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RELATIONSHIP OF PUMP FLOW AND EXPIRED PUMP CO2 ON CARDIOPULMONARY BYPASS: AN OBSERVATIONAL STUDY

Anesthesiology

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ABSTRACT

Aim - To study the relationship of pump flow and expired pump Co2 (PepCo2) on cardiopulmonary bypass (CPB).

Background - PepCo2 (partial pressure of expired pump carbon dioxide) is a good correlator of PaCo2 during CPB. It is established that PaCo2 reflects cardiac output in a state of controlled ventilation.

Hence, it was hypothesized that PepCo2 is an indicator of changes in pump flow (cardiac output) during CPB where oxygenator acts as an ideal lung.

Methodology – An observational study was conducted in 30 patients of either sex undergoing open heart surgeries under CPB to establish the relation between $PepCo_2$ and pump flow.

Keeping constant sweep flow rate and temperature during CPB, $PaCO_2$ and $PepCO_2$ values were measured at stable hypothermia 30oC . The variations in $PepCo_2$ were observed by adjusting the pump flow within the permissible range of cardiac index for that patient. The adequacy of perfusion was also assessed by measuring SvO_2, glucose, and lactate levels.

Results - It was observed that values of PepCO2 correlated with the pump flow (p=0.011) and change in $PepCO_2$ has definite positive relationship with the change in pump flow. One unit change in pump flow resulted in 0.97unit change in $PepCO_2$.

Conclusion - $PepCo_2$ on cardiopulmonary bypass is a good continuous, non-invasive tool for monitoring adequacy of pump flow. Hence ,it is recommended to monitor $PepCo_2$ routinely during CPB.

KEYWORDS

cardiac output, $PepCO_2$ (expired pump CO_2), pump flow

Introduction -

Monitoring carbon dioxide during anesthesia is considered as standard of care. During CPB, blood gas measurements are done frequently to measure $PaCO_2$. Since $PepCO_2$ is correlative of $PaCO_2$, measurement of PepCO2 can be a continuous monitoring tool[1,2,3] .$PepCO_2$ during CPB is dependent on ventilation which corresponds to sweep gas flow of oxygenator , cardiac output which is similar to pump flow on CPB and metabolism which corelates with temperature.$PepCO_2$ can be altered by sweep gas flow and changes in temperature. In this study attempt has been made to establish a relation between Pump flow and $PepCO_2$ keeping the sweep flow and temperature constant.

Methods & Materials -

We studied 30 patients of either sex undergoing elective cardiac surgery under cardiopulmonary bypass.The mean age of patients was 34 years. All patients undergoing open heart surgeries under CPB and cooled to 30oC were taken for study. Patients were induced with inj midazolam 0.01mg/kg , inj fentanyl 5-10µg/kg, inj propofol 0.25-0.5mg/kg and inj vecuronium 0.1mg/kg. Maintenance of anaesthesia was achieved with sevoflurane 0.6-0.8% and intermittent fentanyl and vecuronium. The cardiac index and the pump flows were calculated and given accordingly at baseline temperature and at 30oC which was stable hypothermia.

Medtronic membrane oxygenator (Affinity) was used in all the patients. PepCo2 was monitored continuously by Draeger Primus anaesthesia workstation . The capnography catheter was connected via a vented connecter to the scavenging port of the oxygenator. 1 meter long tube was used to prevent dilution of Co2. Care was taken to prevent occlusion of the oxygenator exhaust port due to kinking of the tube.4 Arterial and venous blood gas analysis was done with alpha stat method. Fio2 and sweep flow rate were kept constant and pump flow and PepCo2 values were recorded after going on cardiopulmonary bypass(baseline). Stable hypothermia was achieved at 300 and lowest permissible flows were given and after 5 minutes PepCo2 was recorded and arterial blood gas(ABG), venous blood gas(VBG) analysis was done. Mean arterial pressure(MAP) and urine output were also recorded. Then the highest permissible flows were given and after 5 min same readings were again taken. Later, the pump flow was resumed to normal. The readings were taken at 2 levels of pump flow at same temperature in order to establish the relation between pump flow and $PepCo_2$.

