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Differences in PO_2 and PCO_2 between arterial and arterialized earlobe samples

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Differences in P_{O_2} and P_{CO_2} between arterial and arterialized earlobe samples. A. Sauty, C. Uldry, L-F. Debétaz, P. Leuenberger, J-W. Fitting. ©ERS Journals Ltd 1996.

ABSTRACT: Arterialized ear lobe blood samples have been described as adequate to gauge gas exchange in acute and chronically ill patients. It is a safe procedure, usually performed by medical technicians. We have conducted a prospective study to verify the validity of this method.

One hundred and fifteen consecutive adult patients were studied. Blood samples were drawn simultaneously from arterialized earlobe and radial artery. Values of partial pressure of oxygen (PO_2) and of carbon dioxide (PCO_2) were measured by means of blood gas electrodes.

The correlation coefficients between the two samples were 0.928 for PO_2 and 0.957 for PCO_2 values. In spite of a highly significant correlation, the limits of agreement between the two methods were wide for PO_2. Earlobe values of PO_2 were usually lower than arterial values, with larger differences in the range of normal arterial PO_2. On the other hand, the error and the limits of agreement were smaller for PCO_2.

We conclude that, in adult patients, arterialized earlobe blood PO_2 is not a reliable mirror of arterial PO_2.

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Blood gas values can be measured using arterialized earlobe blood samples, instead of arterial samples, in order to gauge pulmonary gas exchange in acute or chronically ill patients. This method, described many years ago [1], is a simple and safe procedure which can be performed by medical technicians. Comparing values for partial pressure of oxygen (PO_2) and of carbon dioxide (PCO_2) from arterialized earlobe blood samples with arterial blood samples, several authors have concluded that the earlobe site was suitable for routine clinical purposes [1–9]. This idea was again advocated by two recent studies. PITKIN *et al.* [10] compared PO_2, PCO_2, and pH values from 40 blood samples simultaneously drawn from the radial artery and hyperaemic earlobe. Using the method of BLAND and ALTMAN [11] for the assessment of agreement, these authors also concluded that arterialized earlobe blood gas values were accurate enough to be used in clinical application. Finally, DAR *et al.* [12] reported that earlobe sampling was significantly less painful than arterial sampling in 55 patients, whereas blood gas values were not different with the two techniques.

For several years, the arterialized earlobe technique has been the standard practice for measuring arterial blood gases in our pulmonary function laboratory. However, in some instances, we have noticed a marked discrepancy between arterial and relatively lower arterialized earlobe values of PO_2. We, therefore, conducted a prospective study to compare arterial and arterialized earlobe blood samples in 115 consecutive adult patients.

Material and methods

Our study group included 115 consecutive adult patients investigated in our pulmonary function laboratory for various conditions. None was in cardiovascular shock. Blood samples were drawn simultaneously from the radial artery and the arterialized earlobe of each patient in a sitting position. A commercial capillary system with a 26-gauge needle (AVL Microsampler, Schaffhausen, Switzerland) was used to collect arterial samples. The earlobe capillary blood was arterialized by the application of a Hymenoptera venom cream (Forapin, M. Mack Nachf., Illertissen, Germany) for 5–10 min. A qualified technician then incised the earlobe at its most dependent part with a scalpel blade (surgical blade No. 11, Swann-Morton, Sheffield, UK). A short manual massage was necessary in some instances. Arterialized samples were collected in heparinized glass capillaries (Clinitubes, Radiometer, Copenhagen, Denmark) and immediately introduced into the blood gas analyser (ABL 520, Radiometer, Copenhagen, Denmark) followed within 2 min by arterial samples.

Statistical analysis

The statistical analysis for assessing agreement between arterial and arterialized blood gases was performed according to BLAND and ALTMAN [11].

Results

No complication in the drawing of blood samples was observed with either method. The range of arterial P_{O_2} values was 5.2–13.1 kPa (39.0–98.3 mmHg), median 9.8 kPa (73.3 mmHg). The range of arterial P_{CO_2} values was 3.4–7.3 kPa (25.7–54.6 mmHg), median 4.9 kPa (36.9 mmHg). The relationships between arterial and arterialized samples for P_{O_2} and P_{CO_2} are shown in figure 1a and b. The correlation coefficients were 0.928 ($p<0.0001$) and 0.957 ($p<0.0001$) respectively. Despite this highly significant correlation, regression lines were slightly different from lines of identity, particularly for P_{O_2}. In figure 2a and b, differences between the two

