Original Article

# The Validity of Post Flight Urinary pH Measurement as an Indicator of Inflight Hyperventilation

EM Iyer, NS Baboo, AK Sengupta

*The post flight incidence of appearence of alkaline urine was investigated in sixty seven pilots after a medium stress tail chase sortie of 40 min duration. The pilots were divided into two groups viz conversion trainees (Group A, n=17) and fully operational pilots (Group B, n=50). The above group of pilots were further divided into two groups i.e. pilots with more than 1000 hrs of flying experience (Group C, n=34) and the pilots with less than 1000 hrs of flying experience (Group D, n=33). Taking post flight urinary pH of 6.1 and above as the criteria for the apperance of alkaline urine, the study indicated that such an incidence was higher in Group 'A' (59%) and Group 'D' (67%) as against those observed in Group 'B' (44%) and Group 'C's (35%). This study demonstrates that the urinary pH, on account of its noninvasive nature, can be used for measuring the post flight incidence of appearance of alkaline urine, the probable cause of which appears to be hyperventilation.*

*Keywords : Inflight hyperventilation, urinary pH,*

The investigation of hyperventilation in aviation has proceeded along two main avenues. The first and simpler approach is to make retrospective diagnosis of hyperventilation, either from history or from special tests to identify cases; the second approach is to measure respiratory variables inflight[1,2].

Gibson[3] tried to develop a simple field test for hyperventilation based on single estimate of mixed venous $pCO_2$ ($PV_{CO_2}$) made soon after landing. Ellis and Wells[4] correlated acid/base components in the blood and urine of pilots before and after flight with alveolar CO2 ($PA_{CO_2}$) obtained during the same flight. The measurement of $PV_{CO_2}$ and $PA_{CO_2}$ would not be useful unless it is made immediately after landing[1]. The alternative approach to the investigation of hyperventilation in aviation is to measure respiratory variables in flight[1]. This has the disadvantages that the experimental technique often interferes with the primary task of flying and also that the equipment available is neither sufficiently small nor has adequate electronic stability in the flight environment. The measurement of urinary pH and Hydrogen ion ($H^+$) concentration before and after flight has been indicated as one of the methods for investigating hyperventilation, although the details of such findings are not available[4,5]. This study reports the findings of the preflight to post flight changes in urinary pH and $H^+$ concentration on 67 pilots.

## Material and Methods

*Subjects* : The investigation was carried out on 67 pilots. They were divided into four groups :-

Group 'A' (n = 17) : The subjects of this group were undergoing conversion to high performance aircraft. These subjects after passing out from Air Force Academy report at conversion unit. Syllabus to become fully operational is for one year, consisting, first six months training in basic's and last six months of advanced training. At the time of this experiment, they were at the end of advanced phase.

Group 'B' (n=50) : The subjects of this group were fully operational pilots.

The subjects belonging to group A and B were further divided into group 'C' and 'D'.

Group 'C' (n = 34) : These subjects had more than 1000 hrs of flying experience.

Group 'D' (n=33) : The subjects of this group were having a flying experience of less than 1000 hours.

*Details of Flight Profile* : A medium stress tail chase sortie profile of 40 min duration was flown by all the subjects. Aircraft used was either Kiran or Mig-21. The details of fight profile were as follows:-

Pilot No 1 heading pilot No 2 following take off, 10 seconds stagger, climb to 5 km, exercise hard turn and reversal through 180, two wings overs, three loops in succession, two barrel loops in succession. Pilot No 2, takes the lead and the same exercise repeated, rejoining and landing.

*Preflight and post flight urine collection, measurement of urinary pH and $H^+$ concentration:*

(a) Urine Collection : Control urine samples were obtained just prior to flight. For collection of control urine samples, subjects were asked to empty their bladder completely and were given 250 ml of water. They were asked to sit comfortably for a period of 40 min, and were then again asked to empty their bladder completely in a clean urine collecting jar. For the collection of post flight urine samples, subjects were asked to empty their bladder completely just prior to flight and were given 250 ml of water. Post flight urine samples were obtained 15 to 30 min after cessation of flight.

(b) Urine pH measurement : Measurement of urine pH was made on the freshly voided pre and post flight urine samples. Urinary pH was measured by means of closed glass electrodes (Systronic Digital pH Meter ,Model 335) and was read directly from the scale of a pH Meter. Since the pH meter may drift, it was standardized with three buffers of known pH immediately prior to use. After standardisation, electrodes were sprayed with distilled water, cleaned and dried with tissue paper. Electrodes were immersed in the urine sample. The pH of the urine was reported at the temperature of measurement.

