Induced Hypotension for Surgical Repair of Congenital Dislocation of the Hip in Children

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The surgical repair of congenital dislocation of the hip was performed under normotensive anaesthesia (23 children) and hypotensive anaesthesia (52 children). Hypotension was induced with infusion of hypotensive agents such as trimetaphan or nitroglycerin during inhalation or neurolept-anaeshesia under careful monitoring of blood pressure, haematocrit and electrocardiogram. Blood replacement was done to keep hematocrit value above 30%. Blood loss was significantly less in hypotensive group (2.53 ml/kg/h) than that in normotensive group (4.53 ml/kg/h). Twenty one percent of patients in hypotensive group required blood transfusion with the rate of 3.3 ml/kg/h compared with 43% of cases in normotensive group with the rate of 4.4 ml/kg/h. Depending upon anaesthesia technique blood loss was greater in neuroleptanaesthesia (5.5 ml/kg/h) than inhalation (2.3 ml/kg/h) or epidural (2.1 ml/kg/h) anaesthesia. Urine output and laboratory data for liver and kidney functions were not different between normotensive and hypotensive group. The dose of hypotensive agents required to produce moderate hypotension for paediatric patients was much higher than that for adult. We consider that moderate hypotension is safe procedure if employed by well experienced anaesthetist with careful monitoring of blood pressure, Hct and ECG. Blood loss and requirement of blood replacement are significantly reduced with this technique.
(Key words: Pediatric controlled hypotension, congenital hip dislocation)

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Since induced hypotension was introduced as a technique to minimize bleeding during surgery, many techniques to induce hypotension have been developed. Despite many reports of successful applications in adult surgery, the reports for paediatric use of this method have been limited.

We have been using induced hypotensive technique for surgical repair of congenital dislocation of the hip (CDH), which often requires blood replacement. In our hospital the blood loss during this surgery was about 14 ml/kg when normotensive anaesthesia was employed. Increasing problems in obtaining an adequate blood replacement and the necessity to decrease the risks of blood transfusion obliged us to apply a hypotensive technique for the surgical repair of CDH in children. In this report we describe retrospective (normotensive) and prospective (hypotensive) studies to investigate the clinical use and advantage of induced hypotension during surgical repair of CDH.

Methods

The anaesthetic records of 23 patients

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admitted to the hospital in 1985 for unilateral open reduction of CDH under normotensive anaesthesia were reviewed (group N). In a prospective study we included 52 patients who received unilateral open reduction of CDH with induced hypotensive technique in 1986 (group H). During these periods the surgical and anaesthetic team were virtually unchanged.

For each patient in both groups data were collected regarding age, weight, duration of operation, preanaesthetic haemoglobin levels, anaesthetic technique, estimated blood loss and blood replacement, intraoperative fluid infusion, and urine volume.

The anaesthetic protocol in both groups was essentially the same and as follows: Approximately 90 min before anaesthetic induction, triclofos 100–120 mg/kg per os for children under the age of four years or nitrazepam 0.2–0.3 mg/kg per os for those above the age of four years as premedication. Anaesthesia was induced with 70% N_2O in oxygen with 1.5–2.5% halothane via face mask. To facilitate tracheal intubation pancuronium 0.1 mg/kg was given intravenously. By random selection, one of the following four techniques was chosen for maintenance of anaesthesia. 1) Inhalation of 50% N_2O in oxygen with 1.0 to 1.5% halothane. 2) Inhalation of 50% N_2O in oxygen with 1.5 to 2.0% enflurane. 3) Inhalation of 70% N_2O in oxygen with pentazocine and diazepam intravenously. 4) Inhalation of 70% N_2O in oxygen under continuous epidural anaesthesia with 1% mepivacaine. Ventilation was controlled manually to maintain Pa_{CO_2} between 4.0 and 4.7 kPa during anaesthesia.

Blood pressure was measured by oscillometry every two minutes in both groups. Precordial stethoscope and electrocardiogram were monitored continuously. The rectal temperature and urine volume were measured at appropriate time intervals. Blood loss was estimated by the sum of suction bottle content and weights of sponges and towels. All of the above monitorings were set up in both groups.