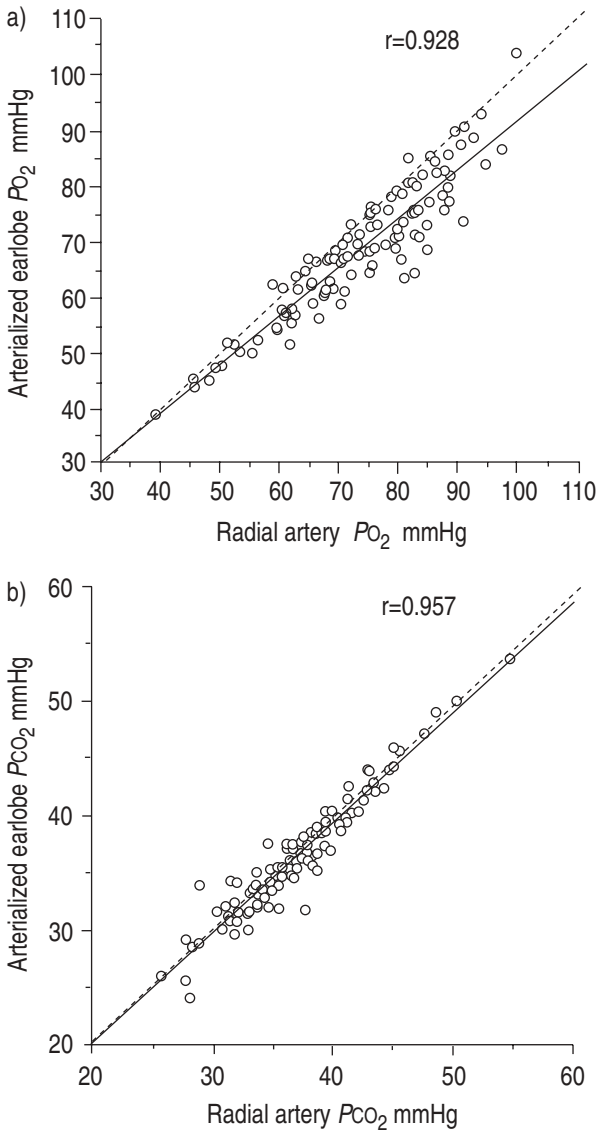

Fig. 1. – Correlation between radial artery and arterialized earlobe blood gas. a) Partial pressure of oxygen (P_{O_2}) values; and b) partial pressure of carbon dioxide (P_{CO_2}) values. ····· : line of identity; ——— : regression lines. (1 mmHg=133.32 Pa).

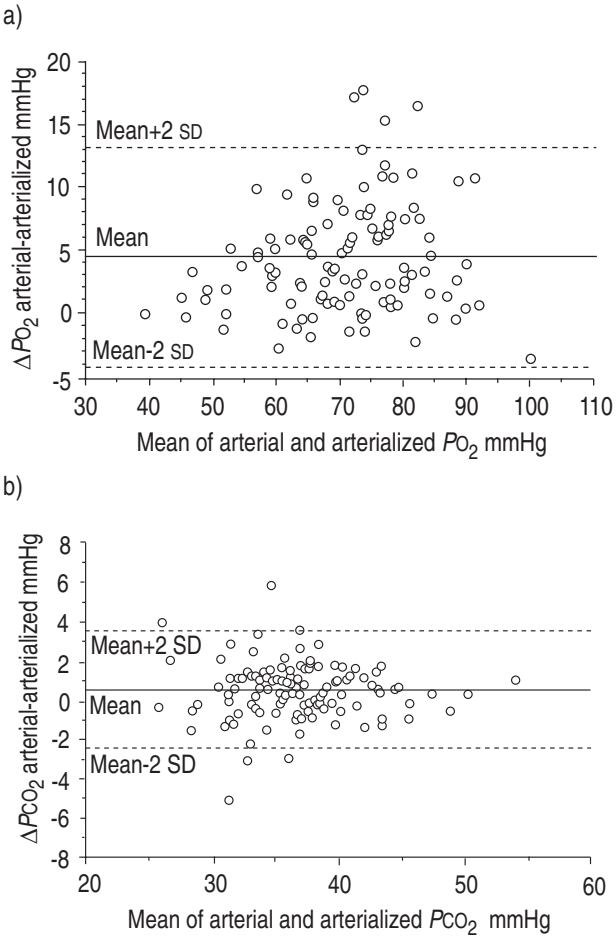

Fig. 2. – a) Differences in arterial-arterialized partial pressure of oxygen values (ΔP_{O_2}) plotted against mean of arterial and arterialized P_{O_2} values. b) Differences in arterial-arterialized partial pressure of carbon dioxide (ΔP_{CO_2}) values plotted against mean of arterial and arterialized P_{CO_2} values. (1 mmHg=133.32 Pa).