Results -

The study enrolled 30 patients undergoing valve replacements, coronary artery bypass grafting(CABG) and intracardiac repair(ICR). Correlation of pump flow with PepCo2 was done by Pearson correlation.The value of PepCo2 to changed pump flow was statistically significant (p value < 0.05).

Table 1

	Initial values (Mean)	Changed values (Mean)
Pump Flow ($L/m^2/min$)	2.59	3.69
$PepCo_2$ (mm of Hg)	22.56	27.86

Change in PepCo2 = 4.229 +0.971 Change in pump flow (F=1.762 , p=0.195, R2 = 5.9 % .Regression equation has been performed using pump flow as an independent variable. This shows a definite positive correlation between them and one unit change in pump flow resulted in 0.97 unit change in $PepCo_2$.

The changes in lactate, SVO2 ,glucose are not significant.There were no significant changes in MAP and urine output.Postoperative cognitive dysfunction was not seen in any patient.

Table 2

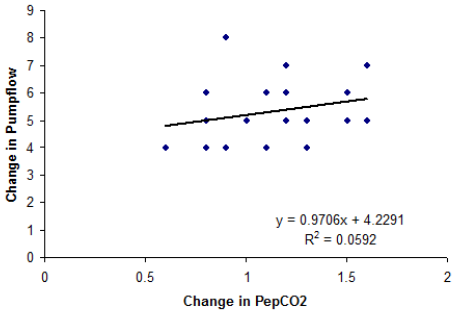
Variable	1st reading	2nd reading	Change	P value
PaO_2	259.57±46.59	260.35±47.27	0.78	0.750
SVO_2	58.22±7.15	60.12±6.82	0.89	0.251
Glucose	134.46±18.58	135.63±18.78	1.17	0.138
Lactate	1.84±0.64	1.86±0.62	0.02	0.246
FiO_2	58.67±5.56	58.67±5.07	1.00	0.184
SaO_2	99.84±0.36	99.84±0.37	0.0	-

Table 3: Correlation of pump flow with pepCo2

	Pearson correlation	P value
Pump flow1 vs $PepCo_2$1	0.238	0.205
Pump flow2 vs $PepCo_2$ 2	0.457	0.011*

Change in PepCo2=4.229+0.971*change in Pump flow (F=1.762; P=0.195; R2=5.9%)

Graph 1



Discussion –

The relationship between $PaCo_2$ and $PepCo_2$ during CPB in routine cardiac surgery has been established[4]. The mean bias and 95% limits of agreement between $PaCo_2$ and $PepCo_2$ are within ± 6 mmHg. Monitoring of $PaCo_2$ is necessary as CO_2 has deleterious effects on central nervous system. The membrane oxygenator capnography ($PepCO_2$) indicates $PaCO_2$ levels during normothermia and stable hypothermia5. Attempt has been made to establish a relation between the pump flow and $PepCo_2$ keeping the sweep flow rate constant.The parameters that affect CO_2 production and washout are temperature and sweep flow. As these are kept constant any changes in CO_2 levels are attributed to changes caused by the pump flow.

The determinants of $PepCo_2$ during CPB are mainly the
1. Ventilation which is determined by sweep flow since oxygenator is an ideal lung there is constant ventilaton
2. Cardiac output which equals pump flow
3. Temperature.

The fundamental relation of end tidal carbon dioxide (ETCO2) and cardiac output is that under constant lung ventilation ETCO2 is a measure of pulmonary blood flow and cardiac output 6,7. Similarly $PepCo_2$ can be used as a measure to monitor the adequacy of pump flow. Thus, according to our study there exists a definite positive correlation between the pump flow and $PepCo_2$.

In conclusion, any changes in $PepCo_2$ should alarm the adequacy of pump flow that is administered to the patient on CPB. Since $PepCo_2$ is a simple, continuous, noninvasive tool it can be used as a routine monitor during CPB.

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