ปริมาณออกซิเจนในสารละลายที่ใช้สำหรับการผ่าตัดตาในประเทศไทย

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บทคัดย่อ
วัตถุประสงค์: เพื่อวัดระดับและเปรียบเทียบแรงดันย่อยของออกซิเจนในสารละลายที่ใช้สำหรับการผ่าตัดตาในประเทศไทย
วิธีการศึกษา: นำสารละลายที่ใช้สำหรับการผ่าตัดตาที่มีจำหน่ายในประเทศไทย 5 ชนิด ได้แก่ Optosol (Thai Otsuka Pharmaceutical Company, Thailand), BSS และ BSS plus (Alcon Laboratories, USA), OSS (General Hospital Products, Thailand) และ Ocusol (ANB Lab, Thailand) มาทำการวัดระดับแรงดันย่อยออกซิเจนด้วยเครื่องตรวจสอบวิเคราะห์ซึ่งในผลิตภัณฑ์ 5 ชนิด ที่เวลา 0, 5, 10, 15, 20, 25 นาทีหลังการฉีดออก แล้วนำค่าที่ได้มาเปรียบเทียบกัน
ผลการศึกษา: อัตราการเพิ่มของออกซิเจนในสารละลายที่ใช้ในการผ่าตัดตาที่มีความแตกต่างกัน โดยบรรจุแก้วประจุกันที่ใช้ระบบวิเคราะห์ มีระดับออกซิเจนในสารละลายเพิ่มขึ้นตามเวลาที่ผ่านไป ในบรรจุแก้วประจุกันที่เป็นระบบบิด มีระดับออกซิเจนในสารละลายเพิ่มขึ้นอย่างรวดเร็วในช่วงแรกหลังจากนั้นจะคงที่ ส่วนบรรจุแก้วประจุกันที่เป็นระบบออกซิเจนในสารละลายน้อยที่สุดที่จะเรียกได้ว่าเป็นสูตรการทดลอง
สรุป: กระบวนการผลิตและบรรจุแก้วที่เป็นปัจจัยความคุ้มค่าแรงดันย่อยออกซิเจนในสารละลายที่ใช้สำหรับการผ่าตัดตา จักษุเวชศาสตร์ 2558; กรณีที่ 29(2): 75-80.

¹ ภาควิชาจุลวิทยา คณะแพทยศาสตร์โรงพยาบาลรามอินทรา ² ภาควิชาพยาธิวิทยา คณะแพทยศาสตร์โรงพยาบาลรามอินทรา
Oxygen Dissolution in Surgical Ophthalmic Solutions Used in Thailand

Pornchai Simaroj, M.D.¹, Donrudee Sirinil, M.D.¹, Somluk Vanavanan², Anchalee Chittamma², Kaevalin Lekhanont, M.D.¹

Abstract

Purpose: This study was to measure and compare oxygen dissolution among ophthalmic balanced salt solutions used in Thailand.

Methods: The partial pressure of oxygen (pO₂) from all balanced salt solutions was measured at fixed intervals at 0, 5, 10, 15, 20 and 25 minutes by a blood gas analyzer (Critical Care Xpress, nova biomedical, Waltham MA, USA). There are 5 kinds of ophthalmic balanced salt solutions available in Thailand: Optosol (Thai Otsuka Pharmaceutical Company, Thailand), BSS and BSS plus (Alcon Laboratories, USA), Ocusol (ANB Lab, Thailand) and OSS (General Hospital Products, Thailand).

Results: All of the containers were plastic bottles except BSS which was in a plastic bag or glass bottle and also BSS plus which was in a glass bottle. There were differences in rate of pO₂ rise among containers. The glass bottles which needed an air vented system produced more O₂ dissolution with respect to time. The closed system plastic bottles had acute rising of pO₂ in the first period and the plastic bags allowed the least amount of oxygen to diffuse into the solution.

