HAEMODYNAMIC MONITORING IN THE MANAGEMENT OF SEVERE PRE-ECLAMPSIA AND ECLAMPSIA

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ABSTRACT

Four case histories are presented to illustrate that haemodynamic monitoring is a useful guide in the acute management of severe pre-eclampsia and eclampsia. The application of intensive monitoring and therapy to patients in the delivery room is both feasible and of great help to the clinician managing fluid therapy and/or anaesthesia.

KEY WORDS: ECLAMPSIA, PRE-ECLAMPSIA: haemodynamic monitoring, management.

PRE-ECLAMPSIA AND ECLAMPSIA of pregnancy are major causes of maternal mortality. The current incidence of pre-eclampsia in North America is five to seven per cent and that of eclampsia 0.7 to 0.1 per cent.^{1,2} Combined, they may cause 40 per cent of maternal deaths from obstetrical causes.³

Pre-eclampsia is classically defined as the development of hypertension associated with either proteinuria or oedema or both.⁴ It becomes severe if any one of the following signs or symptoms is present,^{5,6} viz: systolic blood pressure 21.28 kPa (160 torr) or greater; diastolic blood pressure 14.63 kPa (110 torr) or greater; proteinuria five grams per day or greater; urine output 400 ml or less per 24 hours; headache; visual disturbance; epigastric pain.

Pre-eclampsia becomes eclampsia when seizures occur. The foetal and maternal mortality associated with eclampsia far exceeds that of pre-eclampsia⁷ and thus active treatment of pre-eclampsia should improve the outcome for both.

Severe pre-eclampsia may have widespread consequences.⁸ *Maternal consequences* may be hypertension, cerebro-vascular accident, pulmonary oedema, haemoconcentration and blood volume depletion, coagulopathy, renal and hepatic dysfunction and drug interaction.

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Placental consequences may be insufficiency or abruptio placentae. *Consequences for the foetus* may be intra-uterine death, the effects of premature labour, small size for gestational age and neonatal depression.

In addition to clinical evaluations, circulatory function should be monitored by following arterial blood pressure, electrocardiogram, central venous pressure or left atrial filling pressure and hourly urine output. The following cases highlight the feasibility of intensive haemodynamic monitoring of the patient and provide useful clinical information.

Patient #1

A 32-year-old multipara was admitted at 36 weeks gestation because of increased blood pressure of 22.6/13.3 kPa (170/100 torr) hyperreflexia, pretibial oedema and 4+ proteinuria. Her haemoglobin was 11.2 g, platelet count 325,000 per mm³, serum sodium 128 mmol/l, potassium 4.4 mmol/l, chloride 100 mmol/l, BUN 14 mg/dl and creatinine 0.9 mg/dl. Despite bedrest for two days her blood pressure rose to 22.6/14.6 kPa (200/110 torr). On arrival in the delivery room, diazepam 10 mg was given orally. A bolus of five grams of magnesium sulphate was given intravenously and a continuous infusion of one gram per hour was started. A Foley catheter was also inserted. Hydralazine (Apresoline®) 5 mg and then 10 mg was given intravenously when her diastolic blood pressure exceeded 14.63 kPa (110 torr). The electrocardiogram was monitored continuously.

A balloon-floatation thermodilution catheter (Swan-Ganz) was inserted at the bedside. Cardiac output and other haemodynamic indices

TABLE I
HAEMODYNAMIC INDICES NORMAL NON-PREGNANT VALUES*

	Range	Average
Pulmonary Capillary Wedge Pressure kPa (torr)	0.6–1.73 (4.5–13)	1.2 (9)
Pulmonary Artery Pressure kPa (torr)		
Systolic	2.26–4.26 (17–32)	3.33 (25)
Diastolic	0.53–1.73 (4–13)	1.20 (9)
Cardiac Index (l/min · m ²)	2.1–4.9	3.5
Left Ventricle Work (Joules/min · m ²)	36.3–63.7	50.0
Total Systemic Resistance (Dynes sec/cm ⁵ · m ²)	774–1486	1130
Total Pulmonary Resistance (Dynes sec/cm ⁵ · m ²)	103–307	205

*Indexed to body surface area.

