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EDITORIAL

Blood gas estimations from *arterialized* capillary blood *versus* arterial puncture: are they different?

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Blood gas estimations from *arterialized* capillary blood *versus* arterial puncture: are they different? The answer to this question is that the oxygen tension (P_{O_2}) of arterial blood must be higher than the P_{O_2} of so-called *arterialized* blood flowing freely from the ear lobe after it has been pierced by a scalpel. This is because there is a gradient of P_{O_2} from around 13 kPa (98 mmHg) at the arterial end of the capillary bed to 5 kPa (38 mmHg) at the venous end. Fluid collected from the cut ear lobe is a mixture of blood from capillaries and venules. Nevertheless, it is well-known that under certain circumstances, the differences are so small that the arterial and *arterialized* estimations are, for practical purposes, identical. How is this possible?

As already mentioned, the normal arteriovenous difference for P_{O_2} at rest is 8 kPa (60 mmHg), increasing to 10 kPa (75 mmHg) on light exercise and to 70.7 kPa (530 mmHg) at least when breathing 100% oxygen. This difference can be reduced by increasing ear lobe blood flow relative to oxygen consumption by vasodilatation, either by heat or by application of a vasoactive cream. No one knows the magnitude of the changes induced in the human ear lobe by such manoeuvres, but it would be interesting to find out! For example, increasing the ratio of blood flow to oxygen consumption fivefold would reduce the arteriovenous oxygen content difference from 5 mL per 100 mL to 1 mL per 100 mL, and the arteriovenous P_{O_2} difference to 4.0 kPa (30 mmHg), assuming a normal P_{O_2} of 13 kPa (98 mmHg). Provided sufficient vasodilatation could be achieved, arterial and venous P_{O_2} in the ear lobe would tend to converge, and the *arterialized* P_{O_2} would come to resemble the arterial P_{O_2}.

As indicated by SAUTY *et al.* [1] in this issue, the arteriovenous P_{O_2} difference depends on the shape of the oxygen dissociation curve (ODC). As the arterial P_{O_2} falls, the arteriovenous P_{O_2} difference falls also, to 3.5 kPa (26 mmHg) at P_{O_2} 8 kPa (60 mmHg) and to 2.3 kPa (17 mmHg) at P_{O_2} 6 kPa (45 mmHg). With vasodilatation, these differences might reduce to 1.2 kPa (9 mmHg) and 0.67 kPa (5 mmHg), respectively. Thus,we might expect convergence of arterial and *arterialized* P_{O_2} values at P_{O_2} <8 kPa (60 mmHg) and some divergence when the arteriovenous P_{O_2} difference is higher, especially in hyperoxia. In fact, this is what is found. In two recent studies [1, 2], where a Bland and Altman analysis of differences was used, there was a definite trend for the arterial-*arterialized* P_{O_2} difference, plotted against the mean of the two estimates, to increase as the mean P_{O_2} (breathing air) increased; excluding one point in the study by PITKIN *et al.* [2], there seemed to be a threshold at 9.3 kPa (70 mmHg) above which a significant divergence first appeared. The overall differences were small, but arterial P_{O_2} was systematically higher than *arterialized* P_{O_2} by 0.61 kPa (4.6±4.6 (SD) mmHg) in the study by SAUTY *et al*. [1] (n=115) and by 0.17 kPa (1.28 mmHg) (n=40) in the other series [2]. An earlier study [3] found a much bigger difference under hyperoxic conditions; the arterial-*arterialized* P_{O_2} difference averaged 6 kPa (45 mmHg) at a mean arterial P_{O_2} of 68.8 kPa (516 mmHg) (n=18).