5% dextrose in 1/4- or 1/2-strength saline was infused continuously intravenously. The administration rate was estimated by the guidelines of Holliday and Segar[1]. Guidelines of Holliday and Segar for calculating maintenance fluid requirements based on body weight were as follows:

body weight	fluid requirement
0 – 10 kg	: 100 ml/kg/24h
10 – 20 kg	: 1000 ml + 50 ml/kg/24h
over 20 kg	: 1500 ml + 20 ml/kg/24h

Replacement fluids such as lactated Ringer's solution, Plasmanate® or blood were administered separately. The requirements of fluid and blood were estimated based upon the guidelines of Furman[2] and the value of haematocrit not to fall below 30%. Guidelines of Furman for replacement blood loss:

$$\begin{aligned} \text{ERCM} &= \text{EBV} \times \text{Hct} \\ \text{ERCM30} &= \text{EBV} \times 0.3 \\ \text{ARCL} &= \text{ERCM} - \text{ERCM30} \\ \text{ABL} &= \text{ARCL} \times 3 \end{aligned}$$

(ERCM: Estimated Red Cell Mass, EBV: Estimated Blood Volume, Hct: present Haematocrit, ERCM30: ERCM when haematocrit is 30%, ARCL: Acceptable Red Cell Loss, ABL: Acceptable Blood Loss.)

In order to induce hypotension either 0.5% trimetaphan (TMT) or 0.05% nitroglycerin (TNG) solution was randomly selected and administered through microinfusion pump. The administration rate of the hypotensive agents was adjusted carefully to maintain the systemic arterial pressure about 70% of the preoperative level. Induced hypotension was started just before the skin incision and continued until 30 min before the end of surgery.

In group N measurement of serum electrolytes, liver and renal function tests were done preoperatively, and arterial blood gases were checked once during surgery because minimal impairment seemed to be appeared. In group H these tests were repeated three times; before, during, and after operation for fear of impairment of vital organs due to diminished blood supply to these organs.

Comparison between the two groups was accomplished by using Student's t-test and p values of less than 0.05 were regarded as significant.

Table 1. Patient data and operative procedure

Group	No. of patients	Age (years)	Body wt. (kg)	Hgb (g/dl)	Op. time (h)	Osteotomy	Arthro-plasty	Osteotomy + Arthroplasty
N	23 (M6,F17)	4.8±0.6	15.9±2.1	13±0.2	3.3±0.3	12 (52%)	5 (22%)	6 (26%)
H	52 (M19,F33)	5.3±0.7	20.0±2.4	13±0.3	4.0±0.3	17 (33%)	16 (31%)	19 (37%)

Mean±S.E.

Table 2. Dose of hypotensive drugs (μg/kg/min)

Drug	Induction	Mainte-nance	Average
TNG (n=30)	2.0±0.2	5.2±0.3	4.0±0.3
TMT (n=22)	23±1.4	43±2.0	35±2.5

Mean±S.E.

Table 3. Changes of blood pressure (mmHg)

Group	CONTROL			HYPOTENSION			RECOVERY		
	systolic	diastolic	mean	systolic	diastolic	mean	systolic	diastolic	mean
N	103±2.0	59±1.8	74±1.3				105±2.4	62±1.5	76±1.5
H	105±2.1	62±2.3	76±1.7	77±1.8	45±1.3	56±1.2	101±2.3	61±2.0	74±1.5

Mean±S.E.

Table 4. Amount of blood loss, transfusion, I.V. fluid and urine output (ml/kg/h)

Group	Blood loss	TRANSFUSION Amount	TRANSFUSION Incidence	IV fluid	Urine output
N (n=23)	4.35±0.36	4.4±0.4	43%	6.8±0.5	1.48±0.2
H (n=52)	2.53±0.24*	3.3±0.3*	21%	5.9±0.4	1.53±0.1

The amount of transfusion is the amount among transfused children Mean ± S.E.
*P <0.05 as compared to group N.

Results

There was no difference between group N and group H regarding age, body weight and preoperative haemoglobin levels. However the distribution of the patient population by surgical procedure showed some difference between the two groups (table 1). The percentage of patients who received arthroplasty or osteotomy combined with arthroplasty were higher in group H. This probably explains the longer mean operation time seen in group H because of the application of more precise and complicated operative procedures.

Hypotension was induced with TMT in 22 patients and TNG in 30 patients. The required doses of these agents for induction and maintenance of hypotension were shown in table 2. During operation we intended to maintain their blood pressure near preoperative level in group N, and near 70% of preoperative level in group H. Our results show that blood pressure in group H was reduced to 73% of the initial level (table 3). Postoperatively blood pressure recovered

Table 5. Comparative blood loss and transfusion in operative procedures (ml/kg/h)

Procedure	Group	Blood loss	TRANSFUSION amount	TRANSFUSION incidence
Osteotomy	N (n=12)	3.77±1.82	3.70±5.45	2 (17%)
	H (n=17)	3.47±2.29	5.00±1.81	3 (18%)
Arthroplasty	N (n=5)	3.77±2.56	4.76±3.70	2 (40%)
	H (n=16)	2.14±1.73	3.49±1.19	3 (19%)
Osteotomy +	N (n=6)	5.97±2.64	4.48±2.27	6 (100%)
Arthroplasty	H (n=19)	3.47±1.56*	2.75±1.43	7 (37%)

Mean±S.E.
*P <0.05 as compared to group N.

