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Comparison of Arterial, Venous and Capillary Blood Gas Measurements in Premature Babies in Newborn Intensive Care Unit

Yenidoğan Yoğun Bakım Ünitesindeki Prematür Bebeklerin Arter, Ven ve Kapiller Kan Gazı Değerlerinin Karşılaştırılması

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ABSTRACT

Purpose: To investigate if there were a correlation between blood gas measurements and if we could predict arterial (A) values from capillary (C) or venous (V) measurements in premature infants.

Material and Methods: Premature infants with umbilical artery and venous catheters in Newborn Intensive Care Unit were enrolled in to the study. Umbilical arterial, umbilical venous and capillary blood gases were obtained and correlation of pH, pO2, pCO2, BE, HCO3 and oxygen saturation levels were studied.

Results: 144 paired of blood gases were obtained from 111 premature infants with a mean gestational age of 29.0 ± 2.5 (24-35) weeks and birth weight of 1173 ± 421 (500-2200) g. Patients were divided in to three birth weights groups: <1000 g (n: 45), 1000-1499 g (n: 39) and ≥1500 g (n: 27). Arterial values of pH, pO_2, HCO_3 and oxygen saturation were significantly higher and pCO_2 values were lower than venous and capillary values. pH, pO_2, pCO_2, BE, HCO_3 and oxygen saturation were all significantly correlated in A-V and A-C blood gases in all BW groups ($p<0.001$) except for A-C pO_2 and SO_2 in 1000-1499 g group ($p=0.062$, $p=0.115$). Arterial-venous correlation seemed to be higher than A-C correlation. Arterial pO_2 could not be predicted from capillary measurements. Especially for babies smaller than 1000 g, venous blood gases seemed to be better for predicting arterial pH, pCO_2 and pO_2 values. For babies larger than 1000 g, except for pO_2, the accuracy and precision for pH, pCO_2, BE and HCO_3 were approximately the same between C and VBG samplings.

Conclusions: Although there is a significant correlation in pH, pCO_2, BE, and HCO_3 among arterial-venous and arterial-capillary blood gases, correlation for pO_2 is low and venous and capillary values can grossly predict arterial values.

Key words: newborn, preterm, blood gases, correlation.

ÖZET

Amaç: Bu çalışmada kan gazı ölçümleri arasında bir ilişki olup olmadığı ve kapiller kan gazı örnekleri ile arter(A) ve venöz(V) değerler arasında bir ilişki kurulup kurulamayacağı araştırıldı.

Materyal ve Metod: Yenidoğan yoğun bakım ünitesi(YYBU)nde yatmakta olan göbek arter ve venöz kateter takılan hastalar çalışmaya alındı. Göbek arter ve ven, kapiller kan gazları alınarak pH, pCO2, BE, HCO3 ve oksijen saturasyonları arasındaki korelasyon araştırıldı.

Bulgular: Ortalama gestasyon haftası 29.0 ± 2.5 (24-35) hafta ve ortalama doğum ağırlığı 1173 ± 421 (500-2200) g olan 111 prematür bebekten 114 eş zamanlı kan gazı örneği alındı. olgular üç gruba ayrıldı; <1000 g(n:45), 1000-1499 g(n:39) ve ≥1500 g (n: 27). Arter pH, pO2, HCO3 ve oksijen saturasyon değerleri venöz ve kapiller değerlere göre

anlamlı olarak yüksek ve pCO2 değerleri anlamlı olarak düşüktü. Arter pO2 değerleri kapiller örneklere göre tahmin etmek mümkün değildir. özellikle çok küçük bebeklerde (<1000 gr) arter pH, pCO2 ve pO2 değerlerini tahmin etmek için venöz kan gazı değerleri daha uygundur. 1000gr\'dan daha büyük bebeklerde pO2 dışında, pH, pCO2, BE ve HCO3 kapiller ve venöz kan gazı değerlerinde daha uyumlu idi.

Sonuç: Arter-ven ve arter-kapiller pH, pCO2, BE, ve HCO3 istatistiksel anlamlı olsa da pO2 için korelasyon düşüktür ve venöz ve kapiller değerleri arter değerleri tahmin etmede tam güvenilir değildir.

Anahtar Kelimeler: Yenidoğan, preterm, kan gazı, korelasyon.

