	☐
Life threatening	☐	Involved persistent or significant disability or incapacity	☐
Congenital abnormality	☐	Medically significant; please give details:	

Outcome

Recovered	☐
Recovering	☐
Continuing	☐
Other	☒

COMMITTEE ON SAFETY OF MEDICINES
1 OCT 2001

* This is to enable you to identify the patient in any future correspondence concerning this report

Please attach additional pages if necessary

Intravenous fluid and electrolytes are given to maintain or restore body composition to normal when it is not possible or desirable to use the enteral route. Fluid and electrolytes are given as maintenance and/or replacement therapy.

MAINTENANCE THERAPY

For this purpose fluid and electrolytes (chiefly Na^+, Cl^- and K^+) are given together with glucose to replace usual normal losses of water and electrolytes in quantities to maintain correct body composition. In infants and children, maintenance fluid and electrolyte requirements vary as a function of metabolic activity. The following normal requirements are derived from the relationship that exists between body weight and metabolic rate and may be used outside the neonatal period. The glucose requirement is that needed to minimise gluconeogenesis from amino acids obtained as substrate from muscle breakdown.

It is usual to meet these requirements by using a standard solution. For example, glucose 4%with NaCl 0.18% given in the volumes suggested below meets the fasting fluid, saline and glucose requirements for the purposes of most children under basal conditions. Solutions containing 20mmol/L of KCl also meet usual potassium requirements when given in the suggested volumes. Adjustments will need to be made if there is an inability to excrete fluids or electrolytes, excessive renal loss or continuing extra-renal losses. The exact requirements depend upon the nature of the situation and types of losses incurred.

Fluid requirements/24 hours

Body weight <3kg	
3–10kg For each kg between 10–20 kg For each kg over 20kg	
Sodium requirement/24 hours	
Potassium requirement/24 hours	
Glucose requirement/24 hours	

REPLACEMENT THERAPY

In general, initial intravenous replacement fluid is required if >10% dehydrated or if 5–10% dehydrated and oral and enteral rehydration is not tolerated or possible. Oral rehydration is adequate if tolerated in the majority of those <10% dehydrated. Subsequent fluid and electrolyte requirements are determined by clinical assessment of fluid balance, including measurement of on going excessive renal and extra renal losses, and measurement of plasma electrolytes, bicarbonate and glucose together with calcium, phosphate and magnesium where appropriate. In the UK oral rehydration is under used and severe dehydration over diagnosed clinically.

Intravenous sodium is commonly given as a component of maintenance and replacement therapy. It may be given as saline for initial fluid bolus in acute fluid loss and to replace ongoing gastrointestinal losses from the upper gastrointestinal tract. For maintenance and continuing replacement therapy it is most usually given in combination with glucose and other electrolytes, the exact strength depending on the clinical situation. Other uses include promotion of saline diuresis in the management of some poisoning, as a vehicle for reconstitution and administration of intravenous medications and to maintain patency of arterial/CVP/other lines. It must be given with caution as sodium overload may be easily produced. Particular care is needed in those with renal insufficiency, cardiac failure, other cardio-respiratory disease, hepatic cirrhosis and those receiving glucocorticosteroids.

Solutions available

- ☐ Sodium chloride 0.45% – Na^+ 75mmol/L; Cl^- 75mmol/L; osmolarity 154mOsm/L
- ☐ Sodium chloride 0.9% – Na^+ 150mmol/L; Cl^- 150mmol/L; osmolarity 308mOsm/L
- ☐ Sodium chloride 1.8% – Na^+ 300mmol/L; Cl^- 300mmol/L; osmolarity 616mOsm/L

Other infusion fluids containing sodium – see table. Extreme care must be taken if giving sodium chloride in solutions stronger than 0.9% and there must be specific indications for their administration.

