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Can Capillary Blood Gas be an Alternative to Arterial Blood Gas? – A Comparative Analysis

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Abstract

Introduction: ABG is a painful procedure and it requires lot of skills to master the art of obtaining ABG from sick patients specially who are in shock,thus even the most skilful of person requires quite a few attempts,so main idea of this study is to come up with something which can be an alternative to ABG.Various studies have been done where comparisons have been drawn between ABG VS VBG VS CBG but since VBG is also an invasive procedure, so less invasive procedure was obtaining a CBG and the whole idea of the study is that can CBG replace ABG? CBG only requires a finger prick or heel stick, and is much less painful than an ABG. The results, however, are not as reliable as an ABG. *Aims and Objectives:* To investigate the degree of corroboration between capillary blood gas (CBG) and ABG values using correlation analysis and to evaluate whether capillary blood gas can be equally reliable as arterial blood gas (ABG) to be used in clinical practice. Reliability of CBG over ABG is aimed to make blood gas analysis easier, less painful, faster and equally reliable. Also, it will be easier to assess blood gases in patients with generalized oedema, feeble pulses and in anxious and psychiatric / psychotic patients where ABG can be difficult. *Materials and Methods:* Blood samples were drawn simultaneously from the radial artery via an arterial puncture into a heparinised syringe and the fingertip via finger prick into a capillary tube of every patient participating in the study. Two sets of capillary samples was taken in order to assess the repeatability of capillary sampling. Immediately afterwards an arterial sample was taken from the radial artery in order to assess the agreement between the capillary and arterial samples. These samples so obtained was analyzed immediately by the blood gas analyzer (AVL Compact 3, Roche Diagnostics GmbH, Mannheim, Germany) of the Emergency Department for values of acid-base and oxygenation: pH, PO_2, PCO_2, HCO_3 values will be recorded. Blood gases was obtained if the patients need blood gases analysis for clinical decisions. In addition, the measurement of oxygen saturation (SpO2) was obtained from a finger pulse oximeter (Non-invasive pulse oximeter). *Results and Conclusion:* Although CBG is far less invasive than ABG, but the values obtained by the T-TEST method of analysis shows disparity between the two. There is some level of similarity in the values of HCO_3 and PCO_2 but the values of PO_2 and PH did not have any correlation. Hence, the study concludes that CBG cannot replace ABG until more studies are done with greater sample size.

Keywords: Capillary blood gas; PCO_2; pH; Blood gas analysis.

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Introduction

ABG is the most frequently used investigation to get information regarding oxygenation, ventilation and acid base status in most of the patients.

However, the procedure can be technically difficult,

especially when the patient is in shock, and may require multiple attempts even by an expert. Moreover, ABG is a painful and uncomfortable procedure with the risk of complications like pain, arterial injury, aneurysm formation, haemorrhage and thrombosis with distal ischemia. There is an additional and appreciable risk of needle stick injury to health care workers with the risk of transmission of blood borne viruses such as hepatitis C and HIV.

Because of the discomfort and complications associated with the procedure, researchers have been searching for alternative methods to ABG sampling with incomplete success. Though, numerous studies have been done comparing venous blood gas with ABG, some studies showed good correlation (Harrison and Galloon 1965, Long et al 1971, Harrison et al 1997) while others give contradictory results (Klingstromet al 1976, Brashear et al 1979). Blood gases are used for evaluating O_2 and CO_2 gas exchange, respiratory functions, including hypoxia and acid base balances. It is also useful in assessment of asthma, COPD and other types of lung diseases. Capillary blood gas (CBG) is a less invasive way of evaluating blood gas. It avoids the risk of above mentioned arterial blood gas complications. CBG sampling can be done from finger pulp and ear lobe. The earlobe oxygen tension resembles the arterial oxygen tension due to convergence of arterial and venous oxygen tension.

