THE ROYAL HOSPITALS

THE ROYAL BELFAST HOSPITAL FOR SICK CHILDREN

30th ~~November 1995~~

Dr. G. ~~Murnaghan~~,
~~Director of Medical Administration~~,
~~King Edward Building~~,
RVH.

Statement of RH Taylor ~~MB~~, FFARCS I
Consultant Paediatric Anaesthetist
c/o RBHSC

Dear Dr. ~~Murnaghan~~,

re: ~~**Adam Strain D.O.B. 4.8.91 - Hosp No. 364377**~~

On the 27th November 1995 at 06.45 am I was the Consultant Paediatric Anaesthetist on duty for the Royal Belfast Hospital for Sick Children. I commenced a general anaesthetic for a kidney transplant on a 4 year old boy known to me as Adam Strain. He was in polyuric renal failure as the result of congenital posterior urethral valves and had been receiving continuous peritoneal dialysis. He had been admitted to RBHSC on Sunday 26th Nov 1995 in preparation for the transplant. I was made aware of the preoperative problems of fluid administration, that he usually received night feeds and that iv fluids could not be given 2 hours prior to surgery so I had permitted clear gastric fluids to be given up to the last possible moment. I encountered no difficulties following his arrival in theatre accompanied by his mother.

He weighed 20 kgs. General anaesthesia was induced uneventfully using thiopentone 125 mg, atropine 0.3 mg and atracurium 10 mg given by a 25G butterfly needle in his right antecubital fossa with his mother cuddling him. I.v. access, arterial access and a central venous catheter were all placed without undue difficulty and a lumbar epidural was sited under sterile technique to provide pain relief during and after the procedure.

I administered iv fluids as is usual, and calculated to correct his fluid deficit, supply his maintenance, and replace operative losses. Crystalloid fluids (500 ml bags of 0.18 NaCl in 4% glucose x 3, and Hartmanns 500 mls over 4 hours) were continued to provide maintenance and supply sufficient fluid for the native polyuric kidneys. As there was a substantial ongoing blood loss from the surgery colloid fluids (HPPF) and eventually packed red blood cells were given. His haemoglobin at the start of the procedure was 10.5 g/dl and fell to an estimated 6.1 g/dl during the case and was 10 g/dl at the end. The nurses were asked to weigh blood soaked swabs during

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the case so that they could be more correctly assessed. There was 328 mls of blood loss in the swabs, 500 mls of blood in the suction bottle and a unknown amount in the towels and drapes. I estimated this to be about 300 mls but they were heavily soaked. Thus the total blood loss I estimated to be 1128 mls. The replacement for this included 2 packed cells (180-250 mls each) and 1000 mls of HPPF. The infusion of fluids was titrated against the CVP and BP to ensure that the blood volume was more than adequate to permit maximum perfusion of the donor kidney. This process was complicated by the fact that the donor kidney did not appear well perfused after an initial period of apparently good kidney perfusion.

A low dose dopamine infusion had been commenced near the start of the case to improve the blood flow of the donor organ. The pulse rate, CVP and arterial blood pressure gave me no cause for concern throughout the case, and a blood gas at 09.30 am confirmed good oxygenation and no sign of acidosis or any indication of problems. In view of the CVP, heart rate and BP I did not consider the fliuds to be either excessive or restrictive. Indeed I regarded the fluids to be appropriate and discussed this with other doctors present in the theatre.

At the end of the case I reversed the neuromuscular block with neostigmine and anticipated the child awakening. When there was no sign of this I examined his pupils and found them to be fixed and dilated. I became extremely concerned that he had suffered brain stem injury so I transferred him to the PICU for further ventilation of his lungs and assessment. In the PICU hyperventilation and mannitol was administered and iv fluids restricted to permit fluid to be drawn out of the oedematous spaces. Along with Dr Savage I spoke to Adams' mother and offered my sympathy for the loss of her child but could not supply her with a clear explanation of what had happened to Adam.