MEDICINES FOR CHILDREN 1ST EDITION

Intravenous potassium is commonly given as a component of maintenance and replacement intravenous therapy and in the correction of severe hypokalaemia where oral potassium is insufficient or not possible. For maintenance and continuing replacement therapy it is most usually given in combination with glucose and other electrolytes. Whilst it is often added to glucose/saline solutions, ready-prepared infusion fluid containing these together with potassium may be adequate in many cases and their use may decrease the number of errors in its administration. The quantity required is calculated according to usual maintenance requirements with adjustment for any deficit and ongoing loss. As in all cases, the situation must be monitored by clinical assessment and measurement of plasma potassium levels. Potassium should not be given in established hyperkalaemia and should only be given with extreme caution and close monitoring where there is renal impairment or coincidental administration of drugs which may cause hyperkalaemia. Potassium should only be given as a slow infusion and it is recommended that the concentration of the solution should not exceed 40 mmol of potassium per litre. ECG monitoring should be used where there is concern regarding hypo or hyperkalaemia, together with frequent measurement of plasma potassium.

Solutions available

- ☐ Strong potassium chloride (15%) – K^+ 2mmol/mL; Cl^- 2mmol/mL

Strong KCl should be diluted with not less than 50 times its volume of compatible intravenous fluid, mixed well and given as a slow infusion. Other infusion fluids containing potassium – see table (page G50).

Intravenous glucose is given in maintenance and replacement therapy to minimise gluconeogenesis and is also used specifically in the treatment of hypoglycaemia. For maintenance and continuing replacement therapy it is most usually given in combination with other electrolytes. In hypoglycaemia an initial bolus of 0.2g/kg of glucose given as 2mL/kg of 10% glucose over 2-3 minutes is recommended.

Solutions available

- ☐ Glucose 5 % – osmolarity 278mOsm/L
- ☐ Glucose 10 % – osmolarity 555mOsm/L
- ☐ Glucose 20 % – osmolarity 1110mOsm/L
- ☐ Glucose 40 % – osmolarity 2220mOsm/L
- ☐ Glucose 50 % – osmolarity 2775mOsm/L

Other infusion fluids containing glucose – see below. Solutions stronger than 10% glucose should NOT be used except in exceptional circumstances because of the dangers of hyperosmolality.

Intravenous bicarbonate is used in the management of metabolic acidosis. In most circumstances metabolic acidosis is secondary to hypoxia/ hypovolaemia/ hypoperfusion and treatment of any underlying condition with appropriate fluid replacement and cardiovascular support will improve or correct acidosis.

Bicarbonate may be given to correct the acid-base imbalance in severe metabolic acidosis or in specific circumstances, e.g. renal tubular acidosis. In the acute situation e.g. cardiac arrest, an initial bolus of 1mmol/kg may be given as a slow bolus if required (1mL/kg of 8.4% sodium bicarbonate or equivalent volume of 2mL/kg of 4.2% sodium bicarbonate). The volume required of 8.4% sodium bicarbonate to correct a metabolic acidosis = base deficit x body weight (kg) x 0.3. Half this volume is usually given initially by slow infusion and progress monitored by clinical assessment and measurement of plasma pH or H^+ concentration before giving the remaining half. The standard sodium bicarbonate solutions available are hypertonic. Venous damage or thrombophlebitis may occur at the site of infusion. Continued administration can lead to hypernatraemia and overdosage of sodium bicarbonate may cause diarrhoea, nausea and vomiting, hyperpnoea and convulsions.

Solutions available

- ☐ Sodium bicarbonate 1.26% – Na^+ 150mmol/L; HCO_3^- 150mmol/L; – osmolarity 300mOsm/L
- ☐ Sodium bicarbonate 4.2% – Na^+ 500mmol/L; HCO_3^- 500mmol/L; – osmolarity 1000mOsm/L
- ☐ Sodium bicarbonate 8.4% – Na^+ 1000mmol/L; HCO_3^- 1000mmol/L; – osmolarity 2000mOsm/L

Lactate was previously used in the management of metabolic acidosis but is now not recommended because of the risk of producing lactic acidosis, especially in those with hepatic impairment or poor tissue perfusion. Any solutions containing lactate should not be given to those with impairment of hepatic function.

