Hemodynamic Effects of Peritoneal Dialysis in Three Children Following Open Heart Surgery

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SUMMARY. We studied the hemodynamic responses of peritoneal dialysis (PD) in three children following open heart surgery. Hemodynamic measurements were made prior to a dialysis run, following the instillation of dialysis solution (20 ml/kg), and immediately prior to and 5 min after drainage of the peritoneal cavity. The same protocol was repeated 48 h later. There was a significant increase in right atrial pressure (RAP) and mean pulmonary artery pressure upon instillation of the dialysate into the peritoneal cavity ($p < 0.01$). However, cardiac index, mean arterial blood pressure (MAP), systemic (SVRI) and pulmonary vascular resistances (PVRI), left atrial pressure (LAP), and oxygen saturation did not change significantly. There were no significant differences between responses in the initial study and that performed 48 h later. PD is associated with modest right-sided hemodynamic changes which, in this small group of patients, did not compromise patient care.

KEY WORDS: Peritoneal dialysis—Acute renal failure

Acute renal failure (ARF) occurs in 2 [4] to 8% [1, 3, 5] of children undergoing open heart surgery. Poor preoperative renal function combined with disturbed renal blood flow during cardiopulmonary bypass and cardiogenic shock are important factors in the pathogenesis of this serious complication [4]. The mortality rate among those who developed ARF following heart surgery is double the overall mortality rate varying from 65–89% [1, 4, 5].

Some authors have reported improved survival and recovery of renal function by using very early peritoneal dialysis (PD) [2, 8], although this is controversial [5]. Nevertheless, PD remains a useful method of controlling fluid and electrolyte imbalances in children with ARF secondary to a low cardiac output state. We recently had the opportunity to examine the hemodynamic effects of PD in three children following open heart surgery.

Materials and Methods

Three patients undergoing PD following open heart surgery for complex lesions were studied. Two children were catheterized

transvenously with thermistor-tipped, four-lumen catheters (5F, SP5105H, Gould CritiCath, Oxnard, CA, USA), whereas one infant had a thermidilution probe (94-030-2.5F, EDSLAB, Irvine, CA, USA) inserted by the transthoracic route into the pulmonary artery (PA) during surgery. The decision to pass PA catheters was not related in any way to the present study. Correct positioning of the PA catheter was judged by the typical changes of the pressure tracing when the balloon was inflated and the catheter was in the wedged position. Thermistor and catheter positions were confirmed by standard portable chest x-rays. The catheter was connected to a calibrated pressure transducer which was leveled to the mid-axillary line and referenced to atmospheric pressure. Residual intracardiac shunting was excluded by echocardiography.

Cardiac output was determined in triplicate by the thermidilution technique using the Gould hemodynamic profile computer (No. sp1445, Gould Inc., Cardiovascular Production Division, Oxnard, CA, USA). Three to 5 ml of 5% dextrose/water solution, at room temperature, was injected by hand at end-expiration, and the average of the three readings (within 10% of each other) was recorded. Mean arterial pressure (MAP) was measured by an indwelling radial artery catheter. Left atrial pressure (LAP), right atrial pressure (RAP), mean pulmonary artery pressure (MPAP), heart rate, and electrocardiogram (ECG) were also measured and continuously displayed on a bedside cardiac monitor (OM model, Honeywell Inc., Pleasantville, NY, USA). All measurements were read at end-exhalation.

From these hemodynamic measurements a cardiopulmonary profile (CPP) was formed which included these variables and other hemodynamic parameters, derived using standard for-

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Fig. 1. Hemodynamic and oxygenation responses to a dialysis cycle in 3 children. Solid lines = initial study; dashed lines = 48 h later. CI = cardiac index; RAP = right atrial pressure; LAP = left atrial pressure; MPAP = mean pulmonary artery pressure; MAP = mean aortic pressure.

mulas. These included systemic vascular resistance index (SVRI), pulmonary vascular resistance index (PVRI), and right and left ventricular stroke work index (VSWI).

The children were ventilated by a Servo 900C ventilator (Siemens Elema, Solna, Sweden) at positive end-expiratory pressures of 4 cmH₂O. They were sedated by an intravenous infusion of morphine (0.1 mg/kg/h) and paralyzed by an intravenous infusion of vecuronium (0.1 mg/kg/h). Arterial saturation was continuously measured by a pulse oximeter (Nellcor 100, Nellcor Corp., Hayward, CA, USA).