It has not been determined as to whether, in patients with acute exacerbations of COPD, capillary blood gases are a viable alternative to ABG in patients coming to emergency department.. In this study the author proposes to assess the correlation and level of agreement between measurements of pH, PO_2, PCO_2, calculated HCO_3^-, in arterial and capillary blood in patients attending in Emergency Departments.

Objectives of the Study

- To investigate the degree of corroboration between capillary blood gas (CBG) and ABG values using correlation analysis.
- To evaluate whether capillary blood gas can be equally reliable as arterial blood gas (ABG) to be used in clinical practice.

Research Question

Can capillary blood gas replace arterial blood gas in measuring the levels of pH, PO_2, PCO_2, HCO_3in patients presenting to emergency department?

Methodology

The study was a prospective observational comparative study between ABG and CBG done on patients, attending the Emergency Department of Peerless Hospital between September 2014 – August 2015 (1 year). Peerless Hospital & B.K. Roy Research Centre, Kolkata is a multi-specialty hospital that provides medical, surgical, psychiatric, obstetric and gynecologic and paediatric inpatient care, as well as critical care and emergency services. The hospital has a capacity of 350 beds, of which 75 are acute care beds. Peerless Hospital is a multispecialty teaching hospital where more than 15,000 patients are seen in Emergency Department annually.

Study Sample

The sample size required for this study was calculated as 106, rounded to 110

The expected sample size required for this study was calculated with the help of the following formula:

$$N = \frac{Z2\ S2}{d2}$$

Where: N is the size of sample; Z is the z-statistics for the desired level of confidence;

S is the population standard deviation; D is the half width of the desired interval.

For the purpose of our sample size calculation, we entered the following data:

•Standard deviation (S): 40: Confidence level: 99%, then z = 2.58: desired interval (d): 10

$$n = \frac{2.582 \times 402}{102} = 106$$

The following are the inclusion and exclusion criterion

Inclusion Criteria

- Age >18 years,
- All patients who need ABG in emergency department.

Exclusion Criteria

Patients will be excluded if:

- Age <18 years

All patients attending Peerless hospital Emergency

Department, who were thought to require ABG analysis by the treating physician, was identified and enrolled by Emergency Department doctor during the 12-month study period. A written informed consent was obtained from each patient or his or her family before enrolment into this study.

Blood samples were drawn simultaneously from the radial artery via an arterial puncture into a heparinized syringe and the fingertip via finger prick into a capillary tube of every patient participating in the study. Two sets of capillary samples were taken in order to assess the repeatability of capillary sampling. Immediately afterwards an arterial sample was taken from the radial artery in order to assess the agreement between the capillary and arterial samples. These samples so obtained will be analyzed immediately by the blood gas analyzer (AVL Compact 3, Roche Diagnostics GmbH, Mannheim, Germany) of the Emergency Department for values of acid-base and oxygenation: pH, PO_2, PCO_2, HCO_3 values were recorded.

Blood gases were obtained if the patient need blood gases analysis for clinical decisions. In addition, the measurement of oxygen saturation (SpO_2) was obtained from a finger pulse oximeter (Noninvasive pulse oximeter).

Results

The study showed equal representation among various age groups of population with a preponderance of male gender.

48% of females had normal ABG and 45% (of the total population) had normal CBG.

23% males had normal ABG and 36 % had normal CBG. Average pH values of females in ABG and CBG was 7.37 and 7.39, and that of males was 7.28 and 7.34.

The maximum pH was 7.41 in both ABG and CBG in the age group of 31-40 years, minimum of 7.21 (ABG) above 71 years of age and 7.24 (CBG) in 61-70 years of age.