MF. CHLDRN 2003 3rd Ed

Intravenous fluid therapy

INTRAVENOUS FLUID THERAPY

Intravenous fluid and electrolytes are given to maintain or restore normal body composition when it is not possible or desirable to use the enteral route. Fluid and electrolytes are given as maintenance and/or replacement therapy. In each situation, it is necessary to be cautious as both hyper and hyponatraemia can occur.

Caution

Though uncommon, dilutional hyponatraemia is often an unheralded, but potentially fatal condition. It is due to complex neuro-endocrine mechanisms that can occur in children with a variety of conditions especially in the postoperative period. It is characterised by oliguria and a rapid fall in serum sodium concentration leading to cerebral oedema causing seizures and/or coning of the medulla oblongata. Slow correction and careful monitoring are required to prevent serious morbidity.

To prevent dilutional hyponatraemia and sodium overload, it is recommended that:

1 Body weight be accurately measured or estimated by a professional with substantial paediatric experience. The estimation of body weight can be made using the child's age; Body weight (kg) = (AGE+4) x 2. This weight should be plotted on a centile chart as a crosscheck. If the weight is beyond the 3rd or 97th centile range then the weight must be re-examined.

2 Fluid administration should reflect the composition of fluid lost or in deficit, especially as regards sodium content.

3 A baseline blood sample be sent for serum sodium, potassium, urea and blood sugar estimation. Regular and frequent serum sodium and blood sugar estimation is required and should be documented. This will usually mean at least one specimen per day in general maintenance situations, and at least two blood samples daily in the postoperative period and in deficit and significant ongoing loss situations. An indwelling heparinised cannula or capillary sample will avoid sampling difficulties in the anxious child or those with poor veins. Blood samples must not be taken from the same limb as the intravenous infusion.

4 An experienced doctor must assess fluid balance daily and take appropriate action to correct fluid loss or retention. Measurement of urinary sodium, potassium and urea should be helpful.

5 A child with acute hyponatraemia (<130 mmol/L) needs urgent referral to a hospital with paediatric high dependency facilities (asymptomatic hyponatraemia).

MAINTENANCE THERAPY

For this purpose fluid and electrolytes (chiefly sodium [Na^+], chloride [Cl^-] and potassium [K^+]) are given together with glucose to replace the normal losses of water and electrolytes in quantities needed to maintain correct body composition. In infants and children, maintenance fluid and electrolyte requirements vary as a function of metabolic activity. The following normal requirements are derived from the relationship that exists between body weight and metabolic rate and may be used outside the neonatal period. The glucose requirement is that needed to minimise gluconeogenesis from amino acids obtained as substrate from muscle breakdown.

It is usual to meet these requirements by using a standard solution. For example, glucose 4% with NaCl 0.18% given in the volumes suggested below meets the fasting fluid, saline and glucose requirements for the purposes of most children under basal conditions. Solutions containing 20mmol/L of potassium chloride (KCl) also meet usual potassium requirements when given in the suggested volumes. Adjustments will need to be made if there is an inability to excrete fluids or electrolytes, excessive renal loss or continuing extra-renal losses. The exact requirements depend upon the nature of the clinical situation and types of losses incurred. See cautionary note about dilutional hyponatraemia above.

