Anesthesia for Right Hepatic Lobectomy in a Child: An Exercise in Blood Volume Management

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Hepatic lobectomy in a child may be accompanied by losses of large volumes of blood.[1, 2] An adult undergoing surgery of similar magnitude is routinely cared for by a team providing personnel committed to different phases of the operating room management, with the responsibility for monitoring and maintaining fluid balance in the hands of the anesthesia team leader. Application of similar methods to infants and children is crucial to successful management during complicated operations. Serial intraoperative measurement of Pa_{O_2}, Pa_{CO_2}, *p*H, arterial hematocrit, total serum proteins, and electrolytes, and the use of blood components to replace blood lost, have provided a successful means of fulfilling this need in the management of hepatic lobectomy.

REPORT OF A CASE

A 20-month-old 13.5-kg female infant was scheduled for abdominal exploration and probable hepatic lobectomy after aortic angiography disclosed a large intrahepatic tumor. Anesthesia was induced with oxygen and halothane two hours after premedication with Nembutal, 4 mg/kg. An endotracheal tube with an internal diameter of 4.5 mm was introduced and ventilation was controlled manually using a Jackson Reese modification of Ayre's T piece. Halothane and oxygen were administered throughout the eight hours of anesthesia. Nitrous oxide, 50 per cent, was added in an attempt to minimize inspired halothane concentration, but was discontinued when low blood pressure accompanied rapid blood loss 4½ hours after the operation started. No relaxant drugs were used.

Monitoring. After induction of anesthesia, apparatus appropriate for measurement of blood pressure, heart sounds, and EKG were applied. A 20SWG teflon-coated radial artery catheter and a central venous cannula were placed through incisions in the skin of the left arm and a 16SWG plastic intravenous catheter was placed in the dorsum of the hand. The central venous cannula was positioned in the superior vena cava. A Foley catheter was placed in the bladder and connected to a measuring flask at the head of the operating table. Blood samples were taken from the radial artery at half-hourly intervals (or more frequently when necessary) to determine P_{O_2}, P_{CO_2}, *p*H, hematocrit, total protein, serum Na^+ and K^+ concentrations, and serum osmolality. All results were available within 7 minutes.

Intraoperative Management: Anesthesia. Laparotomy revealed a large hepatic tumor, and the decision to proceed with right hepatic lobectomy was made. The electrocardiogram showed normal sinus rhythm throughout the procedure, with pulse rates ranging between 118 and 144 beats/min. Systolic blood pressure, which was 90 torr at the beginning of the operation, dropped to 60 torr at the time of rapid blood loss during operation, but had returned to 85 torr by the time the infant was taken from the operating room. Central venous pressures ranged between 7 torr and 4 torr throughout. After the operation the endotracheal tube was left in place for 14 hours to facilitate respiratory support in the intensive care unit.

Blood Volume; Fluid and Electrolyte Replacement. The 13.5-kg patient was estimated to have a blood volume of 1.08 l, based on 0.8 per cent of her body weight. Hematocrit was 25 per cent, and preoperative blood transfusion was judged to be unnecessary. Four types of fluid were used for infusion, each passing through a warming bath: 1) fresh heparinized whole blood; 2) ACD packed cells; 3) 5 per cent albumin in physiologic saline solution; 4) 5 per cent glucose in Ringer's lactate solution.

Based on a maintenance requirement of 4 ml/kg/hour of fluid,[3] and the fact that 6 hours had passed since the patient's last oral intake, a fluid deficit of 300 ml was assumed. Maintenance doses of 50 ml of 5 per cent glucose in Ringer's lactate solution were infused hourly. During periods of rapid blood loss, an additional 250 ml (total) of Ringer's lactate solution were infused through the central venous catheter to help restore circulating blood volume, while blood replacement continued through the peripheral venous cannula. The total volume of 5 per cent glucose in Ringer's lactate solution infused was 950 ml, representing a 300 ml deficit, 400 ml for hourly maintenance doses, and 250 ml for volume replacement.

Serial measurement of serum electrolytes and osmolality showed stable sodium and potassium levels and an increase in osmolality, probably as-

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TABLE 1. Intraoperative Management of Right Hepatic Lobectomy