Table 6. Influence of anaesthesia techniques on blood loss (ml/kg/h)

Group	Inhalation	Epidural	Neurolept.
N (n=23)	2.9±0.3 (n=7)	—	4.8±0.8* (n=16)
H (n=52)	2.3±0.2 (n=29)	2.1±0.3 (n=9)	5.5±0.8* (n=14)

Mean±S.E.
*P <0.05 as compared to inhalation

Table 7. Results of serum electrolytes, arterial blood gases, liver and renal function tests

Group	Na (mmol/L)	K (mmol/L)	Cl (mmol/L)	Ca (mmol/L)	pH	Pa_{O_2} (kPa)	Pa_{CO_2} (kPa)
N	138±0.7	3.6±0.1	108±0.6	1.064±0.024	7.45±0.03	20.0±0.9	4.4±0.4
H control	140±0.7	3.9±0.1	114±0.5	1.108±0.008	7.42±0.02	19.3±0.9	4.5±0.3
hypotension	138±1.0	3.9±0.2	113±0.7	0.988±0.032*	7.44±0.02	19.6±1.1	3.7±0.3*
recovery	140±0.8	4.1±0.3	114±1.1	1.068±0.028	7.33±0.03	20.1±1.3	4.5±0.4

Group	HCO_3 (mmol/L)	BE (mmol/L)	SGOT (unit)	SGPT (unit)	BUN (mmol/L)	Creatinine (umol/L)
N	(-)	-2.6±0.4	19±2	9±1.6	(-)	(-)
H control	19.7±0.6	-2.9±0.7	29±2	15±1.3	2.09±0.12	55±2
hypotension	18.0±0.4	-4.2±0.8	(-)	(-)	(-)	(-)
recovery	18.0±0.2	-5.1±0.8	30±1	14±1.1	2.17±0.12	49±3

Mean±S.E.
*P <0.05 as compared to control.

from hypotensive state uneventfully.

The estimated blood loss in group H (2.53 ml/kg/h) was significantly less compared to that in group N (4.35 ml/kg/h). Consequently the incidence of blood transfusion was 21% in group H compared with 43% in group N. The required amount of blood replacement was less in group H (3.3 ml/kg/h) as compared with group N (4.4 ml/kg/h). There were no significant differences between the two groups regarding intravenous fluid requirement or urine output (table 4).

Table 5 shows intraoperative blood loss and blood transfusion for three different surgical procedures: osteotomy, arthroplasty and osteotomy combined with arthroplasty. The patients with osteotomy combined with arthroplasty had greater blood loss compared with other operative procedures. Hypotensive technique significant by reduced the intraoperative blood loss in patients with osteotomy combined with arthroplasty.

Concerning the techniques of anaesthesia, neurolept-anaesthesia showed significantly greater blood loss compared with inhalation or epidural anaesthesia (table 6). Epidural anaesthesia had not been employed in group N because of unawareness of the usefulness of this technique at that time.

During and after induced hypotension, no major alternations were found in serum electrolytes, arterial blood gases and several other laboratory data. Serum calcium concentration was decreased during surgery probably due to low Pa_{CO_2} induced by augmented manual ventilation during induced hypotension (table 7).

Discussion

Induced hypotensive technique in paediatric surgery has been used increasingly in recent years in order to reduce blood loss and facilitate the work of surgeon. Several methods including deep inhalation anaesthesia, hypotensive spinal or epidural anaesthesia, and adrenergic blocking agents can be used to lower the blood pressure.

In previous reports[3–6] it has been shown that children were more tolerant to hypotensive agents. But the reason for this resistance is not known. In this study we used TMT and TNG as hypotensive agents. It has been reported that TMT developed tachyphylaxis more commonly and its effect was less reliable than sodium nitroprusside. But we preferred to use TMT because there was no fear of life threatening toxicity and less overshoot in children. TMT is commonly used in 0.1% solution for adults. We used 0.5% TMT solution through microinfusion pump. 43 μg/kg/min of TMT was required to maintain blood pressure about 73% of the preoperative level. This dose of TMT given to children was higher than that reported given to adults (5–30 μg/kg/min)[7]. We had one patient, a girl 5 years old, who was resistant to TMT, but responded well to TNG.

