

Effects of four different methods of sampling arterial blood and storage time on gas tensions and shunt calculation in the 100% oxygen test

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ABSTRACT: At the present time, plastic syringes are most commonly used for collecting arterial blood. The oxygen tension of the arterial blood (P_{a,O_2}) in these syringes may fall. We studied the effect of the type of syringe, metabolism, and storage time on the arterial oxygen pressures measured and on the pulmonary shunt calculated.

In 10 patients, 2-3 h after aortacoronary bypass surgery, a 100% oxygen test was performed. Four arterial blood gas samples were withdrawn from each patient in random order, two in glass syringes and two in plastic syringes. One glass and one plastic syringe were stored at room temperature (RT), and the others were stored in ice-water (IW). Each sample was analysed as soon as possible, and repeated 15, 30, 60 and 120 min after sampling. The P_{a,O_2} measurement in blood in the glass syringe in IW measured as soon as possible after sampling was considered the "gold standard". Pulmonary shunt calculations were performed using the results of the various blood gas analyses.

Compared with the "gold standard", all of the other methods showed significant deterioration in the P_{a,O_2} measurement. The effect due to diffusion was 0.05 kPa·min⁻¹, and that due to metabolism 0.11 kPa·min⁻¹. The P_{a,O_2} in the glass syringes stored in IW remained stable with time. The pulmonary shunt was significantly overestimated when the "gold standard" blood gas results were not used (range 0.8-9.9%).

Glass (not plastic) syringes should be used in the 100% oxygen test. The syringe should be cooled immediately, even when the sample is analysed as soon as possible.

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In most hospitals, arterial blood samples are drawn from patients by using plastic high density polypropylene syringes. These syringes have become increasingly popular because they are preheparinized, whereas glass syringes need to be manually heparinized by the investigator. Sterilization after use is necessary when using glass syringes but is unnecessary for plastic syringes as these syringes are discarded after single use. Blood gas tensions can alter during storage, especially if blood is collected in plastic syringes [1-4]. Factors responsible for these alterations may be the continuing metabolism of the blood cells [5], and the ability of gases to diffuse through the wall of the syringe [2, 6]. It is, therefore, recommended that blood gas values should be measured within 15-30 min after sampling [3, 4, 7, 8]. However, these recommendations were based on investigations performed in "normoxaemic" blood samples.

The influence of diffusion on arterial blood gas tensions in samples with high partial oxygen tensions, as is the case when one is performing the 100% oxygen test, may be substantially increased because of a higher

diffusion gradient. If this is true, substantial errors may occur in right-to-left shunt estimations calculated from this 100% oxygen test. To our knowledge, only one study has investigated this issue [9]. It was found that, at high partial oxygen pressures, glass syringes were superior to plastic syringes and that prompt and adequate cooling of such samples was important for preserving the oxygen pressure of arterial blood (P_{a,O_2}) in the sample. This study, however, was performed by using tonometered blood. In patients submitted to the 100% oxygen test, the influence of the type of syringe, the temperature of the sample during storage and the total storage time upon the P_{a,O_2} , the arterial carbon dioxide tension (P_{a,CO_2}), and the pulmonary shunt calculation remains unclear. In the present study we investigated these influences.

Materials and methods

Ten patients undergoing elective aortacoronary artery bypass surgery, according to a standard anaesthetic and

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surgical protocol [10] were studied. For all patients, written informed consent was obtained according to the rules of the Medical Ethics Committee of our hospital. Two hours postoperatively, they were submitted to a 100% oxygen test by ventilating them mechanically using 100% oxygen for at least 30 min. Following this, four arterial blood gas samples were drawn from each patient *via* an indwelling arterial cannula. Two samples were drawn using 5 mL glass syringes (Multifit; Becton Dickinson Industria, Brasileira, Brazil), and two samples were drawn using 3 mL plastic syringes (Aspirator; Marquest Medical Products Inc., Englewood, USA). As much air as possible was removed from the syringes immediately after sampling. As soon as possible, two blood gas samples, one in a glass and one in a plastic syringe, were stored in ice-water (IW). The other samples were stored at room temperature (RT). The order in which the samples were taken was randomized using randomization tables [11]. Blood gas analysis was performed on each sample as soon as possible after sampling (the time needed for transport to the laboratory was approximately 5 min) and repeated at 15, 30, 60 and 120 mins after sampling. For blood gas analysis, the ABL 500 (Blood gas system; Radiometer, Copenhagen) was used. The results of the sample drawn in a glass syringe, immediately cooled in IW and determined as soon as possible (*i.e.*, approximately 5 min after sampling) were considered as the "gold standard". All the other results were compared to this.