	Anesthesia Time (Minutes)														
	+30	+60	+90	+120	+150	+180	+210	+240	+270	+300	+330	+360	+390	+420	+450
Estimated total blood loss (ml)	25	27	30	85	215	260	555	810	1065	1200	2070	2250	2795	2980	3800
Hematocrit (per cent)	25	26	24.5	25	25.5	25	42	43	36	35			31	32	33
Fluids given															
ACD packed cells (ml)	30	60	60	140	180	300	650	650	650	650	650	650	700	960	960
Fresh heparinized blood (ml)								450	700	1200	1450	1520	1630	1630	1030
5 per cent glucose in Ringers lactate (ml)	50	150	300	325	350	350	350	450	500	550	600	700	850	900	950
5 per cent albumin in saline (ml)											50	150	300	350	400
Total fluids given (ml)	80	210	360	405	530	650	1000	1550	1850	2400	2750	3020	3480	3840	3940
F_{IO_2}	1.0	1.0	1.0	1.0	.5	.5	.5	.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pa_{O_2} (torr)	406	338	320	441	198	225	220	280	520	565			570	495	478
Pa_{CO_2} (torr)	58	57	53	48	40	32	34	32	33	37			32	30	33
*p*H	7.24	7.26	7.25	7.29	7.31	7.36	7.25	7.28	7.46	7.40			7.42	7.32	7.40
Base excess	−3.0	−2.0	−4.5	−3.5	−5.5	−5.5	−11.5	−11	0	−1.0			−2.5	−5.0	−3.5
Na^+ (mEq/l)	141	141	130	138	137	137	135	136	142	139			133		143
K^+(mEq/l)	4.6	4.6	4.5	4.4	4.9	4.9	5.6	4.8	4.0	3.9			3.6		3.7
Total serum proteins (g/100 ml)	6.9					5.9	5.9	6.0	5.2	5.2			5.0		4.5
Serum osmolality (mOsm)	295	309	319	306	326	309	314	310	316	319			325		327
Total urine volume (ml)	20	50	55	60	65	72	78	83	95	110			140	151	162
Blood pressure—cuff (torr)	100/50	100/50	100/50	105/50	100/50	100/50	90/50	80/50	60/50	70/50			80/50	80/50	80/50
Pulse rate (beats/min)	130	130	130	140	140	140	130	130	120	120			120	120	120
Ventilation assisted/controlled	A	A	A	C	C	C	C	C	C	C			C	C	C
Halothane (per cent)	1.5	1.0	1.5	1.5	1.0	1.0	1.0	0.5	0	1.0			0.5	0.5	0

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sociated with the increasing volume of glucose infusion (blood sugar 200 mg/100 ml after infusion of 300 ml).

Total serum protein levels indicated a progressive dilution, with an initial value of 6.9 mg/100 ml that decreased to 4.5 mg/100 ml. To replace plasma lost in the face of the large volume of fluid replaced, 400 ml of 5 per cent albumin in saline solution were used (table 1). Replacement commenced after 5½ hours of anesthesia, when measurement indicated dilution to 5.2 mg/100 ml despite the use of heparinized whole blood.

To replace the initial blood loss, infusion of 650 ml of ACD packed cells (hematocrit 70 per cent) was begun immediately after the start of the operation to raise the arterial hematocrit to 42 per cent. Because of continuing blood loss, this level was reached only after 3½ hours of anesthesia. The estimated blood loss at this stage was 550 ml (half the estimated blood volume), and the severe metabolic acidosis that developed during the last half hour of this period did not improve until 25 mEq sodium bicarbonate had been given. Thereafter, further replacement was accomplished by infusing fresh heparinized blood (1,630 ml, or 1.5 blood volumes of 34 per cent hematocrit) during the following 3½ hours, diminishing the volume of acid infused during that time. An additional 300 ml of packed cells (hematocrit approximately 70 per cent) were used during the last hour of operation to prevent further heparinization. Protamine, 27 mg, was given intravenously to reverse the effects of the heparin in the heparinized blood. The platelet count at the end of the operation was 165,000. A base deficit again became apparent during infusion of ACD blood, but no further sodium bicarbonate was necessary. Three 100-mg doses of intravenous calcium chloride were administered empirically after the first 650 ml of ACD blood.

Postoperative Course. The patient was nursed in the Intensive Care Unit for five days postoperatively. The endotracheal tube remained in place for 14 hours. The patient was discharged from the hospital on postoperative day 22, following an uneventful recovery.

Discussion

The use of half-hourly estimations of hematocrit and total serum proteins allowed a continuing check on the blood and the replacement necessary. However, the use of heparinized blood in a quantity 1.5 times the estimated blood volume resulted in complete anticoagulation (prothrombin time 16 sec [preop 11] and partial thromboplastin time 80 sec [preop 32]). This probably contributed to more than a third of the total blood loss before reversal with protamine was considered adequate.

The infusion of blood stored in ACD solution combined with inadequate metabolic breakdown of citrate during the operation on the liver raised the organic acid level, as measured in the fourth hour of anesthesia. Perhaps the use of washed frozen cells and albumisol could prevent these problems. Fresh frozen plasma could be used if clotting problems appeared.

A team of two anesthesiologists or an anesthesiologist and an assistant is necessary to implement this approach to blood volume management of children when large alterations of blood volume and content are anticipated. Similarly, an acute care laboratory must be available for rapid and accurate evaluation of the patient's condition. At this time, a 2.5-ml sample of blood is needed to gain all the information required.

Conclusion

Successful management of anesthesia during pediatric surgical procedures associated with massive blood losses is facilitated by close intraoperative monitoring of critical metabolic values. Reductions in mortality and morbidity in these cases are not likely unless such values are followed as closely in the pediatric surgical patient as in the critically ill adult.

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