INTRODUCTION

In Neonatal Intensive Care Units, premature babies account the majority of patients. They have significantly higher incidence of respiratory distress syndrome and need close monitoring of blood gases. Although non-invasive methods such as pulse oximetry, transcutaneous monitoring of oxygen and carbondioxide and end-tidal carbondioxide measurement are useful techniques, neither technique can replace arterial blood gas (ABG) monitoring in critically ill newborn; because neither provides comprehensive and exact information about oxygenation, ventilation and acid-base status. Arterial blood gas determinations provide the most accurate results of oxygenation and ventilation. Umbilical artery (A) and venous (V) catheters are usually placed in premature infants for their diverse condition, but for thrombosis and infection risk, many neonatologists prefer to remove them as soon as possible. And afterwards, mainly capillary blood gas (CBG) sampling is used in newborns.

There are studies about correlation of arterial, venous and CBG measurements for pH, pCO_2, pO_2 and HCO_3 and most of them revealed that CBG samples accurately reflect arterial pCO_2 and pH, but shows poor correlation for pO_2 [1-7]. There are only a few studies about blood gases in premature babies, showing different results [3, 8].

+In this study our aim was to investigate if there were a correlation between arterial, venous and capillary blood gas measurements and if we could predict arterial values from venous and capillary measurements in premature infants in Newborn Intensive Care Unit.

MATERIAL and METHODS

Premature babies who had umbilical artery and venous catheters were enrolled to the study. Patients were excluded if they had congenital heart disease, metabolic diseases, hydrops fetalis or congenital malformation. Arterial blood gases and venous blood gases (VBG) were withdrawn from umbilical catheters before CBG measurement. After taking 2 ml of blood from the catheters, 0.5 ml of arterial and venous blood were obtained with syringe. Capillary (C) blood gases were gained from an unwarmed heel as soon as possible after ABG and VBG. All samples were obtained when capillary puncture was needed for blood glucose or hematocrite measurement.

All samples were analysed on blood gas analyser (Roche, OMNI C Blood Gas Analyser, Germany) located in NICU within 2 minutes of extraction. All measurements of A, V and C blood gases and gestational age of the infant, birth weight, gender, day of life, ventilatory treatment, vital signs, capillary refill time, oxygen saturation measured by pulse oxymeter and oxygen concentration in hood or ventilator were recorded prospectively.

Informed consent was gained from parents, and Faculty of Medicine Local Ethics committee approved the study.

Statistical analysis: SPSS v16 was used for statistical analysis. Arterial, venous and capillary blood gas measurements were tested for normality within each birth weight group. Paired t-test or its non parametric alternative (Mann-Whitney) was used to compare arterial-venous and arterial-capillary measurements. A linear regression was applied to predict arterial blood gas measurements from venous/ capillary blood gas measurements

within each birth weight group. The coefficient of determination, denoted R^2, is used in the context of statistical models whose main purpose is the prediction of future outcomes on the basis of other related information. R^2 is most often seen as a number between 0 and 1.0, used to describe how well a regression line fits a set of data. R^2 closer to 1.0 indicates that a regression line fits the data well, while a R^2 closer to 0 indicates a regression line does not fit the data. It is the proportion of variability in a data set that is accounted by the statistical model. It provides a measure of how well future outcomes are likely to be predicted by the model. The standard error of the estimate (SEE) is a measure of the accuracy of predictions made with a regression line. All measurements were summarized as mean, SD, median, min and max. In all analysis p-values less than 0.05 were accepted as significant.

RESULTS

There were 111 premature newborns. 63 of them (56.3%) were male. Admission diagnosis included prematurity (14 babies, 12.6%), and prematurity and respiratory distress syndrome (97 babies, 87.4%). The mean gestational age of the patients was 29.0 ± 2.5 (24-35) weeks (median 29 weeks) and mean birth weight was 1173 ± 421 (500-2200) g (median 1080 g). Birth weight had an effect on the correlation of blood gases measurements, for this reason patients were divided in to three birth weight groups : <1000 g (n: 45), 1000-1499 g (n: 39) and ≥1500 g (n: 27).