Subsequently, shunt calculations were performed by using the results of the blood gas analysis of the various samples obtained by the four different sampling methods. Shunt was calculated using the formula: $Q's/Q't = 1/(1 + 200/\Delta PO_2)$, where $Q's/Q't$ = shunt fraction and ΔPO_2 = the difference in the alveolar and arterial oxygen tension in kPa [12, 13]. This formula may be used in cases where arterial blood becomes 100% saturated, as was the case in all of the present patients. In this formula, an arterial-venous oxygen difference of 2 mmol·L⁻¹ (4.45 vol %) is assumed. The results of all the shunt valves were compared with those obtained from samples taken by the "gold standard" method.

For statistical analysis of the results, the two-tailed Student's t-test from the Statistical Package for the Social Sciences (SPSS)/PC+ package (Gorinchem, The Netherlands) was used. A p-value equal to less than 0.01 was considered significant.

Results

Measurements of P_{a,O_2}

The P_{a,O_2} values obtained using the four different sampling methods and measured after different storage times are presented in figure 1. These results were compared with the P_{a,O_2} values obtained using the "gold standard" method.

The P_{a,O_2} in the glass syringes stored in IW remained stable for 60 min after sampling. After 120 min, the P_{a,O_2} in this sample deteriorated slightly but significantly (1.1 kPa; $p=0.037$). All the other results differed significantly from the results of the P_{a,O_2} measurements obtained by the "gold standard" method. This difference ranged 2.0–28.6 kPa.

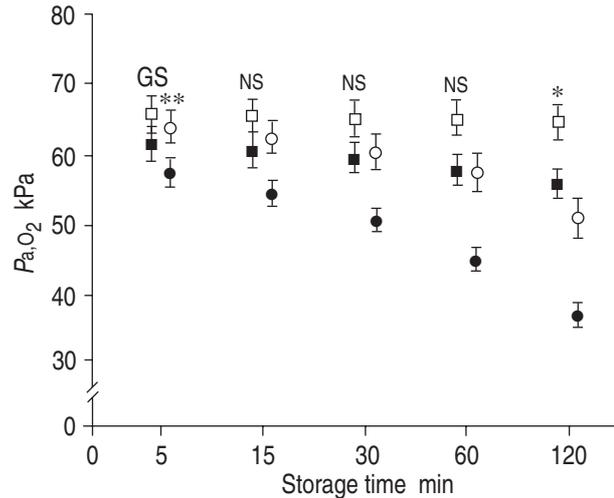


Fig. 1. – Arterial oxygen tension (P_{a,O_2}) in blood samples obtained using four different sampling methods and analysed after different storage times. Values are presented as mean \pm SEM. All results differed highly significantly ($p < 0.001$) from the "gold standard" (GS) method, except where otherwise indicated (ns: not significant; *: $p < 0.05$; **: $p < 0.01$). IW: ice water; RT: room temperature. The storage time of 5 min represents the time needed for transport of the sample to the laboratory. \square : glass, IW; \blacksquare : plastic, IW; \circ : glass, RT; \bullet : plastic, RT.

Measurements of P_{a,CO_2}

A significant increase in the P_{a,CO_2} values compared with the "gold standard" was detected only in the samples taken in a glass syringe, stored at RT and analysed 120 min after sampling, and in the samples taken in a plastic syringe, stored at RT and analysed 60 and 120 min after sampling (fig. 2).

Calculations of pulmonary shunt

Pulmonary shunt values calculated from the results of the analysis of the samples obtained by the four