TABLE II
HAEMODYNAMIC ASSESSMENT* (PATIENT #1)

	Initial Values	After Fluid Before Section	During Anaes. Before Delivery	2 Hours Post-partum
Blood Pressure kPa (torr)	26.6/14.6 (200/110)	18.6/10.6 (140/80)	14.6/10.6 (110/80)	16/9.3 (120/70)
Heart Rate (beats/min)	130	130	90	100
Pulmonary Capillary Wedge Pressure kPa (torr)	0.266 (2)	0.67 (5)	1.6 (12)	1.33 (10)
Pulmonary Artery Pressure kPa (torr)				
Systolic	—	1.6 (12)	2.66 (20)	2.31 (18)
Diastolic	—	1.06 (8)	2.26 (17)	1.86 (14)
Cardiac Output (l/min)	—	12.1	7.7	10.5
Cardiac Index (l/min · m ²)	—	7.1	4.5	6.0
Left Ventricle Work (Joules/min · m ²)	—	123.6	57.9	89.2
Total Systemic Resistance (Dynes sec/cm ⁵ · m ²)	—	372	493	367
Total Pulmonary Resistance (Dynes sec/cm ⁵ · m ²)	—	35	107	67

*Indexed to body surface area.

were measured.⁹ Normal haemodynamic indices in the non-pregnant patient are shown in Table I. The initial pulmonary capillary wedge pressure was 0.266 kPa (2 torr) (Table II). This increased to 0.65 kPa (5 torr) after infusion of 1,000 ml of Normosol-RD and 500 ml of normal saline over 20 minutes. At this time, it was elected to proceed with a primary caesarean section. General anaesthesia was chosen. A live female infant (2183 g) was delivered. The Apgar scores were nine at one and five minutes. At birth umbilical artery [H⁺] was 56.23 nmol/l (pH 7.25), PCO₂ 4.66 kPa (35 torr) PO₂ 3.86 kPa (29 torr) and bicarbonate 20 mmol/l.

During the operation, which took one hour, the patient received 2300 ml of normal saline and 500 ml of Normosol-RD and the blood pressure remained stable. The pulmonary capillary wedge pressure rose from 0.66 kPa (5 torr) before anaesthesia to 1.6 kPa (12 torr) at the end of operation. The estimated blood loss was 800 ml.

She was transferred to the intensive care unit

where she had an uneventful postoperative course.

Patient #2

A 30-year-old multipara was admitted at 31 weeks gestation because of pre-eclampsia and decreasing urine oestriols. Her blood pressure was maintained at 21.6/13.3 kPa (160/100 torr) but on the 14th hospital day she convulsed. An oral airway was inserted and supplemental oxygen started. She was given diazepam 10 mg and magnesium sulphate 4.0 g intravenously.

On admission to the delivery room she was drowsy and her blood pressure was 21.6/14.36 kPa (160/108 torr). Her haemoglobin was 12.7 g, sodium 138 mmol/l, potassium 4.0 mmol/l, chloride 101 mmol/l, bicarbonate 28 mmol/l, BUN 16 mg/dl, creatinine 1.0 mg/dl and creatinine clearance 75 ml/min. Her platelet count was 26,000 per mm³. Other coagulation studies were normal. Her SGOT was 350 units, SGPT 433 units and LDH 1432 units.

TABLE III
HAEMODYNAMIC ASSESSMENT (PATENT #2)

	Initial Assessment After Drug Therapy	90 Minutes Later	24 Hours Post-partum
Blood Pressure kPa (torr)	20/12 (150/90)	21.3/13.3 (160/100)	21.3/11.3 (160/85)
Heart Rate (beats/min)	90	105	110
Pulmonary Capillary Wedge Pressure kPa (torr)	0.53 (4)	0.4 (3)	1.2 (9)
Pulmonary Artery Pressure kPa (torr)			
Systolic	1.2 (9)	1.2 (9)	2.4 (18)
Diastolic	0.53 (4)	0.53 (4)	1.6 (12)
Cardiac Output (l/min)	8.1	8.3	9.5
Cardiac Index (l/min · m ²)	4.3	4.5	5.1
Left Ventricle Work (Joules/min · m ²)	85.3	94.1	102.0
Total Systemic Resistance (Dynes sec/cm ⁵ · m ²)	580	—	—
Total Pulmonary Resistance (Dynes sec/cm ⁵ · m ²)	29	29	63

During the first hour she required three intravenous doses of hydralazine 2.5 mg each to keep the diastolic blood pressure below 14.6 kPa (110 torr). Hourly urine output was monitored. A Swan-Ganz catheter was inserted at the bedside. She received 2900 ml of Normosol-RD, and 250 ml of Normosol-MD in the first three hours. Despite this fluid load the pulmonary capillary wedge pressure was only 0.53 kPa (4 torr) and blood pressure 20/12 kPa (150/90 torr) with a pulse rate of 90 beats/minute. A haemodynamic profile 90 minutes later showed similar values (Table III).