There has been few reports about induced hypotension with TNG in paediatric anaesthesia. Cote[8] reported that TNG might not produce adequate hypotension in children. However the main advantage of lack of tachyphylaxis and toxicity made TNG acceptable for induced hypotension in children. TNG is commonly used in 0.01–0.02% solution and maintenance dose is reported as 0.25–5 μg/kg/min (average 1 μg/kg/min)[7] in adults. In this study 0.05% TNG solution was used and maintenance dose was as much as 5.2 μg/kg/min, which produced only about 27% reduction of the blood pressure. From these results it seemed that the dose of TMT and TNG required to induce moderate hypotension in children corresponded to near maximal dose of the adults. Delayed recovery from hypotension has occasionally been reported after prolonged administration of hypotensive agents. In this study blood pressure recovered to preoperative value within 15 min after cessation of the administration without any rebound phenomenon.

It is very important to monitor blood pressure carefully during induced hypotension. Many anaesthetists believe that intraarterial pressure monitoring is mandatory. Certainly it is very valuable and particulary helpful when the anaesthetist has not been familiar with induced hypotensive technique. But induced hypotension technique could be conducted with noninvasive blood pressure monitoring in children where abrupt fall in blood pressure is rare than in adults. Therefore it was considered that the noninvasive blood pressure monitoring every two minutes was sufficient to maintain the moderate hypotension with microinfusion set in children.

There are some arguments on the safety levels of haemoglobin to sustain a sufficient oxygen carrying capacity during induced hypotension. Cote[8] stated that keeping haemoglobin level at 8 g/dl or higher was necessary for the safety of the patient. We transfused blood to the patient on the basis of an estimated blood loss and tried to maintain haematocrit value more than 30%.

Induced hypotensive technique for the surgical repair of CDH in children resulted in about 42% reduction of blood loss (from 4.3 to 2.5 ml/kg/h). As a result the necessity for and amount of transfusion decreased substantially. The operation time did not change much, probably because more precise and complicated procedures were employed in greater numbers in group H.

The influence of anaesthetic techniques on blood loss was considerable. Blood loss was significantly greater in the patients under neuroleptanaesthesia as previously reported by Rosberg et al[9]. Blood pressure usually rised in some degree during neuroleptanaesthesia, and it was rather difficult to induce and maintain the hypotensive state with this anaesthetic technique. There was no significant difference in blood loss between inhalation and epidural anaesthesia in this study. This could indicate that blood pressure, not cardiac output, is the principal determinant factor affecting the blood loss during hypotension[10]. From these findings we consider that neuroleptanaesthesia is better avoided for the patients whose blood pressures are intended to lower deliberately.

It is stated that glomerular filtration decreases with a fall in arterial blood pressure. Urine output was measured in all children during surgery because it is one of the most reliable indicator for hydration status and renal plasma flow. There was no reduction in urine output during induced hypotension. There are some arguments whether the hepatic function are impaired with reduced hepatic blood flow by hypotension. In this study liver function tests performed one week after operation revealed no significant alteration. Therefore, we consider that 27% reduction of blood pressure from its preoperative level for three or four hours resulted in no major impairment in renal and hepatic functions.

It is reported that there is a decrease in Pa_{O_2} during induced hypotension resulted from the inhibition of hypoxic pulmonary vasoconstriction[11,12] ad alterations in ventilation/perfusion ratio[13–15]. In this study no significant change in Pa_{O_2} was found during and after induced hypotension. Base deficit tended to slightly progress during and after hypotension, but this change was not significant compared with preoperative one. During induced hypotension patient was hyperventilated intentionally to secure sufficient pulmonary gas exchange. If severe hypocapnea was induced by hyperventilation, it might aggrevate the reduction in cerebral blood flow during hypotension. Since all our patients regained their consciousness soon after withdrawl of anaesthesia, we think that cerebral blood flow had probably not been disturbed in this study. As reactionary bleeding sometimes may occur after recovery from hypotension, infusion of hypotensive agent was discontinued at the end of major operative procedure and blood pressure was allowed to return to near preoperative level before closure of the wound. As a result of this, there was no re-do operation due to reactionary bleeding in this study.

From these results it is concluded that: (1) Surgical repair of CDH in children was performed safely with induced hypotensive technique with TMT or TNG under careful monitoring of blood pressure, haematocrit, and electrocardiogram. (2) With hypotensive technique blood loss and the necessity of blood transfusion were considerably reduced. Consequently relative dry operative field made it possible to perform complicated and precise operative procedures. (3) The dose of hypotensive agents required to produce desired hypotensive level for paediatric cases was much higher than that for adult. (4) Neuroleptanaesthesia is better avoided for children when induced hypotension is going to be planned.

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