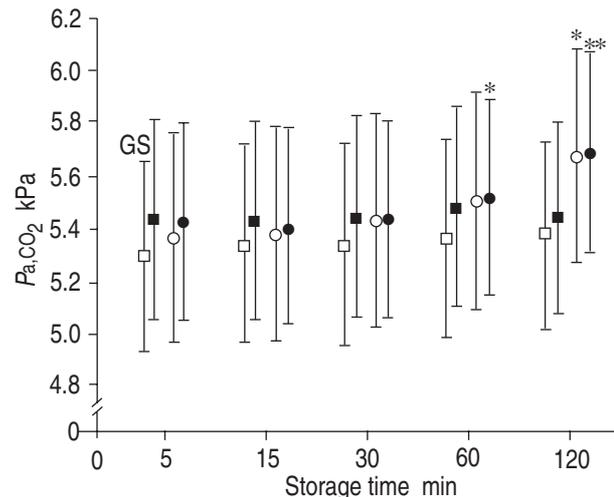


Fig. 2. – Carbon dioxide tension (P_{a,CO_2}) in the blood samples obtained by the four different sampling methods and analysed after different storage times. Values are presented as mean \pm SEM. Results did not differ significantly from the "gold standard" (GS) method, except where otherwise indicated (*: $p < 0.01$; **: $p < 0.001$). IW: ice water; RT: room temperature. The storage time of 5 min represents the time needed for transport of the sample to the laboratory. \square : glass, IW; \blacksquare : plastic, IW; \circ : glass, RT; \bullet : plastic, RT.

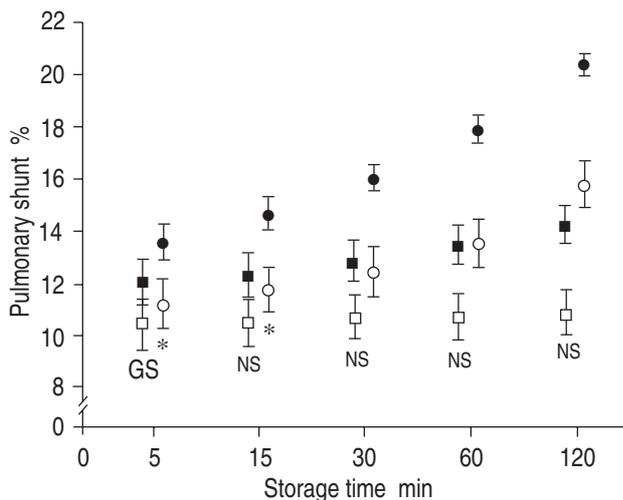


Fig. 3. — Estimated pulmonary shunt from arterial blood gas analysis of the various samples obtained by the four different sampling methods and analysed after different storage times. Values are presented as mean \pm SEM. All results differed highly significantly ($p < 0.001$) from the pulmonary shunt calculated from analysis of the sample obtained by the "gold standard" (GS) method, except where otherwise indicated (NS: not significant; *: $p < 0.01$). IW: ice water; RT: room temperature. The storage time of 5 min represents the time needed for transport of the sample to the laboratory. □: glass, IW; ■: plastic, IW; ○: glass, RT; ●: plastic, RT.

sampling methods after different storage times are shown in figure 3. These values were compared with the shunt calculated from the results of the "gold standard" method of sampling. The shunt values calculated after analysis of the samples taken in glass syringes stored in IW and analysed after different storage times did not differ significantly from that obtained from the results of the "gold standard" method. However, if the calculation was performed using the results from blood collected and/or stored by other methods, a significant increase in pulmonary shunt measurement was seen, even if analysis of the sample was performed as soon as possible after sampling (range 0.8–9.9%).

Discussion

This study shows that at high values the P_{a,O_2} measured in glass syringes differs significantly from the "gold standard" method when these samples are not stored in IW immediately. This occurs even if the sample is analysed as quickly as possible (in our hospital the time for transport of the sample to the laboratory was approximately 5 min). Blood samples in plastic syringes analysed as soon as possible after sampling showed significantly lower P_{a,O_2} values, which decreased further with the duration of storage time and if stored at RT. Substantial errors will be made in the subsequent estimation of pulmonary shunt if plastic syringes or glass syringes stored at RT are used in the 100% oxygen test, even if the samples are analysed as soon as possible after sampling. The P_{a,O_2} in the glass syringes stored in IW remained stable up to 60 min from the time of sampling. This result is comparable with the findings of BIRD *et al.* [14], who could not detect a significant decline in the P_{a,O_2} 60 min after sampling arterialized normoxaemic earlobe blood stored in glass capillary tubes in IW.