The pre flight to post flight changes in the $H^+$ concentration in the Groups A, B, C and D were made by Students 't' test.

## Results

Table I shows the pre to post flight variation in hydrogen ion concentration in the subjects belonging to Group A, B, C and D. No significant variation in $H^+$ concentration was observed in the subjects belonging to these groups.

Table II shows the pre to post flight variation in hydrogen ion concentration in those subjects who had a post flight urinary pH of 6.1 and above. A significant reduction in the $H^+$ concentration was observed in these subjects of Group A, B and D.

## Discussion

The pH of the urine is a reflection of the ability of kidney to maintain normal $H^+$ concentration in plasma and extra cellular fluid[6,7]. The average adult on normal diet excretes about 50 to 100 meq of hydrogen ion to produce urine of about 6 pH[6,7]. In health, urine pH may vary between 4.6 to 8[6,7]. In the present study, when the average pre flight $H^+$ concentration of the subjects belonging to Groups A,B, C and D were converted to their respective pH value, the values of pH were within the above range. Also no significant difference was observed when the pre flight $H^+$ concentration values of different groups were compared with their respective post flight $H^+$ concentration values (Table I).

Greenhill et al[8] in their studies have devised a method by which an approximation of $HCO_3$ reabsorption threshold can be accomplished by giving increasing doses of oral $HCO_3$ and measuring urinary pH. Normally, when urinary pH is below 6.1, no $HCO_3$ is present in the urine. Bicarbonate starts appearing in the urine when the urinary pH is 6.1 and above. Although no theoretical explanation has been accounted for

***Table-I Preflight and postflight values of urinary pH and $H^+$ concentration***

| Group | Urinary $H^+$ concentration (nanomol/litre) | | | | Urinary pH | | | |
|---|---|---|---|---|---|---|---|---|
| | Preflight | Postflight | Mean Diff | p | Preflight | Postflight | Mean diff | p |
| A (n = 17) | 1584.95 ± 2492.20 | 1679.48 ± 2369.57 | +94.53 | NS | 5.80 | 5.70 | -0.10 | NS |
| B (n = 50) | 2318.38 ± 2324.75 | 2018.30 ± 2475.51 | -300.08 | NS | 5.63 | 5.70 | +0.01 | NS |
| C (n = 34) | 2364.03 ± 2545.78 | 2277.61 ± 2625.27 | -86.43 | NS | 5.63 | 5.64 | +0.01 | NS |
| D (n = 33) | 1812.82 ± 1713.35 | 1621.54 ± 2376.79 | -191.27 | NS | 5.74 | 5.79 | +0.05 | NS |

*Table-II Preflight and postflight values of urinary pH and $H^+$ concentration in the subjects with postflight urinary pH more than 6.1*

| Group | Positive Cases | | Urinary $H^+$ concentration (nanomol/l) | | | | Urinary pH | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No | % | Preflight | Postflight | MeanDiff | p | Preflight | Postflight | Mean diff | p |
| A (n = 17) | 10 | 59 | 835.70 ± 541.419 | 290.09 ± 244.455 | -545.637 | < 0.01 | 6.10 | 6.54 | -0.44 | < 0.01 |
| B (n = 50) | 22 | 44 | 1433.16 ± 1374.25 | 419.56 ± 217.031 | -1013.77 | < 0.01 | 5.84 | 6.38 | -0.54 | < 0.01 |
| C (n = 34) | 12 | 35 | 1339.13 ± 1523.73 | 414.258 ± 207.816 | -924.877 | NS | 5.87 | 6.38 | -0.51 | NS |
| D (n = 33) | 22 | 67 | 1306.53 ±1164.75 | 347.547 ± 238.08 | -958.985 | <0.001 | 5.96 | 6.24 | -0.28 | < 0.001 |

this it is likely that when the urinary pH is 6.1 and above, the activity of carbonic anhydrase present in the renal cells gets inhibited or the blood pH is altered beyond 7.45. This can occur either when blood $pCO_2$ is low or when the blood $HCO_3$ is high. These factors might reduce the production of the $H^+$ thereby reducing the renal threshold of absorption of $HCO_3$ ions leading to the appearence of alkaline urine. In the present study when post flight urinary pH of 6.1 and above was taken as the criteria of appearance of alkaline urine, a significant reduction in the $H^+$ concentration was observed in the selected group of population belonging to Groups 'A', 'B' and 'D'.