Fluid requirements/24 hours

Body weight <3kg	150mL/kg (start at 40–60mL/kg if newborn)
3–10kg For each kg between 10–20 kg For each kg over 20kg	100mL/kg add 50mL/kg add 20mL/kg to maximum of 2000mL in adult female and 2500mL in adult male
Sodium requirement	3mmol/kg
Potassium requirement	2mmol/kg
Glucose requirement	2.4–4.8g/kg

Intravenous fluid therapy continued

REPLACEMENT THERAPY

In general, initial intravenous replacement fluid is required if >10% dehydrated or if 5-10% dehydrated and oral and enteral rehydration is not tolerated or possible. Oral rehydration is adequate if tolerated in the majority of those <10% dehydrated. Subsequent fluid and electrolyte requirements are determined by clinical assessment of fluid balance, including measurement of ongoing excessive renal and extra renal losses, and measurement of plasma electrolytes, bicarbonate and glucose together with calcium, phosphate and magnesium where appropriate. In the United Kingdom oral rehydration is underused and severe dehydration overdiagnosed clinically.

Intravenous sodium is commonly given as a component of maintenance and replacement therapy. It may be given as NaCl 0.9% for initial fluid bolus in acute fluid loss and to replace ongoing gastrointestinal losses from the upper gastrointestinal tract. For maintenance and continuing replacement therapy it is usually given in combination with other electrolytes and glucose, the exact strength depending on the clinical situation. Other uses include promotion of saline diuresis in the management of some poisoning, as a vehicle for reconstitution and administration of intravenous medications and to maintain patency of arterial/venous catheters. It must be given with caution as sodium overload may be easily produced. Particular care is needed in those with renal insufficiency, cardiac failure, other cardio-respiratory disease, hepatic cirrhosis and those receiving glucocorticoids. Conversely, hyponatraemia with serious consequences can occur if maintenance and replacement fluids do not meet sodium requirements. See cautionary note about dilutional hyponatraemia above.

Solutions available

- ☐ Sodium chloride 0.45% – Na^+ 75mmol/L; Cl^- 75mmol/L; osmolarity 154mOsm/L
- ☐ Sodium chloride 0.9% – Na^+ 150mmol/L; Cl^- 150mmol/L; osmolarity 308mOsm/L
- ☐ Sodium chloride 1.8% – Na^+ 300mmol/L; Cl^- 300mmol/L; osmolarity 616mOsm/L

Other infusion fluids containing sodium – see table.

Extreme care must be taken if giving sodium chloride in solutions stronger than 0.9% and there must be specific indications for their administration.

Intravenous potassium is commonly given as a component of maintenance and replacement intravenous therapy and in the correction of severe hypokalaemia where oral potassium is insufficient or not possible. For maintenance and continuing replacement therapy it is most usually given in combination with glucose and other electrolytes. Whilst it is often added to glucose/saline solutions, ready-prepared infusion fluid containing these together with potassium may be adequate in many cases and their use may decrease the number of errors in its administration. The quantity required is calculated according to usual maintenance requirements with adjustment for any deficit and ongoing loss. As always, the situation must be monitored by clinical assessment and measurement of plasma potassium concentration. Potassium should not be given in established hyperkalaemia and should only be given with extreme caution and close monitoring where there is renal impairment or coincidental administration of drugs which may cause hyperkalaemia. Potassium should only be given as a slow infusion and it is recommended that the concentration of the solution should not exceed 40mmol of potassium per litre. ECG monitoring should be used where there is concern regarding hypo or hyperkalaemia, together with frequent measurement of plasma potassium.

Solutions available

- ☐ Strong potassium chloride (15%)* – K^+ 2mmol/mL; Cl^- 2mmol/mL
- ☐ Strong KCl should be diluted with not less than 50 times its volume of compatible intravenous fluid, mixed well and given as a slow infusion. Where possible, compounding should be performed in a pharmacy. For other infusion fluids containing potassium – see table.

Intravenous glucose is given in maintenance and replacement therapy to minimise gluconeogenesis and is also used specifically in the treatment of hypoglycaemia. For maintenance and continuing replacement therapy it is most usually given in combination with other electrolytes. In hypoglycaemia an initial bolus of 200mg/kg of glucose given as 2mL/kg of 10% glucose over 2-5 minutes is recommended.