It was decided to allow vaginal delivery and labour was induced. After 6½ hours, labour had failed to progress and moderate variable decelerations were present with each contraction. Consequently caesarean section was done under general anaesthesia.

During the six hours preceding caesarean section she had received 5800 ml of Normosol-RD, 250 ml Normosol-MD and 100 ml of five per cent dextrose. Before induction of general anaesthesia her blood pressure was 18.6/10.6 kPa (140/80 torr) heart rate 110 beats per minute and pulmonary capillary wedge pressure was 1.6 kPa (12 torr). The blood pressure was stable before delivery, but fell to 12/8 kPa (90/60 torr) for approximately five minutes immediately after. She received 1,000 ml of Normosol-RD, one unit of packed cells and one unit of fresh frozen plasma during the anaesthetic. Her post-operative course was uneventful.

The infant weighed 1120 grams. Apgar scores were seven and eight at one and five minutes.

Umbilical artery [H⁺] was 38.02 nmol/l (pH 7.42), PCO₂ 6.92 kPa (52 torr), PO₂ 2.26 kPa (17 torr) and bicarbonate 21 mmol/l. At ten minutes of age the infant became apnoeic. Treatment included intubation and ventilation with 5 cm H₂O continuous distending airway pressure. Transient mild respiratory distress syndrome developed. The infant was discharged home in good condition after an uneventful course in a neonatal intensive care unit.

Patient #3

A 23-year-old primipara was admitted to labour at 36 weeks gestation. She had hyperactive reflexes, 3+ proteinuria and blood pressure of 21.6/14.6 kPa (160/110 torr). Magnesium sulphate was started and hourly urine output was monitored. Laboratory investigations were normal and continuous lumbar epidural analgesia was instituted using 10 ml of bupivacaine 0.25 per cent. Hypertension persisted at 21.6/14.6 kPa (160/110 torr) despite adequate pain relief. Hydralazine 20 mg was given intravenously. The blood pressure fell to 16/10.6 kPa (120/80 torr). A Swan-Ganz catheter and an arterial line were inserted. At this time the pulmonary capillary wedge pressure was 0.266 kPa (2 torr) (Table IV). This increased to 1.33 kPa (10 torr) after infusion of 200 ml of 25 per cent albumin.

A decision was made to do a caesarean section because of failure of labour to progress. She had received 1250 ml of normal saline, 400 ml of dextrose five per cent and 200 ml of 25 per cent albumin. At this time per pulmonary capillary wedge pressure was 0.66 kPa (5 torr) and her

TABLE IV
HAEMODYNAMIC ASSESSMENT (PATIENT #3)

	After Hydralazine 20 mg I.V.	After 200 ml 25% Albumen	Before Final Epidural Dose (With Left Uterine Displacement)	After Final Epidural Dose	Lithotomy	Legs Down	4 Hours Post-partum
Blood Pressure kPa (torr)	16/10.6 (120/80)	18.6/12 (140/90)	20/13.3 (150/100)	16/10 (120/75)	15.3/10 (115/75)	18/10.6 (135/80)	22.6/13.3 (170/100)
Heart Rate (beats/min)	120	100	108	105	115	108	105
Pulmonary Capillary Wedge Pressure kPa (torr)	0.266 (2)	1.33 (10)	0.67 (5)	1.46 (11)	2.0 (15)	1.6 (12)	1.33 (10)
Pulmonary Artery Pressure kPa (torr)							
Systolic	1.6 (12)	2.66 (20)	2.26 (17)	2.26 (17)	3.33 (25)	2.31 (18)	2.31 (18)
Diastolic	1.06 (8)	2.0 (15)	1.6 (12)	1.6 (12)	2.66 (20)	1.6 (12)	1.6 (12)
Cardiac Output (l/min)	9.8	12.4	11.6	10.1	10.1	10.6	9.3
Cardiac Index (l/min · m ²)	4.7	5.9	5.5	4.8	4.8	5.0	4.4
Left Ventricle Work (Joules/min · m ²)	73.5	103.0	106.9	69.6	63.7	83.4	95.1
Total Systemic Resistance (Dynes sec/cm ⁵ · m ²)	360	—	375	325	—	321	472
Total Pulmonary Resistance (Dynes sec/cm ⁵ · m ²)	38	52	45	51	81	50	60