A spurious elevation of *arterialized* P_{O_2} (breathing air) may occur if the collection is not fully anaerobic, and the blood is partially exposed to room air during the sampling period [3]. This artefact acts in the opposite sense to the arteriovenous P_{O_2} gradient or venous admixture effect, and the two errors cancel out. This may explain the excellent agreement, independent of the level of arterial P_{O_2}, between arterial and *arterialized* P_{O_2} reported by so many investigators (see [1–3] for bibliography). The "aerobic" effect may explain in part why *arterialized* P_{O_2} exceeded arterial P_{O_2} by up to 0.6 kPa (4.5 mmHg) in 17 out of 115 [1] and 18 out of 40 [2] of the comparisons in the latest series.

In the study by SAUTY *et al.* [1] the arterial-*arterialized* P_{O_2} difference ranged from -0.5 kPa (-3.8 mmHg) to +2.4 kPa (+18 mmHg) with 95% confidence intervals of +1.76 kPa (13 mmHg) and -0.6 kPa (4.4 mmHg). The variance in the study by PITKIN *et al*. [2] was similar. Is this sufficiently accurate for clinical work? The practical answer is that *arterialized* P_{O_2} will detect the presence of arterial hypoxaemia with adequate sensitivity and accuracy, but that there will be some false positives, where *arterialized* P_{O_2} suggests a greater degree of arterial hypoxaemia than is actually present. Thus, it is a "fail safe" technique. *Arterialized* P_{O_2} values greater than 10.7 kPa (80 mmHg) should be treated with a modicum of caution.

Once the drawbacks of the method are recognized, there are good arguments for the use of *arterialized* P_{O_2} measurements. Firstly, ear lobe sampling can be carried out by nonmedically qualified persons; this is not, in general, true for arterial puncture. Secondly, P_{O_2} can be

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measured on exercise without the need to insert an arterial cannula. The most obvious pitfall is a failure to use or learn good technique. Vasodilatation, a free flow of blood and "anaerobic" sampling are all vital. Manual massaging of the ear lobe, to encourage better flow of blood, is not recommended. Each laboratory should check for quality control against simultaneous sampling of arterial blood.

Samples of *arterialized* P_{O_2} have definite advantages over measurements of arterial oxygen saturation (S_{a,O_2}) using a pulse oximeter. S_{a,O_2} is rather insensitive, because of the shape of the ODC, at P_{O_2} >10 kPa (75 mmHg). Unfortunately, this is the P_{O_2} range at which the *arterialized* measurement performs least well! From *arterialized* blood carbon dioxide tension (P_{CO_2}) and pH can be estimated, and important additional information is gained. As SAUTY *et al*. [1] point out, the arterial-*arterialized* P_{CO_2} difference is negligible (0.067 kPa (0.5± 1.5 mmHg)) because of the small arteriovenous P_{CO_2} difference at rest (0.8 kPa (6.0 mmHg)).

To conclude, *arterialized* ear lobe sampling can be a valuable measurement in clinical practice, but it is only an approximation of the arterial P_{O_2}. The lower the arterial P_{O_2}, the more accurate the estimate becomes. SAUTY *et al*. [1] have performed a valuable service in reminding us that "ear lobe sampling is not a reliable mirror of arterial P_{O_2} in adult patients". But, provided that one is aware of the pitfalls, ear lobe sampling is a useful and noninvasive monitor of arterial P_{O_2}, superior to more indirect methods, such as transcutaneous P_{O_2} and calculations of P_{O_2} from S_{a,O_2} with pulse oximetry.

References

1. Sauty A, Uldry C, Debetaz L-F, Leuenberger P, Fitting J-W. Differences in P_{O_2} and P_{CO_2} between arterial and arterilized ear lobe samples. *Eur Respir J* 1996; 9: 186–189.
2. Pitkin AD, Roberts CM, Wedzicha JA. Arterialised ear lobe blood gas analysis: an underused technique. *Thorax* 1995; 49: 364–366.
3. Christoforides C, Miller JM. Clinical use and limitations of arterialized capillary blood for P_{O_2} determination. *Am Rev Respir Dis* 1968; 98: 653–657.