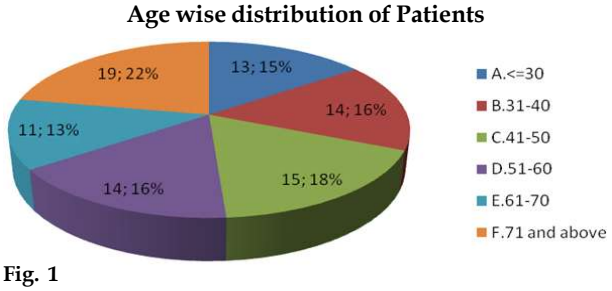

Fig. 1

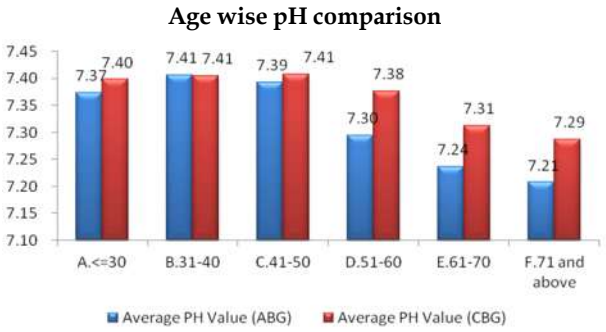

Fig. 2

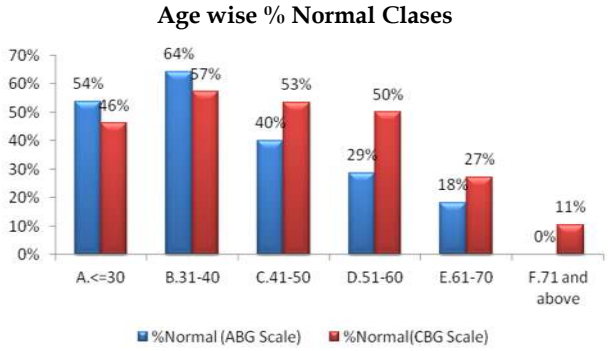

Fig. 3

The graphs showed maximum PCO_2 of 47 in ABG in less than 30 years and more than 71 years and in CBG maximum of 44 in the age group of <30,41-50 and 61-70 years of age, minimum of 38 (ABG) 31-40 years of age and 39 (CBG) in 31-40 years of age.

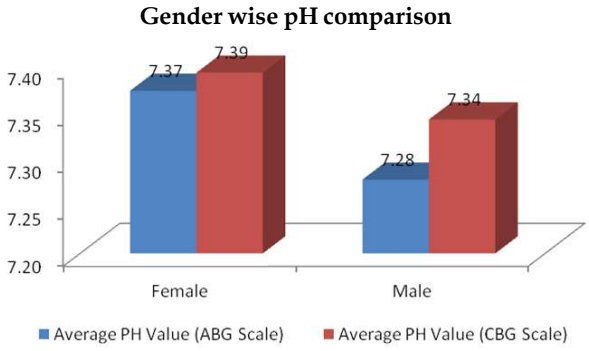

Fig. 4

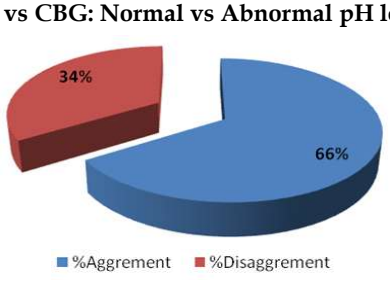

Fig. 5

Average PCO_2 values for ABG and CBG in the study was 43.81 and 42.19. The age wise and gender wise variation is shown in following figures.

