Use of Glass Capillaries Avoids the Time Changes in High Blood P\textsubscript{O}_2 Observed With Plastic Syringes*

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Study objectives: In adults, arterial blood samples are usually drawn using plastic syringes. In contrast to glass syringes, plastic syringes let oxygen diffuse through their wall. This results in P\textsubscript{O}_2 changes during storage, especially when P\textsubscript{O}_2 is high. An alternative to glass syringes is the Microsampler (Roche Diagnostics; Schaffhausen, Switzerland), a commercially available device consisting of a heparinized glass capillary fitted with a 26-gauge needle and used to collect arterial blood in the same way as a plastic syringe fitted with a needle.

Design: We evaluated the performance of the Roche Microsampler for storing arterial blood in view of P\textsubscript{O}_2 measurement, comparatively with glass and plastic syringes. Five approximate initial P\textsubscript{O}_2 levels (650, 400, 200, 130, and 80 mm Hg) and two storage temperatures (ambient temperature and 4°C) were studied.

Settings: Bench study.

Results: Plastic syringes allowed reliable measurement of P\textsubscript{O}_2 values when initial P\textsubscript{O}_2 was too low to ensure complete hemoglobin oxygen saturation, but were associated with time-dependent underestimation of P\textsubscript{O}_2 at higher initial P\textsubscript{O}_2 values. No such underestimation occurred with the Roche Microsampler stored at 4°C for up to 1 h for all P\textsubscript{O}_2 levels studied.

Conclusion: The Roche Microsamplers appeared to be reliable devices in preventing oxygen diffusion.

Key words: blood gas analysis; 100% oxygen test; shunt; specimen handling

In most hospitals, plastic syringes are used to draw arterial blood samples from adult patients. Important advantages of these syringes are that they are preheparinized and disposable. It has long been recognized that, in contrast to glass syringes, diffusion of oxygen occurs through the wall of plastic syringes. This alters P\textsubscript{O}_2 during storage, especially when P\textsubscript{O}_2 is high.\textsuperscript{1–3}

Arterial blood can be collected using the Microsampler (Roche Diagnostics; Schaffhausen, Switzerland), a commercially available device consisting of a heparinized capillary fitted with a 26-gauge needle and used to collect arterial blood in the same way as a plastic syringe fitted with a needle. This device exhibits two potentially important differences with plastic syringes: (1) little diffusion of oxygen should occur through the glass wall, and (2) the very slender needle, which is appropriate because blood flows into the capillary without aspiration, minimizes trauma and pain.\textsuperscript{4}

In this study, we evaluated the Roche Microsampler in terms of oxygen diffusion during storage between blood sampling and P\textsubscript{O}_2 measurement, comparatively with plastic syringes and glass syringes. We hypothesized that the Roche Microsampler could be efficient in preventing oxygen diffusion for high levels of P\textsubscript{O}_2 and therefore responsible for a smaller time-dependent decrease in P\textsubscript{O}_2 that occurs with plastic syringe.

Materials and Methods

Materials

The Roche Microsampler, which was designed in the early 1980s,\textsuperscript{4,5} consists of two glass capillaries containing lithium heparinate, mounted in series, and fitted with a 26-gauge needle
via a short polyethylene connector. A schematic diagram is presented in Figure 1. Total capacity is 240 μL. The glass capillaries fill readily after puncture of the arterial wall by the needle; the rapid, pulsing rise of blood in the capillaries shows that a vein has not been punctured by mistake. We compared the Roche Microsampler to 3-mL preheparinized plastic syringes (Becton Dickinson; Franklin Lakes, NJ) and to 5-mL glass syringes previously rinsed with a heparin solution (Becton Dickinson). Both syringe types were filled with 3 mL of blood. Blood gas analysis was performed using an ABL 520 device (Blood Gas System; Radiometer, Copenhagen).

Protocol

Each experiment was performed on 20 mL of whole blood obtained from normal volunteers who had given their informed consent to the study. All specimens had normal hemoglobin concentrations and normal blood cell counts. Each specimen was placed in a 50-mL glass syringe that had been heparinized manually. Before sampling, the syringe was equilibrated for 40 min with an appropriate mixture of oxygen. Five percent carbon dioxide was present in the equilibrating gas. Temperature was maintained at 37°C by a controlled heating system. Each experiment consisted in comparing the sampling devices (glass syringe, plastic syringe, and Roche Microsampler) after storage for 5, 15, 30, and 60 min, at each of five approximate PO₂ levels. The 12 samples needed for each PO₂ level were taken from the 50-mL glass syringe through a polyvinyl tube fitted with a three-way stopcock to allow flushing and attachment of the syringes or Roche Microsampler. Samples were collected anaerobically into the glass syringes, plastic syringes, and Roche Microsamplers, which were sealed with rubber caps immediately after filling. All samples were periodically agitated during storage to ensure thorough mixing.