I accompanied Adam to the CT-scan room later on that day and was informed by the neuro-radiologist that he had gross cerebral oedema and herniation of his brain.

I remain extremely perplexed and concerned that this happened to Adam and cannot offer a physiological explanation for such severe pulmonary and cerebral oedema in the presence of normal monitoring signs.

Yours sincerely,

R.H. Taylor, MB, FFARCSI.,
Consultant Paediatric Anaesthetist.

c.c. Dr. M. Savage, Consultant Nephrologist, RBHSC
Dr. J. Gaston, Clinical Director ATICS,RVH

~~Dear Dr Murnaghan~~

I wish to append my previous letter to you in regard to Adam Strain to take account of the post-mortem, which I attended, and other details. As previously mentioned I was very familiar with this child who presented complex management problems for renal transplantation.

I wish to make the following observations :-

1. **Polyuric renal failure.** This required great attention to the details of calculating Adam's fluid requirements. It was usual to give this child 1,500 mls of food/fluid overnight to maintain his growth milestones and to compensate for polyuria from his native kidneys. This was given via his gastrostomy button at night as he slept. The delivery of such large quantities of food would have profound effects on his metabolism (eg. sugar, insulin), normally we fast at night. It was therefore necessary to interfere as little as possible with his "normal" fluids.

I had discussed his preoperative fluids with Dr. Savage (Consultant Paediatric Nephrologist) and Mr. Brown (Consultant Paediatric Surgeon) and had decided that "usual" quantities of oral (or gastrotomy) fluids (Diaoralyte=*0.18 NaCl/4% Glucose solution*) should be administered up to the last possible moment (2 hours before surgery) to minimise the likelihood of dehydration and hypoglycaemia. A great amount of consideration was given to maintaining this "normality" during the operation.

He had multiple previous anaesthetics but was otherwise well. His cardio-respiratory status *(normotensive)* and neurological status were normal. FBP, Coagulation Screen and U & E were all within acceptable limits Preoperative medication included bicarbonate and calcium supplements, Keflex & erythropoietin.

2. **Difficult i.v. access.** The paediatric registrar had attempted on several occasions to erect i.v. fluids to further prevent dehydration prior to surgery. This proved impossible and the child came to theatre without iv access. I gained i.v .access on the first attempt and administered a "routine" paediatric anaesthetic induction with thiopentone 125 mg, atropine 0.3 mg and atracurium 10 mg.

A secure iv cannula was then placed on the first attempt as was intubation of the trachea and a right radial arterial line. A central venous line was attempted on 3 occasions in the left subclavian, once in the left internal jugular and then successfully in the right subclavian. With a child in the head-down position failure to locate the subclavian vein suggests that the child is dehydrated. A lumbar epidural was then placed without any difficulty and "routine" drugs administered (bupivacaine 0.25% and fentanyl 5 mcg/kg). This enables minimal volatile anaesthetics to be given during the case and provides excellent postoperative pain

relief. There is other evidence that it may prevent or lessen the "stress response" which causes fluid retention (decreased urine output).

3. **Haemodynamic considerations.** On measuring the CVP the initial pressure reading was 17 mmHg. There were both cardiac and respiratory patterns to the waveform confirming correct intravascular placement. However, from the pressure reading I concluded that the tip of the line was not in close relation to the heart (later confirmed by X-Ray). I therefore used the initial reading (17 mmHg) as a baseline.

The systolic BP at this time was 85-90 mmHg. This is low, but within the normal range for a child of this age without pre-existing hypertension. I therefore concluded that the child required more i.v. fluid to increase the CVP and BP from this baseline level.