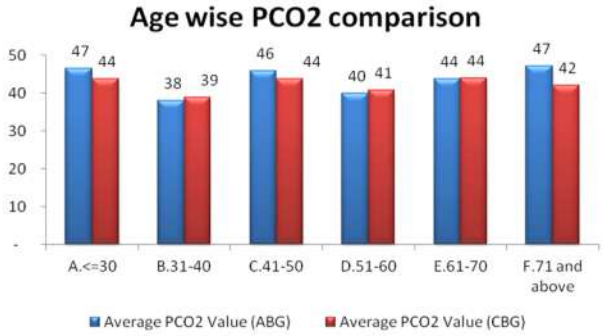

Fig. 6

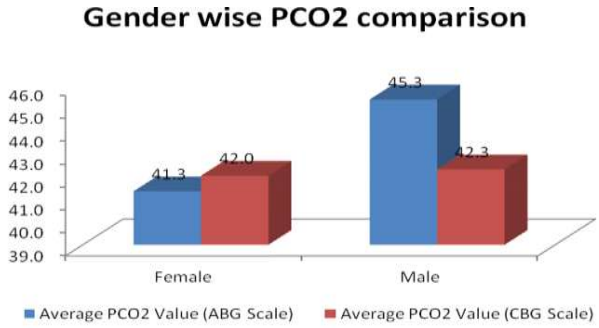

Fig. 7

Fig. 1: Degree of corroboration between capillary blood gas (CBG) and ABG for pH values

t-Test: Paired Two Sample for Means (All observations)	ABG	CBG
Mean	7.315232558	7.362209302
Variance	0.021594651	0.011438591
Observations	86	86
Pearson Correlation	0.716967024	
Hypothesized Mean Difference	0	
Df	85	
t Stat	-.252135514	
P(T<=t) one-tail	2.70527E-05	
t Critical one-tail	1.6629785	
P(T<=t) two-tail	5.41054E-05	
t Critical two-tail	1.988267868	

Spearman's Rank Correlation: 0.6904

Since t stat is less than two tail critical t value, we could safely conclude that at 5% level of significance, both the method yield similar average pH value.

Combining above t-test results along with fairly high correlation value, we can safely consider ABG and CBG as consistent predictor for pH value.

However there is significant difference in case we proceed into more granular level:

		CBG Scale		
ABG Scale	Indicator	Abnormal	Normal	Total
	Abnormal	40	18	58
	Normal	12	16	28
	Total	52	34	86

		CBG Scale	
ABG Scale	Indicator	Abnormal	Normal
	Abnormal	47%	21%
	Normal	13%	19%

- In 66% cases, both the methods measure abnormal and normal pH in similar direction
- In 34% cases, both the methods measure abnormal and normal pH in opposite direction (which is pretty high)

Fig. 2: Degree of corroboration between capillary blood gas (CBG) and ABG for PCO_2 values

	ABG	CBG
Mean	43.80930233	42.19186047
Variance	405.0620301	262.8153447
Observations	86	86
Pearson Correlation	0.876002516	
Hypothesized Mean Difference	0	
Df	85	
t Stat	1.528982976	
P(T<=t) one-tail	0.064990864	
t Critical one-tail	1.6629785	
t Critical one-tail	1.6629785	
P(T<=t) two-tail	0.129981727	
t Critical two-tail	1.988267868	

Spearman's Rank Correlation: 0.8736

Since t stat is less than two tail critical t values, we can safely conclude that at 5% level of significance, both the method yield similar average PCO2 value.

Combining above t-test results along with fairly high correlation value, we can safely consider ABG and CBG as consistent predictor for PCO2 value.

There is also fair association between ABG and CBG in terms of predicting "normal versus abnormal "PCO_2 level.

ABG Scale	Indicator	CBG Scale Abnormal	Normal	Total
	Abnormal	42	13	55
	Normal	13	18	31
	Total	55	31	86

ABG Scale	Indicator	CBG Scale Abnormal	Normal
	Abnormal	49%	15%
	Normal	15%	21%

- In 70% cases, both the methods measure abnormal and normal PCO_2 in similar direction
- In 30% cases, both the methods measure abnormal and normal PCO_2 is opposite direction (which is moderately high)

Average PCO_2 values for ABG and CBG in the study was 18.85 and 18.97.

