

EFFECT OF PERITONEAL DIALYSIS ON BLOOD LEVELS OF CARBON DIOXIDE IN CHILDREN UPTO 16 YEARS OF AGE

K.R. Chaitra¹, Vinay Badri²

¹Assistant Professor, Department of Pediatrics, Navodaya Medical College, Raichur, Karnataka, India

²Associate Professor, Department of Nephrology, Rajiv Gandhi Super speciality Hospital, Raichur, Karnataka, India

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Corresponding Author:
Dr. K R Chaitra
Email: chetu.kims@gmail.com

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ABSTRACT

Background: Despite maximal ventilator support, many patients die from hypercarbia in the setting of potentially reversible respiratory failure. There remains a pressing need for additional pulmonary supportive measures, which are feasible and cost effective. The objective was to determine whether peritoneal dialysis had any effect on blood levels of CO₂. **Materials and Methods:** It was a prospective observational study in which 30 children in whom peritoneal dialysis was indicated were enrolled in the study in Pediatric intensive care unit of Kalawati Saran Children Hospital, Lady Hardinge Medical College, New Delhi and serial measurement of venous blood and dialysate fluid at 0hrs, 30min, 1hr, 4hrs, 12hrs and 24hrs were done using the ABG 800 basic analyser and pH, pCO₂ and pO₂ of both the fluids were subsequently measured and interpreted. **Result:** Venous levels of blood pCO₂ measured at the start of peritoneal dialysis was 46.18±10.61, followed by which venous pCO₂ measured at 1 hr showed a mean decrease in pCO₂ levels to 43.07±8.89 with a continuous in pCO₂ levels observed over a period of 24 hrs. The dialysis fluid pCO₂ analysed at baseline was 17.67± 1.82 and that measured at 1 hr showed a mean increase to 33.94± 11.6, showing there was an increase in dialysate fluid pCO₂ in comparison to baseline, showing the exchange of CO₂ through peritoneum, and also a rapid equilibration of dialysate fluid pCO₂ to blood pCO₂ levels subsequently. **Conclusion:** Our study demonstrated that peritoneal dialysis effectively decreases the blood levels of CO₂, supported by the observation that carbon dioxide levels of returning dialysate fluid increased with respect to the baseline and subsequently attained equilibrium with blood levels. This study opens up new avenues in the management of respiratory failure and use of peritoneal dialysis as an alternative mode of therapy in respiratory failure to decrease pCO₂ levels.

INTRODUCTION

Peritoneal dialysis is a common procedure done in pediatric intensive care unit (PICU) setting in children with renal diseases, electrolyte imbalances, metabolic disturbances and poisonings. The concept of osmotic equilibrium between peritoneal fluid and plasma was established by Putnam in 1922.^[1] This novel concept of equilibration dialysis can be studied for carbon dioxide exchange and the same applied as a mode of therapy in respiratory failure.

In cases of respiratory failure, a variety of methods are used for treatment, those being ventilators,^[2] extracorporeal oxygenators,^[3] intragastric oxygen,^[4] and hyperbaric oxygen,^[5] in order to maintain adequate oxygenation. However the results are not uniformly satisfactory. The greatest disadvantage with ventilator methods is that they attempt to force

gaseous exchange through a diseased lung. This demands an additional or an alternative method to handle the gases in respiratory failure.^[6]

In cases of respiratory failure, primary aim is to provide adequate oxygenation with adequate CO₂ removal using safe ventilation strategies. Despite all conventional modalities of treatment refractory hypercarbia may persist. In some cases ventilator support may be sufficient to handle hypoxia alone, however levels of CO₂ remains higher than accepted levels. This demanded an alternative way to handle CO₂. The peritoneum, has a large, absorptive, highly permeable, rich vascular bed, making it potentially an ideal organ for extra pulmonary gas exchange. Also CO₂ is a highly diffusible gas whose exchange can be effectively measured and studied.^[7] Hence in this preliminary pilot study, we had planned to assess the role of peritoneal dialysis in gas exchange

particularly carbon dioxide. Peritoneal dialysis may be beneficial or act as a supportive measure to ventilation in children with respiratory failure with persistent hypercarbia.

Methods: It was a prospective observational study done within a time frame of Jan 2013 to March 2014 in PICU of Kalawati Saran Children Hospital, where 30 consecutive children requiring peritoneal dialysis and fulfilling inclusion criteria were enrolled. Inclusion criteria was any child aged up to 16yrs and that child requiring peritoneal dialysis for any of the indication: acute or chronic renal failure or metabolic disturbances. However children who have sustained cardiorespiratory arrest before, children with ascites, grossly distended bowel loop and hypovolemic shock were excluded from the study.