A total of 144 paired of blood gases were obtained. 132 paired samples (91.7%) from 101 patients were gained when patients were on ventilator, with a mean FiO_2 0.58 ± 0.27 (0.21-1.0). Three of the patients were gaining oxygen in hood, 7 patients were on room air. 89 (61.8%) of the samples were obtained in the first day of life, 25 (17.4%) in the second day of life, 9 (6.2%) in the third day and 21 (14.6%) were gained after the third day. 120 (83.3%) paired samples were obtained from patients with capillary refill time ≤ 3 seconds, 24 (16.6%) paired samples were gained from patients with capillary refill time >3 seconds. Three patients were hypothermic and 3 patients were hyperthermic.

As there was no statistically significant difference between BW groups except for mean capillary BE, (p=0.028), mean values of blood gas measurements are shown in Table 1.

Arterial values of pH, pO_2, HCO_3 and oxygen saturation (SO_2) were statistically significantly higher and pCO_2 values were lower than venous and capillary values. There was no difference between arterial and venous BE levels (Table 2).

Oxygen saturation values measured by pulse oxymeter significantly correlated with arterial SO_2 in BW groups, respectively (r=0.688, 0.566 and 0.491; p<0.001, p<0.001 and p<0.005, respectively). As shown in Table 3, pH, pO_2, pCO_2, BE, HCO_3 and oxygen saturation were all significantly correlated in A-V and A- C blood gases in all BW groups (p<0.001) except for A-C pO_2 and SO_2 in 1000-1499 g group (p=0.062, p=0.115). Arterial-venous correlation seemed to be higher than A- C correlation.

We have tried to formulate arterial blood gas values from capillary and venous values. The parameters used in calculation have been shown in Table 4. Arterial pO_2 could not be predicted from capillary values. Especially for babies smaller than 1000 g, venous blood gases seem to be better for predicting arterial values. For babies larger than 1000 g, except for pO_2, the accuracy and precision for pH, pCO_2, BE and HCO_3 were aproximately the same between both C and VBG samplings.

Table 1. Mean values of arterial, venous and capillary blood gas measurements

	n	Mean	SD	Median	Minimum	Maximum
apH	138	7,31	0,12	7,32	6,68	7,52
apO_2	138	85,66	35,38	77,00	28,40	205,40
$apCO_2$	137	45,99	17,86	42,00	6,60	133,30
aBE	138	-3,95	5,53	-3,95	-31,10	7,90
$aHCO_3$	137	21,98	5,70	21,70	3,10	40,80
aSO_2	125	90,27	13,61	94,00	13,20	99,70
vph	131	7,29	0,12	7,30	6,63	7,60
vpO_2	131	59,56	24,05	54,90	16,00	155,00
$vpCO_2$	129	49,83	19,45	46,30	3,50	152,00
vBE	130	-3,80	5,19	-3,60	-24,00	16,20
$vHCO_3$	131	22,31	5,85	22,00	10,40	51,10
vSO_2	116	81,43	18,01	86,95	9,10	99,00
cpH	139	7,27	0,12	7,29	6,66	7,48
cpO_2	139	50,11	16,49	48,00	16,60	103,00
$cpCO_2$	138	56,71	20,75	52,00	23,00	160,00
cBE	139	-2,53	4,97	-2,20	-22,50	10,80
$cHCO_3$	139	24,34	5,24	23,70	12,00	50,40
cSO_2	118	77,55	19,02	82,40	7,80	99,00

Table 2. Paired differences between arterial, venous and capillary blood gas measurements

				95% CI		
	Mean	SD	SE	Upper	Lower	Sig. (2-tailed)
apH – vpH	0,021	0,056	0,005	0,011	0,031	p<0,001
apH – cpH	0,038	0,095	0,008	0,022	0,054	p<0,001
apO2 - vpO2	27,357	24,807	2,210	22,983	31,731	p<0,001
apO2 - cpO2	35,758	32,179	2,780	30,260	41,257	p<0,001
apCO2 – vpCO2	-4,981	12,383	1,112	-7,182	-2,779	p<0,001
apCO2 – cpCO2	-11,210	14,784	1,282	-13,746	-8,674	p<0,001
aBE – vBE	-0,341	3,093	0,277	-0,888	0,207	p=0,220
aBE – cBE	-1,617	3,708	0,320	-2,251	-0,984	p<0,001
aHCO3 – vHCO3	-0,762	3,992	0,357	-1,469	-0,056	p<0,05
aHCO3 - cHCO3	-2,538	3,717	0,322	-3,176	-1,901	p<0,001
aSO2 - vSO2	9,194	9,891	0,956	7,299	11,090	p<0,001
aSO2 - cSO2	12,831	13,611	1,304	10,247	15,415	p<0,001