Urine is likely to become alkaline when the blood pH is greater than 7.45[6,7]. The change of blood pH to this critical level can either occur from decreased $PCO_2$ concentration in blood termed as respiratory alkalosis or when there is a loss of fixed acids or increase in blood alkali defined as metabolic alkalosis [6,7]. It can also be induced by diet high in certain fruits and vegetables especially citrus fruits[6,7]. In this study, the appearance of alkaline urine either due to loss of fixed acids or due to ingestion of alkali is unlikely. The possibility of various dietary factors leading to the production of alkaline urine is also ruled out as the pre-flight meals of the subjects belonging to the present study were high in protein which would normally lead to the production of acidified urine[6]. In the present study, the most probable cause leading to the production of alkaline urine appears to be respiratory alkalosis.

In aviation, respiratory alkalosis can result from lowered $pCO_2$ due to hyperventilation. Several potential stimuli to hyperventilate exist in the flight environment. These include hypoxia, vibration, thermal stress, increased resistance to breathing with oxygen equipment and pressure breathing[1,2]. Hyperventilation causes an exponential washout of $CO_2$ from the body. The amount of $CO_2$ lost depends upon the level of pulmonary ventilation, $CO_2$ production and the time for which the hyperventilation lasts[1,2]. Lowered $pCO_2$ causes alkalosis and pH of the blood increases. A lower $pCO_2$ hinders renal $H^+$ secretion and $HCO_3$ reabsorption and $HCO_3$ is excreted[6,7].

The incidence of hyperventilation in aviators has been reported to vary from 37-44%[1,2,9,10]. The present observation of appearance of alkaline urine and thus inflight hyperventilation in the fully operational pilots was about 44% which is consistent with that found by the other workers. The incidence of appearance of alkaline urine was found to be higher in conversion trainees (59%) as well as in the pilots having less than 1000 hrs of flying (67%). The incidence of appearance of alkaline urine was considerably less in fully operational pilots (44%) as well as in the pilots having a flying experience of more than 1000 hours (35%). This corroborates the findings of Murphy and Young[11] who reported that the professional had a lower pulmonary ventilation inflight than the amateurs.

Gibson et al[1,2] have reviewed the various experimental techniques available for

investigating hyperventilation in military operational flight. He suggested that the technique must not interfere with the primary purpose of sorties. This effectively eliminates any invasive measurements. Measurement of pulmonary ventilation, respiratory frequency or mixed expired $pCO_2$ is insufficient. The measurement of end tidal $pCO_2$ ($p_{et}CO_2$), the most ideal way of investigating inflight hyperventilation, is technically difficult in the air and unreliable if the ventilation perfusion ratio in the lung changes as in acceleration. The diagnosis of hyperventilation by examination of blood pH and $pCO_2$ (mixed venous $pCO_2$) is also difficult as the pilots are generally not available within fifteen minutes after landing, thereof if hyperventilation has occured, recovery should have been well established by the time experimenters take the sample. Considering the short-coming of various available techniques, the measurement of urinary pH appears to be ideal because it is non-invasive in nature and also gives a fairly good test for the appearance of alkaline urine in the post flight urinary sample, most probable cause for which appears to be inflight hyperventilation.

## *REFERENCES*


1. Gibson TM : Hyperventilation in aircrew : A review. Aviat Space Environ Med 1979 ; 50 : 725-733

2. Gibson TM : Hyperventilation inflight. Aviat Space Environ Med 1984; 55 : 411-412

3. Gibson TM : End tidal and mixed venous $CO_2$ tensions during exposure to and recovery from voluntary hyperventilation. FPRC Report No 1355, 1976.

4. Ellis JP Jr, Wells JG : The detection of inflight hyperventilation by blood and urine analysis. SAM-TDR-62-117, 1962.

5. Brassfield CR, Hehranam VG : A correlation of the pH of arterial blood and urine as affected by changes in pulmonary ventilation. Am J Physiol 1941 ; 118 : 272-280

6. Davenport HW : The ABC of acid-base chemistry. Sixth Edition. Published by University of Chicago Press, 1974.

7. Harper AH : Review of physiological chemistry 16th Ed. Tokyo. Large Medical Publication, Marusen Co Ltd, 1977.

8. Greenhill A, Grusk AB : Laboratory evaluation of renal function. Pediatr Clin North Am 1976; 23: 661

9. Balke B, Wells JG, Clark RT Jr : Inflight hyperventilation, during jet pilot training. J Aviat Med 1957; 28 : 241-248

10. Baboo NS, Banerjee PK, Dikshit MB and Rao PLN : Incidence of hyperventilation in IAF aircrew - A preliminary survey. Aviat Med 1987;31:23-25

11. Murphy TM, Young WA : Hyperventilation in aircraft pilots. Aerospace Med 1968; 39:463-466.