MATERIALS AND METHODS

Venous blood and dialysate fluid were analysed separately for the pCO₂ levels. Venous blood was collected through venepuncture and blood was withdrawn through 1ml heparinized syringe. Heparinized syringe was used as all gases were forced into solution in acidic environment⁸. Air bubbles were immediately removed to avoid inaccurate values. Venous blood which was collected was analysed immediately within 10 minutes of collection by the analyser in the PICU. After the baseline was drawn at 0hrs venous blood was collected at 1, 4, 12, 24 hrs of the start of the peritoneal dialysis and were subsequently analysed. Peritoneal dialysis was performed in patients in whom it was indicated. Initially the bladder was emptied by catheterization and the abdomen was prepared and draped in patient lying in supine position. The skin and subcutaneous tissue was anaesthetized in the midline at one third of the distance from the umbilicus to pubic symphysis. A 16 or 18 gauge intracath was inserted at the above mentioned point into the peritoneal cavity and 20 – 40ml/kg of warm dialysate fluid was infused over a period of 5 – 10 min to distend the abdomen and facilitate catheter insertion. Later the intracath was removed and the PD catheter was prepared.

Subsequently the stylet was inserted into the catheter and the black markings were noted which indicated the direction of the curve of the tip, which was facing the pubic symphysis. Then the abdominal wall was punctured with no. 15 blade held vertically.

PD catheter was inserted along with the stylet using a gentle boring motion. The right angled of the connecting set was attached to the catheter and dialysis fluid was run, where the flow was in a continuous stream. The inflow was then started with a time of 10 – 15 min, indwelling time of 20 – 30 min and outflow time of 10 – 15 min. Strict asepsis was maintained throughout the procedure.

A baseline value of dialysate fluid was also obtained and was analysed at 30min, 1,2, 4, 12, 24hrs. Dialysate fluid was collected through the

outflow tube of the dialysis unit which was in turn connected to a three way system in order to avoid air bubbles.

ABL 800 basic analyser was used for both VBG analysis and Dialysis fluid analysis.

Baseline value of PD fluid pCO₂ were analysed ,50 each of conventional PD fluid of 1.7 dextrose concentration and 4.2% dextrose concentration with a total of 100 samples before the start of the above mentioned study in the same analyser used for venous blood gas analysis ABL 800 basic analyser. It was noted that the mean dialysate pCO₂ levels was 17.89± 2.34. It was done in different batches of peritoneal fluid. Similarly the mean baseline value of dialysate fluid pCO₂ in our study matched with the above-mentioned trial with a mean value of 17.67±1.82 at 0 hrs.

Ethics: The study was approved by the institutional ethical committee.

Statistical Analysis: Descriptive statistics were used to present the data collected. Normality of the data was tested using Shapiro wilk test. Data with normal distribution were described using mean (SD) and the continuous outcome variables were analysed using student t test and paired t test. Data with skewed distribution were described using median (IQR). The corresponding non parametric data were compared using Wilcoxon sign test and Mann Whitney U test. p value of < 0.05 was taken as significant. Results of study were tabulated and analysed using standard statistical methods such as SPSS software.

RESULTS

Demographic characteristics showed that out of the 30 children enrolled, 50% were <1yr, 33.3% were between 6-10yrs and 16.7% were above 10yrs of age with equal sex distribution of 50% each of males and females.

Baseline characteristics of the study showing the frequency of different clinical manifestations, general physical examination, duration of stay in hospital, mean duration of illness and baseline laboratory parameters at the start of the study are shown in [Table 1].

Disease parameters mainly showed the disease conditions for which the child was admitted and subsequently peritoneal dialysis indicated. 17 out of 30 children underwent peritoneal dialysis for acute kidney injury and associated indications, 11 of them chronic kidney disease and 2 of them had acute on chronic kidney disease.

Levels of blood and returning dialysate fluid were analyzed separately at 1, 4 ,12 and 24 hrs in comparison with the baseline. Serial changes in blood and dialysate were analyzed and tabulated separately. Values at 4, 12 and 24 hrs of blood pCO₂ levels were compared with the baseline using paired sample test, while value at 1hr was compared with the baseline using Wilcoxon sign rank test (non-normal distribution) The change in blood pCO₂ was

statistically significant at 1, 4, 12 and 24 hrs in comparison with the baseline that is at 0 hrs. Maximum change was seen at 4 hours with a p value of <0.001. [Table 2]

Mean values plotted on a graph showed a progressive decrease in blood pCO₂ levels which was maximum at 4hrs and with a gradual increase thereafter.