In the first part of the study, five approximate levels of PO₂ were studied (650, 400, 200, 130, and 80 mm Hg), and the sampling devices were stored at ambient temperature (range, 22°C to 24°C). At each time point, the contents of each sampling device were quickly hand mixed before PO₂ measurement. The three devices were studied in random order; < 5 min elapsed from the first to the last measurement at each time point. The experiments were repeated three times on different days with each of the five PO₂ levels.

In the second part of the study, to separate the effects of oxygen diffusion from those of blood cell metabolism, we stored the sampling devices in the laboratory refrigerator at 4°C. The three higher approximate PO₂ levels were studied (650, 400, and 200 mm Hg) at the same time points as in the first part of the study (5, 15, 30, and 60 min). In addition, PO₂ in the 50-mL glass syringe was measured at baseline and after 65 min of storage at 4°C. The experiments were repeated three times on different days with each of the three approximate PO₂ levels. Oxygen gradients across the syringe are shown in Table 1.

Statistics

Data are expressed as mean ± SEM. Comparisons between the PO₂ variations at five different times with three different devices were made using a two-way analysis of variance for repeated measures. When significant differences were found, individual means were compared using the Scheffe test. For all comparisons, p values < 0.05 were considered significant.

RESULTS

Figure 2 illustrates PO₂ changes over time at ambient temperature. With PO₂ at 650 mm Hg, a sharp fall in PO₂ (approximately 150 mm Hg at 60 min) was noted in the plastic syringes and a considerably smaller decline (approximately 60 mm Hg) was noted in the glass syringes and Roche Microsamplers. With PO₂ at 400 mm Hg, the PO₂ fall was also larger in the plastic syringes (approximately 90 mm Hg at 60 min) than in the glass syringes and Roche Microsamplers (approximately 40 mm Hg at 60 min). With PO₂ at 200 mm Hg, in contrast, similar decreases were seen in all three devices (approximately 40 mm Hg at 60 min). With the two PO₂ levels below full hemoglobin oxygen saturation (approximately 130 mm and 80 mm), there was no significant difference among the three devices.

We repeated the experiments with storage at 4°C instead of ambient temperature, using the three approximate PO₂ levels associated with significant changes in the first part of the study (650, 400, and 200 mm Hg). As shown in Figure 3, with PO₂ of 650 mm Hg, PO₂ remained unchanged in the glass syringes, but decreased by approximately 40 mm Hg and 90 mm Hg after 60 min in the Roche Microsamplers and plastic syringes, respectively. With PO₂

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**Figure 1.** Schematic drawing of the Roche Microsampler. 26g = 26-gauge.
at 400 mm Hg, \( P_{O_2} \) remained unchanged in the glass syringes and Roche Microsamplers, but fell by approximately 40 mm Hg after 60 min in the plastic syringes, although the difference was not statically significant. With \( P_{O_2} \) at 200 mm Hg, \( P_{O_2} \) remained unchanged throughout the 60-min storage period in all three sampling devices. No significant \( P_{CO_2} \) changes were demonstrated in any of the experiments. The mean change over 1 h was \(-0.5\) mm Hg (range, \(-1.6\) to \(-0.3\) mm Hg).

**Discussion**

Preheparinized plastic syringes are the devices most commonly used to store blood for blood gas analysis. It has been demonstrated repeatedly that a major drawback of plastic syringes is oxygen diffu-

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**Table 1—Oxygen Gradients Across the Syringe at 23°C and 4°C**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>( P_{O_2}, 650 ) mm Hg</th>
<th>( P_{O_2}, 400 ) mm Hg</th>
<th>( P_{O_2}, 200 ) mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>23°C</td>
<td>520</td>
<td>365</td>
<td></td>
</tr>
<tr>
<td>4°C</td>
<td>351</td>
<td>196</td>
<td>216</td>
</tr>
</tbody>
</table>

*\( P_{O_2} \) values measured in a temperature-controlled blood gas analyzer at 37°C change to lower values when the blood is stored in a syringe placed in the refrigerator or at 23°C, according to the change in oxygen solubility (oxygen solubility increases by approximately 85% and approximately 25% when temperature decreases from 37°C to 4°C and from 37°C to 23°C, respectively). Oxygen gradient across the syringe (ambient \( P_{O_2} \) is considered to be 155 mm Hg) is therefore lower. For the situation of a \( P_{O_2} \) of 200 mm Hg at 37°C, the computation cannot be performed since full saturation of hemoglobin is no longer present.