The rate of decline in P_{a,O_2} using the glass syringe at RT method was $0.11 \text{ kPa}\cdot\text{min}^{-1}$ (theoretically, the decline in the P_{a,O_2} here was caused mainly by the continuing metabolism of the blood cells). Using the plastic syringe in IW method, the decline was $0.05 \text{ kPa}\cdot\text{min}^{-1}$ (where, theoretically, diffusion was the most important factor). In plastic syringes at RT the rate of decline was $0.18 \text{ kPa}\cdot\text{min}^{-1}$ (here, diffusion and metabolism were responsible for the decline in the P_{a,O_2}), which appears to be approximately the cumulative effect of the decline of the glass syringe at RT method and the rate of decline of the plastic syringe in IW method. In the study by PRETTO and ROCHFORD [9] higher rates of decline were reported for samples taken in glass stored at RT ($0.49 \text{ kPa}\cdot\text{min}^{-1}$), and the samples taken in plastic syringes stored at RT ($1.21 \text{ kPa}\cdot\text{min}^{-1}$). These rates of decline represented the decline in P_{a,O_2} in the first 10 min after sampling. In the present study, the rate of decline was calculated considering the decline in P_{a,O_2} over the whole period of 120 min. However, if the decline in P_{a,O_2} within the first 5 min was considered (representing the transport time of the sample to the laboratory) in the present study, fairly comparable results were found (0.40 and $1.68 \text{ kPa}\cdot\text{min}^{-1}$, representing the decline in P_{a,O_2} in the first 5 min for the samples taken in a glass syringe stored at RT and those taken in a plastic syringe stored at RT, respectively).

A further striking observation was that the P_{a,O_2} values measured in the plastic syringes determined as soon as possible after sampling differed more from the "gold standard" method than was expected, even taking into account the rate of decline calculated for the different sampling methods. This observation was confirmed by applying regression analysis to the results of the different sampling methods. This procedure made it possible to estimate the P_{a,O_2} values in the glass syringes at RT and the plastic syringes at RT and in IW at the time of withdrawal of the sample, assuming a transport time for the samples of 5 min. The estimate for the glass syringe at RT method was 63.8 kPa (95% confidence interval (95% CI) $60.5\text{--}67.2 \text{ kPa}$), for the plastic syringe in IW method 61.2 kPa (95% CI: $58.3\text{--}64.0 \text{ kPa}$), and for the plastic syringe at RT method 56.6 kPa (95% CI $54.3\text{--}59.0 \text{ kPa}$). Comparing these results to the result of the "gold standard" method (*i.e.* 65.6 kPa), this "gold standard" value was outside the range of the 95% CI of both the methods using the plastic syringes. This observation may be explained if a systematic intrinsic error is made when sampling blood with a plastic syringe. It is possibly more difficult to remove the air bubble completely from the plastic syringe than with glass syringes, as was observed during the study by one of the authors (FWJMS). Another explanation might be the smaller volume of blood which was aspirated in the plastic syringes. The same air bubble might lower the P_{a,O_2} in this smaller volume of blood to a greater extent.

The P_{a,CO_2} remained very stable with the different sampling methods. This was expected because carbon dioxide is unable to diffuse through the walls of plastic or glass syringe. Therefore, metabolism is the only factor which is likely to alter the P_{a,CO_2} . In the present study, significant differences were found only between the measured mean P_{a,CO_2} in the samples stored at RT and determined 60 (for the samples taken in plastic

syringes) or 120 min (for the samples taken in glass and plastic syringes) after sampling (fig. 2). This is consistent with the notion that metabolism is the main factor which can alter the P_{a,CO_2} measurement. These alterations, although significant, were fairly small and were comparable with the findings of PRETTO and ROCHFORD [9].

The mean pulmonary shunt found in the present study with the glass syringe in IW method was 10.4%. A significant shunt was expected in these patients as they had all been on extracorporeal circulation a few hours prior to sampling. It is known that extracorporeal circulation can induce a pulmonary shunt [15, 16]. The error in the calculated pulmonary shunt when not using the glass syringe in IW method was highly significant and ranged 0.8–9.9%.

In conclusion, we recommend that glass syringes and not plastic syringes should be used in the 100% oxygen test, and that these syringes should be cooled immediately, even if the sample is to be analysed as soon as possible. When using this method of sampling, it appeared that the value of arterial oxygen tension measured did not deteriorate significantly within 60 min after sampling, and that no significant errors were made in the calculated pulmonary shunt fraction. Furthermore, the results of this study suggest that an intrinsic error is likely when plastic syringes are being used. The cause of this intrinsic error remains unclear and calls for further investigation.

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