Solutions available

- ☐ Glucose 5 % – osmolarity 278mOsm/L
- ☐ Glucose 10 % – osmolarity 555mOsm/L
- ☐ Glucose 20 % – osmolarity 1110mOsm/L

☐ Glucose 40 % – osmolarity 2220mOsm/L
☐ Glucose 50 % – osmolarity 2775mOsm/L

For other infusion fluids containing glucose – see below. Solutions stronger than 10% glucose should NOT be used except in exceptional circumstances because of the dangers of hyperosmolarity.

Intravenous bicarbonate is used in the management of metabolic acidosis. In most circumstances metabolic acidosis is secondary to hypoxia/hypovolaemia/hypoperfusion and treatment of any underlying condition with appropriate fluid replacement and cardiovascular support will improve or correct acidosis.

Bicarbonate may be given to correct the acid-base imbalance in severe metabolic acidosis or in specific circumstances, e.g. renal tubular acidosis. In the acute situation e.g. cardiac arrest, an initial bolus of 1mmol/kg may be given as a slow bolus if required (1mL/kg of 8.4% sodium bicarbonate or 2mL/kg of 4.2% sodium bicarbonate). The volume required of 8.4% sodium bicarbonate to correct a metabolic acidosis = base deficit x body weight (kg) x 0.3 for children other than newborns (x 0.5-0.6 in premature neonate; x 0.4 in term neonates). Half this volume is usually given initially by slow infusion and progress monitored by clinical assessment and measurement of plasma pH or H^+ concentration before giving the remaining half. The standard sodium bicarbonate solutions available are hypertonic. Venous damage or thrombophlebitis may occur at the site of infusion, and extravasation can cause severe tissue injury. Continued administration can lead to hypernatraemia and overdosage of sodium bicarbonate may cause diarrhoea, nausea and vomiting, hyperpnoea and convulsions.

Solutions available
☐ Sodium bicarbonate 1.26% – Na^+ 150mmol/L; $HCO3^-$ 150mmol/L; – osmolarity 300mOsm/L
☐ Sodium bicarbonate 4.2% – Na^+ 500mmol/L; $HCO3^-$ 500mmol/L; – osmolarity 1000mOsm/L
☐ Sodium bicarbonate 8.4% – Na^+ 1000mmol/L; $HCO3^-$1000mmol/L; – osmolarity 2000mOsm/L

THAM (tris-hydroxymethyl aminomethane trometamol) is an organic buffer used for correction of metabolic acidosis. It is an alternative to sodium bicarbonate when there is concern about carbon dioxide retention, hypernatraemia or renal impairment. THAM is available as 3.6% or 7.2% solution, and should be used as 3.6% solution when given intravenously. 1mL of 7.2% solution (2mL of 3.6% solution) is equivalent to 1mmol of bicarbonate ion.

Lactate was previously used in the management of metabolic acidosis but is now not recommended because of the risk of producing lactic acidosis, especially in those with hepatic impairment or poor tissue perfusion. Any solutions containing lactate should not be given to those with impairment of hepatic function.

Solutions available
☐ Sodium lactate M/6 – Na^+ 167 mmol/L; lactate 167 mmol/L

For other infusion fluids, which contain lactate – see table.

Combined intravenous fluids

	Na^+ (mmol/L)	Cl^- (mmol/L)	K^+ (mmol/L)	Other (mmol/L)	Osmolarity †(mOsm/L)	Energy (kcal/L)
Glucose 2.5%/NaCl 0.45%	75	75	–	–	293	100
Glucose 4%/NaCl 0.18%	30	30	–	–	263	160
Glucose 5%/NaCl 0.45%	75	75	–	–	432	200
Glucose 5%/NaCl 0.9%	150	150	–	–	586	200
Glucose 10%/NaCl 0.18%	30	30	–	–	567	400
Glucose 10%/NaCl 0.45%	75	75	–	–	660	400
Glucose 5%/KCl 0.15%	–	20	20	–	318	200
Glucose 5%/KCl 0.2%	–	27	27	–	332	200
Glucose 5%/KCl 0.3%	–	40	40	–	358	200
Glucose 4%/NaCl 0.18% with KCl 0.15%	30	50	20	–	322	160
Glucose 4%/NaCl 0.18% with KCl 0.2%	30	57	27	–	336	160