Table 1. – Limits of agreement of the differences in P_{O_2} and P_{CO_2} values between arterial and arterialized earlobe blood samples

	ΔP_{O_2}		ΔP_{CO_2}	
	kPa	mmHg	kPa	mmHg
Mean±SD	0.59±0.59	4.4±4.4	0.07±0.20	0.5±1.5
Range	-0.51–2.4	-3.8–18.0	-0.68–0.79	-5.1–5.9
95% CI of				
mean+2 SD	1.6–1.9	11.8–14.6	0.34–0.52	2.9–3.9
mean-2 SD	-0.4–0.77	-3.0–-5.8	-0.25–-0.37	-1.9–-2.8

ΔP_{O_2}: difference in partial pressure of oxygen (arterial-arterialized); ΔP_{CO_2}: difference in partial pressure of carbon dioxide (arterial-arterialized). 95% CI: 95% confidence interval.

methods (arterial - arterialized values) were plotted against means of arterial and arterialized P_{O_2} or P_{CO_2}. The mean±SD and the range of the differences, as well as the 95% confidence intervals for the lower and upper limits of agreement are reported in table 1. Arterialized earlobe P_{O_2} was lower than arterial P_{O_2} in most cases, and the difference increased as arterial P_{O_2} increased. These results show that the limits of agreement for P_{O_2} were wide, disclosing a lack of agreement between the two methods. For P_{CO_2}, on the other hand, the mean difference between the two methods was close to zero, and the limits of agreement were narrower.

Discussion

Sampling arterialized earlobe blood has been advocated by several authors as a simple and reliable method for arterial blood gas determination. The validity of this method was supported on the basis of simple comparison [2], lack of significant difference [1, 4, 8, 12], or presence of significant correlations between arterialized earlobe and arterial blood P_{O_2} and P_{CO_2} [3, 5–8]. Recently, PITKIN *et al.* [10] addressed the same question, using the method of BLAND and ALTMAN [11] to compare blood gas values from arterialized earlobe and arterial samples. They also concluded that the earlobe method was accurate enough for clinical purposes and recommended its use in routine clinical practice [10].

Our study combines the largest number of blood gas comparisons and the use of the method of BLAND and ALTMAN [11] to compare P_{O_2} and P_{CO_2} between simultaneous samples of arterialized earlobe and arterial blood. The data show that P_{O_2} was usually lower in earlobe than in arterial blood, and that the limits of agreement were wide between the two methods. Thus, using the same method of comparison as PITKIN *et al.* [10], our results and our conclusion differ from theirs. The reasons are that our study included both a larger number of subjects and a larger number of P_{O_2} values in the normal range. The main cause of underestimation of arterial P_{O_2} in earlobe samples is insufficient arterialization of blood, corresponding to a certain venous admixture. The effect of a given venous admixture in earlobe blood depends on the arterio-venous P_{O_2} difference: the larger the arterio-venous O_2 difference, the wider the discrepancy between earlobe and arterial P_{O_2}. This is one likely reason for the unreliable P_{O_2} values measured in arterialized earlobe blood in patients breathing 100% oxygen [4, 9, 13]. Because the arterio-venous P_{O_2} difference is large in subjects with normal arterial P_{O_2}, a small venous admixture in earlobe blood will result in a greater discrepancy between earlobe and arterial P_{O_2}.

Our data support this explanation. Indeed, figure 2a shows that arterial P_{O_2}, when in the normal range, was often markedly underestimated by the earlobe sample. Interestingly and despite fewer normal P_{O_2} values, the study of PITKIN *et al.* [10] also showed a trend towards increased difference between arterial and arterialized P_{O_2} with increasing mean P_{O_2} values. Accordingly, and as reported by the same authors, we observed a better agreement between the two methods for arterial P_{O_2} values lower than 8.0 kPa (60 mmHg), where the effect of venous admixture is smaller. The similarity of data over similar ranges of P_{O_2} argues against differences in techniques for arterializing and collecting earlobe blood between the two studies. On the other hand, there was a good agreement between earlobe and arteria values of P_{CO_2}, as previously reported [10]. This reflects the insignificant effect of venous admixture, due to the comparatively smaller arteriovenous P_{CO_2} difference.

In a recent study performed in 55 patients, DAR *et al.* [12] concluded that the mean differences (arterial minus capillary) were trivial and nonsignificant for P_{O_2} and P_{CO_2}. However, their reported standard deviation for P_{O_2} differences was the same as ours (0.59 kPa, (4.4 mmHg)). Thus, displaying their data according to BLAND and ALTMAN [11] would probably disclose a lack of agreement between the two techniques.

The usefulness of each method should be weighed according to its advantages and inconveniences. The advocated advantages of the earlobe method are that it is safe and can be performed by nonmedical staff. However, the method is not straightforward and requires trained personnel. The poor agreement with arterial blood demonstrated in this study adds to the limitations of the method. On the other hand, radial artery puncture using a capillary kit with a thin needle is a safe procedure. In our experience, no adverse effect has been noted, and although discomfort and pain were not formally assessed, most patients stated that radial artery puncture was less painful than earlobe hyperaemia and incision. This observation is at variance with that of DAR *et al.* [12], who quantified the discomfort associated with each procedure and found that radial arterial puncture was significantly more painful than earlobe incision. This discrepancy may be explained by the fact that we used a thinner needle for radial arterial puncture.

In conclusion, our study indicates that arterialized earlobe blood is not suitable for clinical assessment of arterial P_{O_2} because it often underestimates its actual value. If systematic arterial sampling is not feasible, we recommend that arterial blood be drawn whenever arterialized earlobe P_{O_2} is below the normal range.

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