The change in dialysate fluid pCO₂ was statistically significant at 1, 4, 12 and 24 hrs in comparison with the baseline that is at 0 hrs. The change was equally

statistically significant at all hours with a p value of <0.001 [Table 3].

Comparison between blood and dialysate fluid pCO₂ values reflects the peritoneal exchange of CO₂ measured simultaneously both in blood and the returning dialysate fluid. [Table 4]. There is a rapid equilibration of blood and dialysate fluid pCO₂ levels indicating exchange of carbon dioxide through peritoneal dialysis. [Figure1]

Table 1: baseline characteristics of study population at admission

Baseline parameter	Frequency	Baseline parameter (investigations)	Frequency
Median age (range)	5.5years(0.25-15)	pH (mean)	7.20±0.10
M:F ratio	1:1	pCO ₂ (mean)	46.18±10.61
Weight for age <3rd centile	33.33%	pO ₂ (mean)	59.82±13.77
Height for age <3rd centile	50%	HCO ₃ mEq/l (mean)	15.23±4.00
BP>95th centile	46.67%	Blood urea mg/dl (median)	222.5 (138.75 - 337.0)
GCS<8	16.6%	Serum creatinine mg/dl (median)	4.7 (2.375 - 6.65)
Palor	86.7%	CXR(s/o pulmonary edema)	33.33%
b/l pedal pitting edema	63.3%	USG KUB (contracted kidney)	36.66%
Hospital stay (median)	12 days(4-60 days)	CKD	43.3%
Duration of illness(mean)	4.3 days	AKI	56.7%

Table 2: Serial changes in blood pCO₂ levels

PCO ₂	Mean ± SD	Min - Max	Mean Difference from Baseline	P value
Baseline	46.18 ± 10.61	25.0 - 80.6		
1HRS	43.07 ± 8.89	23.0 - 71.6	3.11 ± 4.37	0.001*
4HRS	38.89 ± 7.41	23.1 - 58.0	7.29 ± 6.42	<0.001
12HRS	39.51 ± 7.03	28.0 - 52.0	6.67 ± 10.96	0.002
24HRS	41.34 ± 6.37	29.0 - 54.0	4.84 ± 12.05	0.036

Table 3: serial changes in dialysate fluid pCO₂ levels

PCO ₂	Mean ± SD	Min - Max	P value difference from baseline
Baseline	17.67 ± 1.82	13.6 - 23.6	
30 min	20.27 ± 2.87	16.0 - 28.0	<0.001
1hr	33.94 ± 11.61	16.2 - 56.0	<0.001
2 hrs	36.53 ± 9.95	17.0 - 55.0	<0.001
4 hrs	35.19±8.27	17.0 - 54.7	<0.001
12 hrs	36.95±10.92	23 - 53	<0.001
24 hrs	39.52 ± 9.43	14.4 - 57.6	<0.001

p value <0.05 taken as significant.

Table 4: comparison between blood and dialysate fluid pCO₂ levels

	Blood PCO ₂ Mean±SD	Dialysate PCO ₂ Mean±SD
0 HRS	46.18 ± 10.61	17.67±1.82
1HR	43.07 ± 8.89	33.94±11.61
4HRS	38.89 ± 7.41	35.19±8.27
12HRS	39.51 ± 7.03	36.95±10.92
24HRS	41.34 ± 6.37	39.52±9.43

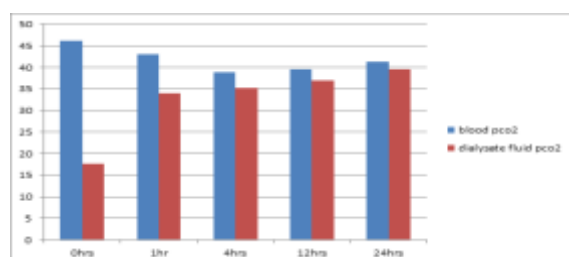


Figure 1: comparison between blood and dialysate fluid pCO₂.

DISCUSSION

In this study the trend of change in pCO₂ was studied in both blood and dialysate fluid along with the change in hemodynamic parameters.

Our main aim of the study was to see the effect of peritoneal dialysis on the blood levels of carbon dioxide. Venous levels of blood pCO₂ at the baseline, that is at the start of peritoneal dialysis was 46.18±10.61, followed by which venous pCO₂ measured at 1 hr showed a mean decrease in pCO₂ levels to 43.07±8.89 and subsequently measured at 4hrs showed a mean improvement of venous pCO₂ levels to 38.89±7.41. This was comparable to a study conducted by Boda et al and P.J. Collipp(1968)

where peritoneal dialysis was conducted in premature infants having respiratory distress syndrome⁹, which showed a decrease in pCO₂ at 3hrs of PD in comparison to the baseline, with subsequent rise in pCO₂ levels, however never reaching the baseline values.^[8-15]

The improvement in hypercarbia at 1,4, 12 and 24hrs with peritoneal dialysis can be compared to a study done by Barr J et al,^[10] (1994) where peritoneal ventilation was used as adjunct to mechanical ventilation in an animal model of ARDS, where significant improvement in hypoxia and hypercarbia was seen over a study period of 120 min.