Maximum HCO3 was 22 in ABG in the age group of <30 years and 41-50 years of age, and maximum CBG was 22 in the age group of 31-40 years of age. The minimum was 13 (ABG) >71 years of age and 15 (CBG) in >71 years of age

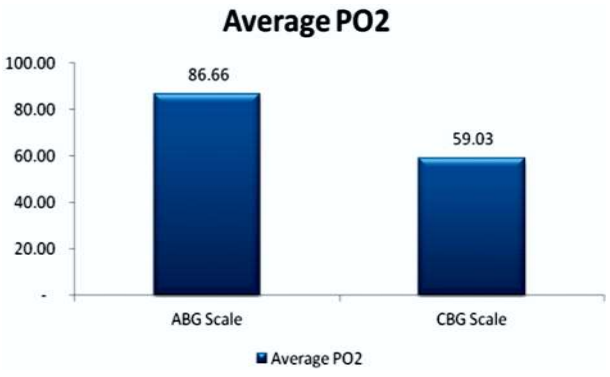

Fig. 8

Average PO_2 values for ABG and CBG in the study was 86.66 and 59.03

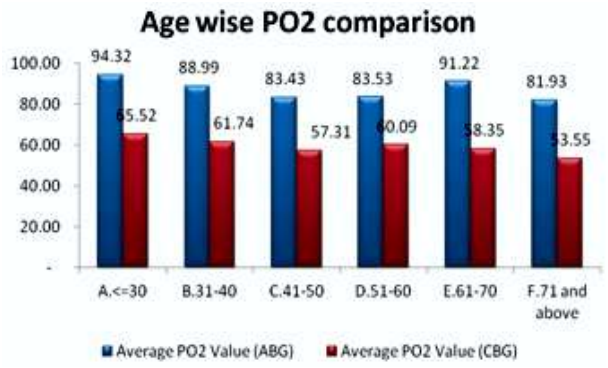

Fig. 9

The above bgraph shows maximum average PO_2 of 94.32 in ABG in the age group of <30 years, and in CBG maximum of 65.52 in the age group of <30 years of age, minimum of 81.93 (ABG) >71 years of age and 53.55 (CBG) in >71 years of age.

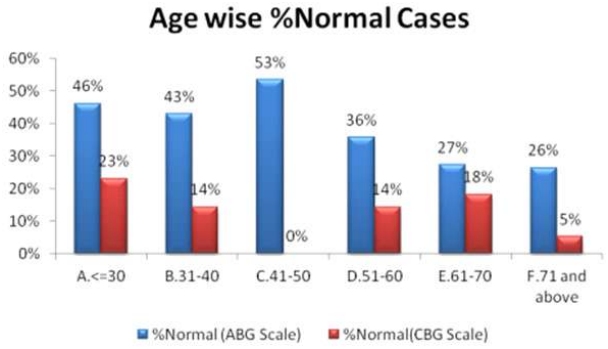

Fig. 10

The above graph shows maximum normal level of PO_2 of 53% in ABG of age group 41-50 years of age and that of CBG was 23% in the age group of <30 years of age.

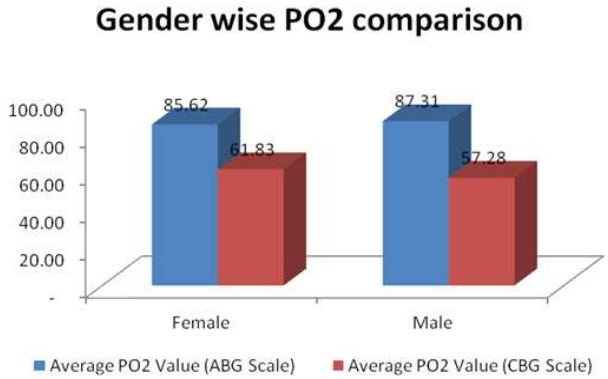

Fig. 11

Average PO_2 values of females in ABG and CBG was 85.62 and 61.83, and that of males was 87.31 and 57.28

