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# The Influence of Deadspace of Pressure Connecting Tubing on Arterial Blood Gas Determinations

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*This study was undertaken to determine the effect on blood gas determinations of an incomplete purging of the heparinized flush solution from an indwelling arterial catheter and pressure tubing. Arterial blood gases were measured serially after withdrawing 2,4,6,8,10, and 12 ml of flush-blood solution from a 20-gauge radial artery catheter which was connected to one of two kinds of pressure tubing (4-ft and 6-ft Cobe pressure lines). In those samples from the 4-ft Cobe pressure tubing, the pH was nearly unchanged in sampes 2 thru 6, while the $PaCO_2$, $PaO_2$, actual bicarbonate, and base excess remained approximately constant in samples 3 thru 6. The results of samples taken from the 6-ft tubing were that the pH remained unchanged from samples 3 to 6, and $PaCO_2$, actual bicarbonate, and base excess remained the same from samples 4 onward. $PaO_2$ was unchanged in all samples. In conclusion we suggest that at least 4 ml of blood from a 4-ft Cobe pressure tubing and 6 ml from a 6-ft tubing should be withdrawn prior to arterial blood gas measurements.*

**Key Words:** Arterial blood gas, heparinized flush solution, Cobe pressure tubing, radial artery catheter.

Radial artery cannulation is frequently used in the operating room to monitor blood pressure continuously and to provide a means for continuous blood gas analyses including acid base balance. Sometimes the results do not agree with the clinical impression, most notably a sporadically low $PaCO_2$. In this case, a reanalysis often gives results which are more compatible with the clinical evaluation. Based on these findings, we evaluated the affects of an incomplete removal of the heparinized solution from an arterial catheter and the connecting pressure tubing on arterial blood gas determinations.

## METHODS

Arterial blood samples from 20 randomly chosen patients (Table 1) were reviewed. The patients' cardiopulmonary status were normal, and all surgeries were performed in the supine position. We selected lengthy operations. Either 4-ft or 6-ft Cobe pressure tubing (Cobe Laboratories, Inc.) was applied to each of 10 patients.

One hour prior to surgery Robinul (0.2 mg) and hydroxyzine (1 mg/kg) were given and 2.5% thiopental (4 mg/kg) and succinylcholine (1.5 mg/kg) were injected intravenously as induction agents. Following intubation pancuronium (0.03 mg/kg) was injected and controlled ventilation using a volume type Ohio® anesthesia ventilator was maintained throughout the operation.

Tidal volume was 10 ml/kg and the respiratory rate was 12 times/min.. 50% $N_2O$-$O_2$-halothane ($O_2$:OL/min., $N_2O$:2L/min.) or enflurane was administered as an inhalation agent. After induction, a modified Allen's test was performed, and radial artery cannulation was done with a 20 gauge angiocatheter. 4-ft or 6-ft Cobe pressure tubing was connected to a pressure transducer to each of 10 patients and blood pressure was monitored continuously. The internal

**Table 1. Age, Weight, and Sex distribution of patients (Mean±SD, N=20)**

| | Pressure Transmission Lines | |
|---|---|---|
| | 4-ft Cobe | 6-ft Cobe |
| No. of Patients | 10 | 10 |
| Age(yr) | 48±11 | 53±8 |
| Weight (kg) | 60±11 | 56±18 |
| Sex (m/f) | 8/2 | 5/5 |

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volume of 4-ft and 6-ft Cobe pressure tubing was 3 ml and 5 ml respectively.

A flushing solution of heparin 1000 units (10 mg) mixed with 1000 ml of Hartman's solution was flushed intermittently through the catheter during surgery. 6 plastic syringes (volume: 3ml) which were flushed with the heparin solution were prepared. Arterial blood was withdrawn serially 6 times (syringes 1-6) through the 3-way stopcock, which is attached at the distal end of the pressure tubing, 30 to 60 minutes after induction. Each 2 ml sample was withdrawn, debubbled, capped, iced, and then immediately analyzed in a blood gas analyzer (model 75, Corning, Millford, MA).

Three minutes before sampling the arterial line was flushed and the internal volume of the arterial line was filled with the flushing solution. The statistical analyses performed were Analysis of Variance (ANOVA) and the multiple range test. One-way ANOVAS with the Scheffe procedure was used to test the significance of differences among the means of the six samples. Results were considered statistically significant if the p value was less than 0.05.

## RESULTS

### 4-ft Cobe pressure tubing (Table 2)

Although there was a significant difference in pH between samples 1 and 2, the mean pH was nearly identical in samples 2,3,4,5, and 6. The mean $PaCO_2$, $PaO_2$, actual bicarbonate and base excess presented differences between samples 2 and 3. However there were no significant differences between samples 1 and 2, and among 3,4,5, and 6.

### 6-ft Cobe pressure tubing (Table 3)

While the mean pH was nearly identical in samples 3,4,5, and 6, there was a significant difference between samples 2 and 3. In $PaCO_2$, actual bicarbonate, and base excess there were no differences among samples 1,2 and 3, and among 4,5, and 6, but there was a significant difference between samples 3 and 4. $PaO_2$ was nearly identical in all samples.