Table 3. Correlation of arterial, venous and capillary blood gases for pH, pO_2, pCO_2, BE, HCO3 and oxygen saturation in premature babies

	Birth Weight (g)					
	500-999		**1000-1499**		**≥1500**	
	Pearson Correlations	Sig (2-tailed)	Pearson Correlations	Sig (2-tailed)	Pearson Correlations	Sig (2-tailed)
	apH		**apH**		**apH**	
vpH	0,925	p<0.001	0,834	p<0.001	0,850	p<0.001
cpH	0,632	p<0.001	0,810	p<0.001	0,800	p<0.001
	apO2		**apO2**		**apO2**	
vpO2	0,772	p<0.001	0,579	p<0.001	0,796	p<0.001
cpO2	0,580	p<0.001	0,272	p=0,062	0,409	p<0.05
	apCO2		**apCO2**		**apCO2**	
vCO2	0,756	p<0.001	0,789	p<0.001	0,840	p<0.001
cCO2	0,727	p<0.001	0,779	p<0.001	0,648	p<0.001
	aBE		**aBE**		**aBE**	
vBE	0,844	p<0.001	0,842	p<0.001	0,703	p<0.001
cBE	0,712	p<0.001	0,829	p<0.001	0,713	p<0.001
	aHCO3		**aHCO3**		**aHCO3**	
vHCO3	0,777	p<0.001	0,762	p<0.001	0,747	p<0.001
cHCO3	0,807	p<0.001	0,769	p<0.001	0,707	p<0.001
	aSO2		**aSO2**		**aSO2**	
vSO2	0.843	p<0.001	0.551	p<0.001	0.923	p<0.001
cSO2	0.792	p<0.001	0.260	p=0.115	0.809	p<0.001

DISCUSSION

The literature regarding A, C and VBG values in newborns reveals general agreement that capillary pO_2 values are of little use in predicting arterial pO_2, however capillary pH values and in some studies, capillary pCO_2 values are reliable predictors of apH and $apCO_2$[1-4]. Similarly we have found significant correlation between A- V and A-CBG in the present study. However, though capillary pO_2 values were significantly correlated with arterial values except for pO_2 and SO_2 in 1000-1499 g group, it was less strong compared to other parameters.

We tried to predict arterial values from capillary and venous values. Although there was a significant correlation between A-V and A-C blood gas measurements, SEEs of the regression analysis predicting arterial values from capillary results were large. Especially for babies smaller than 1000 g, venous blood gases seem to be more convenient for predicting arterial values. For babies larger than 1000 g, except for pO_2, the accuracy and precision for pH, pCO_2, BE and HCO_3 were approximately the same between both C and VBG samplings. So we may conclude that

capillary blood gas values are not useful especially for infants smaller than 1000 g.

Results may change according to the sample site. In Zavorsky et al's meta- analysis study [6], arterialized earlobe capillary blood sample and fingertip blood sample were compared and found that obtaining an arterialized earlobe CBG of pO_2 closely reflected any arterial sample compared to an arterialized fingertip capillary blood sample (R^2=0.88, residual SE 5.9 for earlobe, and R^2=0.48 for fingertip, residual SE 15). Both side sampling closely reflected arterial pCO_2 (R^2=0.94 for earlobe, and R^2=0.95 for fingertip) and apH (R^2=0.90, residual SE 0.025 for earlobe, and R^2=0.94 for fingertip, residual SE 0.029). In neonates, usually heel is used for CBG samplings. But in Karna and Poland's study[9], CBG from warmed distal phalanx of the right hand was compared with temporal/right radial ABG and they showed a very good correlation in pO_2 (r= 0.92), pH and pCO_2. We can not comment about capillary blood sampling site, as we have gained all samples from heels, but it would be very difficult to obtain finger CBG from these tiny babies.

Vasodilatation with a topical vasodilatory substance to the skin or warming the area may result arterialized capillary sample. In this study we did not warm heels of the patients because it is not practical to warm the extremity in Newborn Intensive Care Units. Although some studies showed agreement with apO_2 and arterial oxyhemoglobin saturation compared to arterialized samples in adults[10,11] in preterm infants, McLain et al[3] found no significant improvement in blood gas results by warming.