At 20 kg Adam had a calculated blood volume of 1600 mls and calculated fluid requirement of 60 ml/hr. However he would "normally" receive a sugar solution at 150 mls/hour. Thus I gave him the deficit of fluid 300-500 mls plus his on-going requirements (150 mls/hour). During the following 30-40 minutes his CVP increased to 20-21 mmHg, corresponding to an **actual** increase of 3-4 mmHg. This is a relatively mild increase in CVP and is necessary in such cases to provide the child's tissues with sufficient water, sugar and electrolytes. The heart rate also gives evidence of fluid status. Although this is "blocked" by the administration of atropine at the start of the case there was a gradual decrease throughout the procedure (120-100 beats/minute) consistent with the clearance of atropine and gradual rehydration. All the more important in this case is the need to avoid **dehydration** that will deprive the donor kidney of sufficient fluid to produce urine. There are several feedback systems in the body which act to retain fluid (ADH, renin-angiotensin ANP etc). These decrease urine output, thus it is necessary to prevent these systems becoming activated for successful transplants.

The systolic BP increased, in accordance with the CVP, and was stable at around 100 mmHg throughout most of the case. It is vital to provide sufficient BP to perfuse the vital organs and the donor kidney. A low-dose dopamine infusion (5 mcg/kg/min) was commenced near the beginning of the case to provide a renal vaso-dilating effect. This dose has minimal (if any) systemic effects and is regarded as routine practice in renal transplantation in centres where I have worked.

The haemodynamics (HR, CVP, BP, SaO_2) were remarkably stable (*see print-out*) despite the ongoing blood loss (>1211 mls *almost a full blood volume*) which I discussed in my earlier letter. The sudden "increase" in CVP to 28 mmHg occurred when the table was raised 5-6 inches for surgical reasons but the transducer was attached to a drip-stand and thus an "artefact" occurred. When the transducer was "re-zeroed" to take account of the differences in levels the pressure returned to the previous

"stable" range (20-22 mmHg) consistent with no net increase in fluid load or circulating blood volume. When the child was taken to the PICU and his head placed in the midline his CVP was 10-12 mmHg suggesting that in theatre, with his head rotated there was some mild venous occlusion of the great veins.
There are two small increases in the systolic BP at around 10.00 am corresponding to two small boluses of dopamine (1 mcg/kg). The rationale for this was to increase the perfusion pressure (without fluid challenge) to the donor kidney, which at that stage was not "looking good" and not producing urine.

4. **Intraoperative Fluids.** This is the area requiring the greatest consideration and I keep returning to it. It is my practice, and teaching that fluids must be carefully calculated in relation to the child's size and requirements. Furthermore Colloid or Hartmanns is preferred to Dextrose solution to replace blood losses.

In this case HPPF and Hartmanns (500 mls) were given for volume expansion (to raise and maintain the CVP 3-4 mmHg above baseline). The blood loss (>1211 mls) was carefully balanced by administration of colloid (HPPF, 1000mls and 2 units Packed Cells). This is also confirmed by observing the haemoglobin concentration. The initial haemoglobin was 10.5 g/dl, fell to 6.1 during the case, confirming significant blood loss, and was restored by careful calculation to 10.1 at the end of the procedure.

The glucose containing crystalloid was given over 4 hours (1,500 mls 0.18 NaCl/4% Glucose), again carefully calculated to restore the deficit (>300 mls), supply maintenance 150 ml/hr (in view of the polyuria) and insensible losses (large area of abdominal cavity exposed). The calculation was complicated and included many subjective factors not easily measured (skin colour, skin mottling, peripheral perfusion, pulse volume, pulse response to fluid bolus, etc.) which become "natural" for an anaesthetist. In the final analysis the blood sugar gives a reliable indication of the quantity of glucose solution given. Since the blood sugar at the end of this case was 4 mmol/l then there was not an excess of this type of solution given. In fact, if less had been given then there would have been a danger of HYPOglycaemia, a much more serious condition in early childhood.

~~So what did happen~~?

can not explain what has happened

I ~~do not know~~. However I can explain several things that could not have happened.