TABLE V
HAEMODYNAMIC ASSESSMENT (PATIENT #4)

	Initial Assessment	Pre-op.	Pre-partum during G.A. with Halo	Post-partum N ₂ O/O ₂	10 Hours Post-partum
Blood Pressure kPa (torr)	25.3/17.3 (190/130)	25.3/16 (190/120)	22.6/14.6 (170/110)	18.6/13.3 (140/100)	13.3/12 (100/90)
Heart Rate (beats/min)	92	95	110	85	95
Pulmonary Capillary Wedge Pressure kPa (torr)	1.06 (8)	1.6 (12)	2.66 (20)	1.33 (10)	0.67 (5)
Pulmonary Artery Pressure kPa (torr)					
Systolic	2.31 (18)	3.99 (30)	5.32 (40)	3.72 (28)	2.31 (18)
Diastolic	1.06 (8)	2.9 (22)	3.99 (30)	2.66 (20)	1.33 (10)
Cardiac Output (l/min)	4.9	6.4	6.2	5.5	5.2
Cardiac Index (l/min · m ²)	2.7	3.6	3.5	3.0	2.7
Left Ventricle Work (Joules/min · m ²)	67.7	85.3	69.6	53.0	38.2
Total Systemic Resistance (Dynes sec/cm ⁵ · m ²)	1274	938	856	838	—
Total Pulmonary Resistance (Dynes sec/cm ⁵ · m ²)	144	173	293	185	104

blood pressure 20/13.3 kPa (150/100 torr). A single epidural injection of 30 ml carbonated lidocaine two per cent was given. The haemodynamic indices remained stable. A vaginal examination was then done. It was felt that this patient could be delivered vaginally by forceps and accordingly this was done.

The infant weighed 1800 grams and Apgar scores were seven and nine at one and five minutes. The umbilical artery PO_2 was 1.46 kPa (11 torr), P_{CO_2} was 7.32 kPa (55 torr), $[H^+]$ 63.1 nmol/l (pH 7.20) and bicarbonate 20 mmol/l. Umbilical venous PO_2 was 2.13 kPa (16 torr), P_{CO_2} 6.78 kPa (51 torr) $[H^+]$ 61.66 nmol/l (pH 7.21) and bicarbonate 20 mmol/l.

Post partum the mother's blood pressure remained at 20/14.6 kPa (150/110 torr) and she was started on propranolol 40 mg four times daily.

Patient #4

A 33-year-old primigravida was admitted at 34 weeks gestation. She complained of epigastric pain. Her blood pressure on admission was 23.3/14.6 kPa (175/110 torr), reflexes were increased and there was 2+ protein in the urine. She had been receiving methyldopa 250 mg twice daily for two weeks before admission.

She was given 250 mg of methyldopa orally and 4 g of magnesium sulphate intramuscularly followed by a continuous infusion of one gram per hour. The blood pressure decreased to 21.3/13.97 kPa (160/105 torr).

Laboratory investigations were all normal except for the platelet count of 120,000 per mm^3 . Six hours after admission the patient complained of increasing upper abdominal pain and her blood pressure rose to 23.9/15.3 kPa (180/115 torr). A Swan-Ganz catheter was inserted.

A decision was made to do a caesarean section because of difficulty in maintaining a stable blood pressure. In the eight hours preceeding caesarean section the patient received one litre of Normosol-RD and 1150 ml of 3.3 per cent dextrose and 0.3 per cent normal saline solution. Immediately before operation her blood pressure rose to 25.27/15.96 kPa (190/120 torr) and the wedge pressure was 1.6 kPa (12 torr). Cardiac output had risen from 4.9 l/min to 6.4 l/min (Table V).

The patient was pre-oxygenated for five minutes and received a further 700 ml of Normosol-RD. General anaesthesia was induced. Blood pressure was 22.6/14.6 kPa (170/110 torr) before delivery, and rose transiently to 29.26/15.96 kPa

(220/120 torr) immediately after and returned to 18.6/13.3 kPa (140/100 torr) by 11 minutes post-partum. The haemodynamic data are shown in Table V. The patient received 2700 ml of balanced salt solution before delivery.