Results may change in different age groups. Capillary blood gas values appear to be more accurate in older children than in newborns. In the present study most of the samples were taken in 72 hours of life so we do not know if the results would change in older newborns. In Escalanto-Kanashiro et al's study[5], the authors found that there was a higher correlation between arterial and capillary blood gases in children older than 1 month. Also Yildizdas et al[4] showed significant correlation for pH, pO_2, pCO_2 and HCO_3 in 116 simultaneous venous, arterial and capillary blood samples gained from children in pediatric intensive care unit. Except for A-V pO_2 all correlations seem to be higher than correlations in the present study. In Yildizdas et al's study[4], arterial blood gases could be predicted from venous and capillary values with a less number of variants, with higher R^2 and lower SEE, compared with the present study.

In the present study, in Table 4, we show arterial blood gas prediction from venous and capillary gas measurements. As seen, there are complicated measurements and it is often not very practical to calculate arterial values. But maybe, in further studies including increased numbers of samples, it may be possible to add a formulation programme to blood gas machines which converts venous and/or capillary values to arterial values.

In conclusion, although we have shown good correlation in arterial, venous and capillary pH, pCO_2, BE and HCO_3 in different weight groups in premature babies, both capillary and venous blood gas values are mostly gross predictors of arterial results. If one had to be used, venous values seem to be more useful and specially for babies smaller than 1000 g venous values should be preferred, however in larger babies, venous and capillary blood gases look like similar in accuracy and precision for arterial pH, pCO_2, BE and HCO_3.

Table 4. Prediction of arterial blood gas measurements from venous and capillary values.

	Arterial	Venous		Capillary	
		R2adj/SEE	Prediction model	R2adj/SEE	Prediction model
pH	<1000 g	0.837/0.059	0.475 + 0.93 pH + 0.002 HCO_3	0.491/0.115	7.201 -0.004 CO_2 + 0.014 HCO_3
	1000-1499 g	0.743/0.048	4.755 + 0.375 pH – 0.003 pCO_2 + 0.006 BE	0.666/0.057	0.868 + 0.895 pH – 0.003 HCO_3
	≥1500 g	0.743/0.036	1.681 + 0.779 pH – 0.001 pO_2	0.772/0.033	5.454 + 0.307 pH – 0.001 pO2 + 0.012 BE – 0.011 HCO_3
pO_2	<1000 g	0.576/24.23	-316.87 + 46.38 pH + 1.116 pO_2	0.083/34.7*	
	1000-1499 g	0.407/25.64*		0.194/30.8*	
	≥1500 g	0.689/18.56	-549.34 + 79.34 pH + 0.907 pO_2	0.152/32.6 *	
pCO_2	<1000 g	0.806/9.54	1359.14 – 179.18 pH + 1.677 BE	0.520/14.65	12.16 + 0.580 CO_2
	1000-1499 g	0.630/9.49	61.99 + 1.4p CO2 + 2.97 BE – 3.298 HCO_3	0.648/9.72	-13.66 + 0.694 CO_2 + 0.834 HCO_3
	≥1500 g	0.706/8.48	-71.25-3.706 BE + 4.562 HCO_3	0.614/9.28	386.58 – 57.34 pH + 0.319 pO_2 + 2.451 HCO_3
BE	<1000 g	0.703/2.98	-1.062 + 0.798 BE	0.574/4.39	240.2 – 35.25 pH – 0.32 CO_2 + 1.23 HCO_3
	1000-1499 g	0.716/2.72	6.791 + 1.154 BE – 0.312 HCO_3	0.692/2.91	-2.01 + 0.941 BE
	≥1500 g	0.457/3.31	-16.129 + 0.571 HCO_3	0.491/3.07	-1.604 + 0.916 BE
HCO_3	<1000 g	0.574/3.59	7.345 + 0.644 HCO_3	0.664/3.55	237.11 -31.99 pH – 0.198 pCO2 + 1.163 HCO_3
	1000-1499 g	0.624/3.59	19.659 + 0.099 pCO_2 + 0.836 BE	0.649/3.54	-244.45 + 33.25 pH + 0.20 CO2 + 0.537 HCO_3
	≥1500 g	0.543/3.60	5.893 + 0.733 HCO_3	0.486/3.64	-0.416 + 0.932 HCO_3

*Model is not useful for prediction as R^2 value is too small

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