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**Figure 2.** Time changes in \( P_{O_2} \) during storage at room temperature of blood in plastic syringes \( \triangle \), glass syringes \( ■ \), and Roche Microsamplers \( ○ \). At the 650 mm Hg and 400 mm Hg levels, there was an overall significant difference among the three devices (analysis of variance for repeated measures < 0.01). The behaviors of the Roche Microsamplers and the glass syringes were identical, whereas the \( P_{O_2} \) with plastic syringes was significantly lower at 15, 30, and 60 min (p < 0.04 to p < 0.004). At the 130 mm Hg and 80 mm Hg levels, there was no significant difference among the three devices (analysis of variance for repeated measures, not significant [NS]).

**Figure 3.** \( P_{O_2} \) changes over time during storage of blood at 4°C in plastic syringes \( \triangle \), glass syringes \( ■ \), and Roche Microsamplers \( ○ \). At the 650 mm Hg level, there was an overall significant difference among the three devices (analysis of variance for repeated measures < 0.01). The behaviors of the Roche Microsamplers and the glass syringes were identical, whereas the \( P_{O_2} \) with plastic syringes was significantly lower at 15, 30, and 60 min (p < 0.02 to p < 0.001). See Figure 2 legend for expansion of abbreviation.
Heparinized capillaries are commonly used to collect blood samples, usually after making a scalpel incision in the heel in neonates or in the earlobe in adults. Of commercially available capillary sampling devices, only one, the Roche Microsampler, can be fitted with a needle to allow arterial puncture. This device exhibits two characteristics that would be expected to minimize artifacts in PO₂ determination: (1) the capillaries are made of glass, which is impermeable to oxygen; and (2) the device allows rapid sampling, thus minimizing the risk of error due to any contact with ambient air. In this study, we investigated whether PO₂ in blood collected into Roche Microsamplers remained constant after sampling. We found that the Roche Microsampler behaved in the same way as glass syringes at five different PO₂ levels.

Comparison of Roche Microsamplers, Glass Syringes, and Plastic Syringes With PO₂ Values > 150 mm Hg

When blood specimens were stored in glass syringes at 4°C, we observed no changes in PO₂ with any of the three approximate PO₂ levels studied: 650, 400, and 200 mm Hg. These results confirm that no significant diffusion of oxygen out of the glass syringes occurred, as previously described, and that storage at 4°C prevented metabolic uptake of oxygen; it should be noted that placing the syringe in the refrigerator is as efficient as immersing the syringe in chilled water.

Our data indicate that the Roche Microsampler is suitable for sampling arterial blood with high PO₂ levels, whereas large errors can occur with plastic syringes stored at room temperature, even for short periods. These changes in PO₂ are of particular importance when estimating shunting by the 100% oxygen technique: normal shunting can be overestimated to a value located within the abnormal range (> 5%) after a delay as short as 5 min at room temperature in a plastic syringe.

Comparison of Roche Microsamplers, Glass Syringes, and Plastic Syringes With PO₂ levels < 150 mm Hg

For this range of PO₂ values, PO₂ changes during storage were small and clinically nonsignificant with all three sampling devices. Indeed as PO₂ falls to < 150 mm Hg, apparent oxygen solubility increases gradually because of the shape of the oxyhemoglobin dissociation curve: the hemoglobin is not fully saturated, the apparent solubility of oxygen is considerably larger than the solubility of oxygen in plasma, and any change in oxygen content due to oxygen diffusion is buffered by a change in hemoglobin saturation.

With the Roche Microsamplers and glass syringes, no difference in PO₂ changes was observed and these changes were related to metabolic oxygen uptake. As PO₂ decreases, the apparent solubility of oxygen increases, and consequently the metabolic uptake of oxygen is responsible for a smaller change in PO₂ during storage (approximately 10 mm Hg at 130 mm Hg vs 5 mm Hg at 80 mm Hg). Cohill and White studied a sampling device consisting of a 200-μL glass capillary tube attached to a 23-gauge needle; they evaluated the effect of storing the blood-filled device in ice for 1 h, and found no change in PO₂ (approximately 100 mm Hg). This suggests that storage in ice or a refrigerator would eliminate the small PO₂ changes seen with the Roche Microsampler in our study.

In conclusion, we have shown that with all initial PO₂ levels tested, the Roche Microsampler, an arterial blood sampling device consisting of glass heparinized capillaries fitted with a 26-gauge needle, is effective in preventing oxygen diffusion. Since glass syringes are no longer used routinely, the Roche Microsampler is a good alternative for sampling high PO₂ blood in situations in which blood gas analysis cannot be performed immediately. In addition, because blood flows into the capillary without aspiration, a very slender needle can be used to reduce pain during sampling.

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