~~Cause of death.~~

The cerebral oedema was gross and there was X-Ray evidence of pulmonary interstitial oedema (No cardiomegaly). Despite aggressive

measures to reduce brain swelling, (mannitol x 2 , hyperventilation, fluid restriction) he was confirmed brain stem dead.

~~Cardiac Arrest?~~

There were no intraoperative "events" which could account for cerebral oedema eg, hypoxia, hypotension, arrest or anaphylaxis (*see print out*). There were no external signs of a suffusion or "hanging" injury (no facial swelling, no petechiae, no sub-conjunctival haemorrhages) causing fluid to sequestrate in the brain. Also the presence of pulmonary oedema is against such a notion. Also there were no associated signs of raised Intracranial Pressure (ICP) such as Hypertension & Bradycardia. The heart rate "drifted" lower over the first hour (120-100 beats per minute--*see print-out*)of the operation consistent with the effects of atropine. Thereafter the heart rate remained stable until towards the end of surgery when neuromuscular reversal was given (neostigmine/glycopyrollate).

~~Equipment?~~

I am familiar with all the anaesthetic equipment used, which was checked prior to the case. Records show they were recently and routinely serviced. As one of the paediatric anaesthetists working in the RBHSC my contribution to the vital aspect of equipment safety had been to order the purchase and installation of oxygen monitors (FiO_2), capnographs (CO_2), equipment log-books and printed records of actual monitoring measurements.

If there had been an equipment malfunction, (and there is NO evidence in this case) then back-up systems would show it. For instance an arterial blood gas at 09.30 confirms that both the CO_2 and Oxygen monitors (SaO_2) were accurate in this case. If the BP was lower than that displayed (malfunction) then the blood gas would have indicated a metabolic acidosis (hypo-perfusion of tissues). In fact the blood gas did NOT indicate a metabolic acidosis confirming that the BP was adequate for full tissue perfusion. The heart rate and BP are also consistent between the theatre and PICU monitors in this case.

~~Fluids?~~

Conditions likely to precipitate "osmotic" fluid shifts were not present. Adam's preoperative albumin was 38 mmol/l, and other electrolytes were in an acceptable range. Although blood sugar was not measured during the case the final blood sugar was 4 mmol/l. There is no reason to believe that it was much different from this during the case as he was receiving basic sugar containing fluids.

Appropriate quantities and types of fluid were given, as I have set out above. This is confirmed by the fluid calculations, Heart rate, CVP, BP, haemoglobin concentration, blood sugar and autopsy (no evidence of fluid overload). In fact there is no evidence that excessive quantities or incorrect types of fluid were given.

~~Brain "Insult"~~?

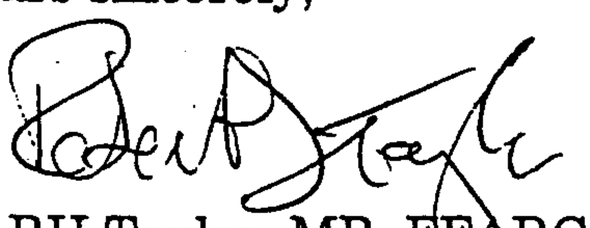
Another difficulty in attempting to explain the cerebral oedema is the fact that Adam received cerebral-protective drugs during the operation, not for specific reasons but for other purposes. **Thiopentone** was used for induction and, being a barbituate, has well documented cerebral-protective effects, especially when given prior to the brain"insult". **Prednisolone** was given for "anti-rejection" therapy and, being a steroid, is also recognised as a cerebral-protective agent.

Conclusion;

By the careful exclusion of possible causes I can only assume that "something" occurred during this case which defies physiological explanation.

I remain totally devastated by this unexpected, unexplained and tragic death of a 4 year old boy during a complicated operation. My only consolation is that I consider the management to have been caring, appropriate, expert and representative of the highest quality and intensity of care that I can provide.

Yours sincerely,



Dr RH Taylor. MB, FFARCSI
Consultant Paediatric Anaesthetist.