Combined intravenous fluids continued

	Na^+ (mmol/L)	Cl^- (mmol/L)	K^+ (mmol/L)	Other (mmol/L)	Osmolarity †(mOsm/L)	Energy (kcal/L)
Glucose 4%/NaCl 0.18% with KCl 0.3%	30	70	40	–	362	160
Glucose 5%/NaCl 0.45% with KCl 0.15% (Alder Hey Special K)	75	95	20	–	426	200
NaCl 0.9%/KCl 0.15%	150	170	20	–	340	0
NaCl 0.9%/KCl 0.2%	150	177	27	–	354	0
NaCl 0.9%/KCl 0.3%	150	190	40	–	380	0
Ringer's – compound sodium chloride	147.5	156	4	Calcium – 2	310	0
Hartmann's – compound sodium lactate	131	111	5	Lactate – 29 Calcium – 2	278	0
Half Hartmann's with glucose 5%	66	56	3	Lactate – 14 Calcium – 1	418	200
Darrow's – lactated potassic saline	121	103	35	Lactate – 53	312	0

†Osmolarity may differ slightly depending on brand. The figures quoted are mainly for Baxter products

COLLOIDS
These are used for plasma replacement or expansion. They may be natural products like human albumin solution (HAS) and fresh frozen plasma (FFP), or synthetic: based on gelatin like Gelofusine® (succinylated gelatin) and Haemaccel™ (urea-linked gelatin); or hydroxyethyl starches (HES) like Pentastarch™; or dextrans. HAS and gelatins are essentially plasma substitutes, whereas hydroxyethyl starches and dextrans are true plasma expanders – they produce an increase in plasma volume greater than the volume of colloid infused. A meta-analysis of clinical trials has suggested that use of HAS may be associated with increased mortality across all age ranges; a more recent review of studies in newborns could not confirm this finding. NaCl 0.9% is often an effective crystalloid alternative for rapid volume expansion in resuscitation, sepsis and dehydration. There is no justification for use of FFP as a plasma substitute unless there is also a coagulopathy.

4.5% HAS has been the standard fluid used in neonates and infants, but it is expensive and there is a small risk of anaphylaxis or infection. More recently, there has been concern about possible variant CJD (vCJD) transmission from UK sources of HAS. A synthetic gelatin is a cheap and safe alternative to 4.5% HAS. A succinylated gelatin is preferable to a urea-linked gelatin as the reported anaphylactoid reaction rate is lower (0.05% and 0.1% respectively). Dextrans are not routinely indicated because of increased side-effects compared to gelatins and hydroxyethyl starches.

Hydroxyethyl starches (HES) have anaphylactoid reaction rates similar to gelatins but as HES are true plasma expanders the risk of fluid overload is greater. For this reason, HES are probably best restricted to an intensive care setting.

Liver

Acute hepatitis. This is often due to hepatitis A virus infection but it may be the first presentation of serious liver disease. Serology, liver function tests and coagulation studies should be undertaken in all cases. No specific treatment is necessary in the vast majority of cases. All cases not due to hepatitis A virus or where coagulation studies are abnormal should be referred for further investigation.

Hepatitis B. Hepatitis B infection rarely causes acute hepatitis in childhood but may result in chronic carriage. Chronic infection and carriage is more likely to occur the younger the age at which the infection is acquired. It is usually asymptomatic in childhood but, if untreated, carries a high lifetime risk of progression to cirrhosis and hepatocellular carcinoma.