The infant weighed 2012 grams and the Apgar scores were three and eight at one and five minutes. The baby responded to positive ventilation by mask within two to three minutes. Umbilical arterial blood $[H^+]$ was 58.88 nmol/l (pH 7.23), P_{CO_2} 6.25 kPa (47 torr), bicarbonate 22 mmol/l and base excess -6. Umbilical venous $[H^+]$ was 52.48 nmol/l (pH 7.28), P_{CO_2} 5.45 kPa (41 torr) PO_2 3.33 kPa (25 torr), bicarbonate 19 mmol/l and base excess -7.

The infant did well.

Post partum the mother was given methyldopa 250 mg twice daily.

DISCUSSION

The authors believe that the anaesthetists should be notified as soon as any critically ill patient arrives in the delivery room. Pre-eclampsia and eclampsia is but one of these situations. Their skills and experience with fluid management and pain control are useful in the treatment and monitoring of these patients.

The aim of monitoring patients were severe pre-eclampsia or eclampsia is early detection of complications in mother and foetus. This minimizes the risks of both. Blood pressure must be measured frequently and an arterial line is useful. Deep tendon reflexes are used as a guide to magnesium therapy. Hyper-reflexia indicates impending seizures and a need for more magnesium. Decreased reflexes indicate an excessive serum magnesium level. One must remember that epidural anaesthesia may alter knee or ankle reflexes,¹⁰ and thus the biceps reflex is more reliable. Maternal ventilation should also be monitored as magnesium intoxication may cause muscle weakness. Maternal sedation may further decrease adequacy of ventilation. Frequent serial vital capacity determination will detect early muscle fatigue.¹¹ A Foley catheter is essential for measurement of hourly urine output.

Monitoring of the severe pre-eclamptic should also include a central venous pressure line, since many of these patients are significantly volume depleted.¹²⁻¹⁵ A Swan-Ganz catheter is a useful guide to the infusion of large volumes of fluid over a short period of time, since pulmonary

oedema may develop due to cardiogenic or other causes.^{2,15-17} Swan-Ganz catheterization, however, can be done safely only in the delivery suite by an experienced team.

The four cases reported illustrate the haemodynamic changes associated with pre-eclampsia.^{13,14,16} Previous studies^{12,18,19} have demonstrated marked differences in haemodynamic indices of normotensive and hypertensive pregnant patients. The hypertensive patient also has a higher total peripheral resistance and a decreased plasma volume.¹²⁻¹⁵ These indices are subject to rapid and frequent changes as a result of medical therapy and/or anaesthesia. In particular induction of anaesthesia, whether regional or general, may cause profound haemodynamic changes.

Monitoring of the pulmonary capillary wedge pressure allows accurate and immediate assessment of the patient's fluid requirements. The four cases are presented to illustrate this. Insertion of a Swan-Ganz catheter can be done by the bedside in the delivery room.

We believe that all patients with severe pre-eclampsia should have cardiac filling pressures monitored. In many patients the central venous pressure (CVP) (right heart filling pressure) would be adequate because it accurately reflects the haemodynamics of the left side of the heart. However, the CVP is not always reliable because of the possibility of non-cardiogenic pulmonary oedema.^{3,15-17} There are not enough data in our series for useful comparison of the CVP and pulmonary capillary wedge pressure. We maintain that rapid infusion of large volumes of fluids may cause significant morbidity and should be closely monitored. We aim for a pulmonary capillary wedge pressure of 1.33 kPa (10 torr) before induction of anaesthesia for caesarean section.

Hodgkinson and coworkers²⁰ recently compared systemic and pulmonary blood pressure during caesarean section in hypertensive parturients. Hodgkinson cautioned (and we agree) against using the small number of cases reported to draw any conclusion as to the relative safety of general and epidural anaesthesia. Enough information is not yet available.

Patients with pre-eclampsia and eclampsia of pregnancy offer a major challenge to the perinatal team. Continuous co-operation of obstetricians, anaesthetists, neonatologists and nurses is required to improve maternal and neonatal outcome.

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RÉSUMÉ

Quatre observations sont présentées dans le but d'illustrer que le monitoring hémodynamique peut-être utile au traitement de la pré-éclampsie grave et de l'éclampsie. L'application d'un traitement intensif guidé par un monitoring adéquat à des patientes en salle d'accouchement est réalisable et peut être d'un grand secours dans la conduite de la thérapie liquidienne et/ou de l'anesthésie.