The mean decrease in pCO₂ at 1hr and 4 hrs in comparison to the baseline was 3 and 7 mm of Hg respectively in contrast to Rowney et al,^[11] where carbon dioxide insufflation for laparoscopic surgery showed a median increase in pCO₂ of 7.6 mm of Hg, with a median duration of 2 hrs, signifying the exchange of CO₂ through peritoneum.

There were certain confounding factors in the study such as, the major route of excretion of CO₂ being lungs, the level of oxygenation and CO₂ removal depended upon the diseased status of the lungs; metabolic status of the body such as in metabolic acidosis, there was compensatory decrease in blood levels of CO₂; ventilated status of the patient. Hence in order to overcome the influence of these factors, the corresponding levels of dialysate fluid pCO₂ were checked in order to show that exchange of CO₂ does happen through peritoneal membrane also, thus signifying the use of peritoneal dialysis.

The dialysis fluid pCO₂ was analysed at baseline and subsequently along with the blood pCO₂ at 1, 4, 12 and 24hrs. The initial value being 17.67±1.82 and 33.94±11.61, 35.19±8.27, 36.95±10.92 and 39.52±9.43 at 1, 4, 12 and 24 hrs respectively with a statistically significant difference in comparison to the baseline with a p<0.001. It showed there was an increase in dialysate fluid pCO₂ in comparison to the baseline, showing the exchange of CO₂ through peritoneum, and there was rapid equilibration to the blood pCO₂ levels subsequently. This is in accordance with Sherlock et al (1972),^[12] Kolobow et al,^[13] (1977) which showed that carbon dioxide can be exchanged through artificial membranes other than lungs for extracorporeal carbon dioxide removal. This was an empirical observation of carbon dioxide reduction seen during renal replacement therapy. This concept also suggested that respiratory function can be supported by an artificial kidney or an artificial lung which led to the development of new concepts of membrane gas exchange. This was comparable to a study conducted by Bharat S Shah,^[14] in an invitro model of a new method for paracorporeal removal of CO₂, consisting of modified peritoneal dialysis combined with chemical extraction of predominantly bicarbonate CO₂, which also showed that carbon dioxide removal increased in patients with hypercarbic states with increased peritoneal supply of CO₂ for a given blood supply.

The diffusion of CO₂ across the peritoneal membrane was seen, evident by the changes in dialysate fluid pCO₂ levels even at 30 min. (pCO₂ at 30 min was 20.27±2.87 as compared to the baseline pCO₂ of 17.67±1.82, with a p value of <0.001). Reduction of pCO₂ in blood to a level <45mm of Hg however could only be achieved by 4 hrs (blood pCO₂ at 4hrs was 38.89±7.41 compared to baseline pCO₂ value of 46.18±10.61 with a p value of <0.001). pulmonary oedema following acute or chronic kidney disease was one of the major indication for peritoneal dialysis. Therefore reduction of fluid overload and pulmonary oedema could have also led to improved ventilation following PD. These observations suggest that the reduction in CO₂ possibly indicate a total sum of removal of CO₂ with peritoneal as well as respiratory system.

The study highlights the role of peritoneal dialysis may be expanded to use in children with respiratory failure, specifically in children with refractory hypercarbia. If similar results could be reproduced in a trial involving a larger study population, it could extend the use of peritoneal dialysis and would provide another option for management in respiratory failure.

CONCLUSION

In our prospective observational study we found out that peritoneal dialysis as a modality in handling CO₂ is both safe and efficient. This is the first study of its kind where CO₂ exchange was studied in patients undergoing peritoneal dialysis. We found out that peritoneal dialysis effectively decreases the blood levels of CO₂, supported by the observation that the carbon dioxide levels of returning dialysate fluid increased with respect to the baseline signifying the exchange of CO₂ through peritoneal dialysis. The hemodynamic stability was achieved, sustained and the sensorium of the patients improved by the end of the study. This study opens up new avenues in the management of respiratory failure throwing open the debate whether peritoneal dialysis should be used as an alternative mode of therapy in cases of respiratory failure refractory to conventional methods of treatment.

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