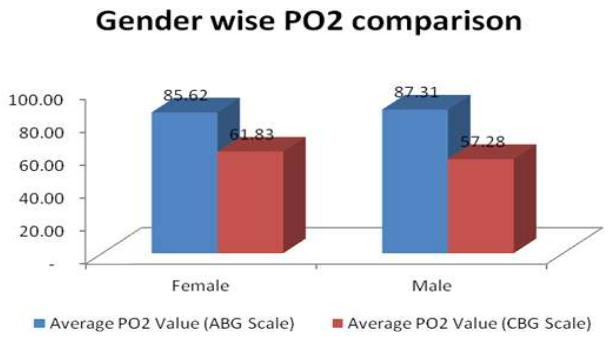

Fig. 11

The above shows 48% of females had normal ABG and 18% had normal CBG, and 32% males had normal ABG and 8% had normal CBG

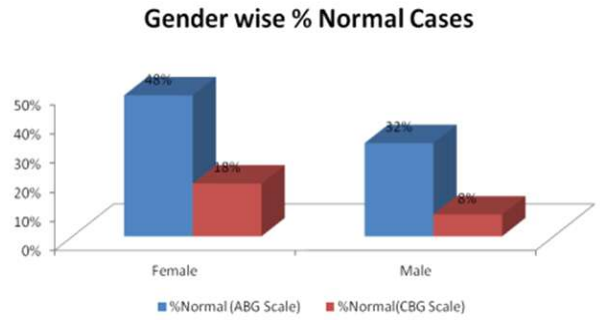

Fig. 12

Discussion and Conclusion

In this study we took a sample size of 104. The samples were taken either from emergency department, ICCU or ITU.

To our knowledge this validation study is to evaluate analytical performance, diagnostic capabilities and applicability of finger tip capillary blood gas analysis technique in any ill patients with varied medical conditions and severity. Capillary blood gas measurement from finger tip has been extensively evaluated in various physiological and pathological situations. Nevertheless, contradictory results as to its accuracy have been reported, especially for PO_2 measures.

This can be explained by the physiological changes in the body as the oxygen levels in the arteries differ from that of capillaries, as capillaries are the small blood vessels which connect arteries to veins.

In a recent analysis reported that, although agreement was not high, finger tip capillary estimations could be used for clinical management since they followed arterial values [9]. The main sources of variability were attributed to different collection techniques and procedures. Our results have evidenced a high level of precision of capillary gasometrical analysis when a dedicated collector and procedures are used to the collection technique. However, results from the present analysis demonstrate that arterialized capillary blood is not a good estimator of arterial PO_2 values in critically ill patients due to poor concordance, underestimation of values, wide limits of agreement and elevated error in the measure. As previously reported, the higher the arterial PO_2 the higher the discrepancy between capillary and arterial blood measures, which could be explained by poor arterialisation and excessive venous blood admixture

As per the study conducted and the calculations done by T- test method, the mean of the ABG and CBG values of HCO_3 and PCO_2 showed that they can be safely considered as consistent predictors. Also, when the normal and abnormal values of PCO_2 and HCO_3 were correlated there is a fair agreement in the CBG values.

By the similar test performed for the pH, the mean of ABG and CBG values can be considered as consistent predictors, but when normal and abnormal values were correlated there was significant difference in case we proceed to granular level within normal and within abnormal range of pH the comparison is making no sense.

On the other hand, for PO_2both the methods ABG and CBG, yield significant difference in PO_2 values. Further comparison of normal and abnormal values also showed, significantly high differences. Hence, there is high disagreement in values of CBG over ABG.

Another important finding of the study was high capillary sampling failure rate. Total sample size was 104, but only 86 were taken into consideration for data analysis due to sample failure. High sampling failure ratios were associated with insufficient blood flow delivery to the collecting system. This was attributed to a reduced capillary blood flow in the finger tip, this was noticed mainly in old age patients or patients in shock.

With the above discussion we conclude that at this level it is difficult to prove if CBG can replace ABG. We recommend a greater sample size for the analysis of the same and more studies to be conducted for concluding if CBG can replace ABG.

We also recommend that since CBG is frequently used in the paediatric and neonate age group and as per our study there has been significant differences in the data so more studies to be conducted for reliability of CBG in all age groups.

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