**Table 2. Arterial blood gas values obtained using 4-ft Cobe pressure tubing (Mean±SD, N=10)**

| | Sample No. | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Aliquot (ml) | 0–2 | 2–4 | 4–6 | 6–8 | 8–10 | 10–12 |
| pH | 6.29±0.06 | 7.49±0.07* | 7.56±0.07 | 7.55±0.06 | 7.56±0.06 | 7.56±0.07 |
| $PaCO_2$ (torr) | 9.0±2.7 | 9.9±2.7 | 27.1±5.0+ | 29.0±5.5 | 28.7±5.8 | 28.9±5.1 |
| $PaO_2$ (torr) | 130.7±17.2 | 159.2±25.0 | 207.9±39.2+ | 201.6±44.0 | 210.9±36.7 | 212.5±39.0 |
| $HCO_3^-$ (mEq/L) | 0.4±0.5 | 7.5±1.8 | 24.2±2.2+ | 25.3±2.2 | 25.5±2.1 | 25.7±2.0 |
| B.Ex (mEq/L) | −37.4±3.0 | −12.3±3.0 | 3.6±2.4+ | 4.5±2.2 | 4.5±2.3 | 4.5±2.5 |

* $P<0.05$ between samples 1 and 2 for pH

+$P<0.05$ between samples 2 and 3 for $PaCO_2$, $PaO_2$, $HCO_3^-$, and B.Ex.

**Table 3. Arterial blood gas values obtained using 6-ft cobe pressure tubing (Mean±SD, N=10)**

| | Sample No. | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Aliquot (ml) | 0–2 | 2–4 | 4–6 | 6–8 | 8–10 | 10–12 |
| pH | 6.32±0.26 | 6.15±0.22 | 7.47±0.11* | 7.50±0.12 | 7.50±0.11 | 7.49±0.11 |
| $PaCO_2$ (torr) | 7.7±0.7 | 8.4±0.7 | 13.4±2.5 | 32.4±5.9+ | 34.2±6.1 | 34.2±5.8 |
| $PaO_2$ (torr) | 162.4±15.1 | 165.4±12.7 | 183.4±27.6 | 200.6±53.0 | 201.9±56.9 | 105.9±55.1 |
| $HCO_3^-$ (mEq/L) | 0.3±0.5 | 0.2±0.4 | 10.0±1.7 | 24.7±2.8+ | 26.3±3.4 | 26.3±3.3 |
| B.Ex (mEq/L) | −47.4±6.9 | −51.9±5.8 | −10.1±4.0 | 2.8±4.5+ | 4.1±5.2 | 4.1±5.2 |

* $P<0.05$ between samples 2 and 3 for pH

+$P<0.05$ between samples 3 and 4 for $PaCO_2$, $HCO_3^-$, and B.Ex

## DISCUSSION

Errors in hematocrits due to incomplete flush purging have been reported (Bourke 1976), and errors in blood gas determinations as a result of in vitro dilution by heparin due to the dilution of the deadspace of the syringe has also been reported (Hutchison *et al.* 1983; Holliday 1983; Jones *et al.* 1983; Mellor & Innanen 1983; Turton 1983).

No appreciable decrease in pH was observed until 40% of the sample volume had been replaced by heparin. There were appreciable decreases in the carbon dioxide pressure and bicarbonate concentration until 10% of the sample volume had been replaced by heparin. There was an inverse relation to the volume of heparin used. A similar change in base excess is also shown, but no appreciable change in the oxygen pressure was seen, even with high dilutions of heparin (Hutchison *et al.* 1983).

Bradley (1972) reported that carbon dioxide pressure was decreased from 4% dilution by the heparin, but there was no appreciable decrease in pH and $PO_2$ until 15% of the sample volume had been replaced by heparin.

Dennis *et al.* (1985) used 7-ft pressure tubing (they didn't explain precisely about the kind and character of the pressure tubing) and withdrew 2 ml of arterial blood serially from the distal end of the pressure tubing. They reported that the pH was nearly identical in syringes 4,5, and 6 (syringe numbering is the same as ours). $PaO_2$ was nearly identical in syringes 5 and 6, while $PaCO_2$ was different between syringes 5 and 6. They reported that the change in $PaCO_2$ was greater than that of pH and $PaO_2$ by sample dilution.

In the 4-ft Cobe pressure tubing the pH was not diluted by heparin from sample 2, and $PaCO_2$, $PaO_2$, actual bicarbonate and base excess were not from sample 3 onward. $PaCO_2$ increased from 9.9 to 27.1 torr (274%), actual bicarbonate from 7.5 to 24.2 mEq/L (323%), and base excess from −12.3 to 3.6 mEq/L (1500%). However pH increased minimally from 6.29 to 7.49 (120%), and $PaO_2$ from 159 to 208 torr (130%). $PaCO_2$, actual bicarbonate and base excess increased more than pH and $PaO_2$. Based on these results $PaCO_2$, actual bicarbonate, and base excess were affected much more than pH and $PaO_2$ when the sample was diluted with heparin. These results are in agreement with other reports (Hutchison *et al.* 1983; Bradley 1972; Dennis *et al.* 1985).

In 6-ft Cobe pressure tubing pH was accurate (not diluted by heparin) from sample 3, $PaCO_2$, actual bicarbonate, and base excess were from sample 4, and $PaO_2$ in all samples. $PaCO_2$ increased from 13.4 to 32.4 torr (242%), actual bicarbonate from 10 to 24.7 mEq/L (247%), and base excess was from −10.1 to 2.8 mEq/L (1290%). pH was from 6.15 to 7.47 (120%), while $PaO_2$ was not changed (0%). Based on these results $PaCO_2$, actual bicarbonate and base excess were more affected than pH and $PaO_2$. These results are also compatible with other reports as described above.

## CONCLUSION

In order to achieve acceptable blood gas results through 4-ft and 6-ft Cobe pressure tubing at the distal end of the pressure tubing, we conclude that at least 4 ml of arterial blood should be withdrawn before sampling in 4-ft Cobe pressure tubing and 6 ml in 6-ft Cobe pressure tubing.

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