Each child was studied on the day of insertion of the catheter and 48 h later. The FIO₂ was reduced until the pulse oximeter saturation was reading between 95 and 97%. The first CPP was obtained when the peritoneal cavity was drained of dialysis fluid. Warmed dialysis solution (Dianel 1.5%; 20 ml/kg) was instilled by gravity into the peritoneal cavity over 5 min and a second CPP performed. Following a 20-min dwell period, a third CPP was determined. The peritoneal fluid was drained over a 10-min period and a final CPP was measured. Arterial oxygen saturation was documented each time a CPP was performed.

The means of continuous data was compared by a two-way split-plot analysis of variance. *p* Values of < 0.05 were considered statistically significant. Informed parental consent was obtained and the study was approved by the Research Committee of the IWK Hospital for Children.

Results

Patient demographic data are presented in the Table 1. Instillation of dialysis fluid into the peritoneal cavity was associated with a significant increase in

RAP and MPAP ($p < 0.01$, Fig. 1). There were no significant changes in mean cardiac index, mean pulmonary artery wedge pressure, or arterial oxygen saturation. However, cardiac index fell from 4.2–3.3 L/min/m² in one child during instillation and dwell period of the dialysate in the abdomen. This was associated with a reduction in arterial oxygen saturation (from 93–85%) in this particular instance (Fig. 1). MAP, SVRI, PVRI, and right and left VSWI did not change significantly during the dialysis run.

There were no significant differences between responses of the children during the initial study (solid lines in Fig. 1) compared to that performed 48 h later (dashed lines in Fig. 1).

Discussion

To our knowledge, there are no previous studies, either in adults or children, looking at the hemodynamic effects of PD in the immediate postoperative period. The three children reported here represented all of the children in our unit, for a 12-month period, who had PA thermodilution catheters in situ and also required PD.

Studies looking at the effects of PD on the cardiovascular function in adult patients with chronic renal failure, showed a decrease in cardiac output

Table 1. Characteristics of the three patients studied

Patient no.	Sex	Age	Diagnosis	Operation
1	M	7 days	Truncus arteriosus	Correction with RV-PA homograft
2	M	6 years	DORV, previous Sennings RVOT obstruction	RVOT repair
3	F	2 years	Down's syndrome AV canal	AV canal repair

RV-PA, right ventricle to pulmonary artery; DORV, double-outlet right ventricle; RVOT, right ventricular outflow tract, AV, atrioventricular.

following the infusion of 2–3 L of dialysis fluid into the peritoneal cavity [7, 10]. It is obvious that adult studies are not strictly comparable to the present study in respect to the age distribution of the subjects, their clinical condition, and the volume of dialysis fluid. We have seen that PD in three critically ill children had modest right-sided hemodynamic effects following the instillation of fluid into the peritoneal cavity. The increase in RAP following instillation failed to produce significant changes in cardiac output, and oxygen saturation remained stable during all but one dialysis run. The fall in cardiac output in this instance was most likely due to the negative inotropic effect of hypoxia on the myocardium.

The increase in right-sided pressures during instillation may be due to increased intrathoracic pressure transmitted from the rise in abdominal volume and pressure. It could also reflect increased venous return to the heart. In an experimental study, the effect of increased intraabdominal pressure on central hemodynamics is complex, the net effect depending on the level of RAP. At low RAPs, venous return is depressed, whereas at high atrial pressures, venous return is augmented by increased abdominal pressure [6]. Cardiac output response to increased intraabdominal pressure is also dependent on the size of the intravascular space [6]. Although total peripheral vascular resistance increased with a rise in intraabdominal pressure, this negative effect on cardiac performance was offset in hypervolemic animals by an increase in venous return. In hypovolemic animals, cardiac output decreased dramatically as a result of both the reduction in venous return and the increased afterload to the left ventricle.

Swartz et al. [10] showed a decrease in perfusion to the bases of the lungs during PD. Although

the exact mechanism of this observation is speculative, it may, in part, be related to pressure changes transmitted from the abdomen to the chest. Such responses would therefore depend on the compliance of the thoracic system. In patients with highly compliant lungs there would be less attenuation of the intraabdominal pressure and possibly greater hemodynamic and respiratory effects. Patient with stiff lungs might be expected to have less cardiorespiratory effects. The absence of major cardiorespiratory changes in all but one dialysis run during the present study does not preclude the possibility of such changes occurring in patients with more compliant lungs, particularly when larger volumes of dialysate are used.

We conclude that PD is associated with modest right-sided hemodynamic changes in children following open heart surgery. The rise in pulmonary artery pressure could exacerbate preexisting pulmonary hypertension and this should be a consideration in the management of ARF in these patients. Careful attention to cardiorespiratory status by continuous monitoring of arterial and central venous pressures, along with oxygen saturation is warranted, particularly during the dwell period of dialysis.

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