Conclusion: The factors controlling the initial pO₂ and O₂ dissolution may be related to the manufacturing and packaging. Thai J Ophthalmol 2015; July-December 29(2): 75-80.

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**Introduction**

Oxidative stress from hydroxyl radicals during phacoemulsification is one of the major mechanisms that damage the eye. The production of hydroxyl radicals depends on the presence of oxygen even with irrigation and aspiration process\(^1\), proportional to phacoemulsification time and was reduced in the presence of BSS plus\(^2\). There have been efforts trying to reduce endothelial cell damage by adding organic molecules (e.g., citrate, acetate, glutathione, dextrose) as a buffer\(^3,4\) to reduce free radicals or using viscoelastic as a protector\(^5\). This study quantifies the amount of oxygen, which is assumed to be the precursor of the hydroxyl radicals, by measuring the partial pressure of oxygen (pO\(_2\)) and identifying factors which affect it.

**Materials and Methods**

There were five kinds of ophthalmic balanced salt solutions used in the study including Optosol (Thai Otsuka Pharmaceutical Company, Thailand), BSS and BSS plus (Alcon Laboratories, USA), Ocusol (ANB Lab, Thailand) and OSS (General Hospital Products, Thailand). The experimental model was set up in the laboratory to simulate the irrigation pathway in cataract surgery by allowing fluid from the containers to flow through a closed system infusion pump (Volumat Agilia, Fresenius Kabi, Germany) with fixed flow rate at 1,200 mL/hour which means 500 mL per 25 minutes, approximately the same amount of time for uncomplicated cataract surgery. The fluid (0.5 mL) was collected from the end of the infusion line and about 0.1 mL was analyzed by blood gas analyzer machine (Critical Care Xpress, nova biomedical, Waltham MA, USA) at fixed intervals of 0, 5, 10, 15, 20, 25 minutes. All six samples of each ophthalmic balanced salt solution were examined by the same blood gas analyzer in clinical chemistry laboratories under the same atmospheric pressure, 760 mmHg, which provided room air pO\(_2\) about 159.19 mmHg, but the blood gas analyzer was calibrated to report at body temperature (37°Celsius); therefore the estimated pO\(_2\) was 180.75 mmHg in the environment. The results from all samples were recorded and mean pO\(_2\) was calculated from six samples of each solution at all points of time. All data were then analyzed. Continuous data were expressed as either mean ± standard deviation (SD) or median and range, depending on the normality of distribution. Categorical data described as frequency and percentage.

**Results**

The initial pO\(_2\) varied among brands and rose highest during the first five minutes (initial phase) then stabilized throughout twenty-five minutes (steady phase). The initial and mean pO\(_2\) were lowest in Optosol. The means pO\(_2\) at different points of time from all ophthalmic balanced salt solutions are compared in Table 1 and Figure 1.

All products of BSS were compared. BSS in the plastic bag had the highest initial and mean pO\(_2\). Both BSS and BSS plus which were contained in glass bottles shared the same trend of pO\(_2\) with lower initial pO\(_2\). Plastic bag BSS shows steady pO\(_2\) through 25 minutes while glass bottle BSS rose higher in the initial phase then roseless steeply in the steady phase. pO\(_2\) in BSS solutions are compared in Figure 2.

Initial phase rise of pO\(_2\) was analyzed as a percentage of increase in oxygen concentration during the initial phase. It was calculated from the difference of pO\(_2\) value at 0 and 5 minutes as shown in Table 2.
pO₂ in all solutions rose in the initial phase and further rose in BSS and BSS plus however pO₂ of OSS, BSS bag and Ocusol reached steady phase at 190-200 mmHg after first 5 minutes. Optosol pO₂ approached its steady phase at 60-70 mmHg after the first 10 minutes.

\[
\text{pO}_2 \text{ at initial phase} = \frac{\text{pO}_2 \text{ at 5 min} - \text{pO}_2 \text{ at 0 min}}{\text{pO}_2 \text{ at 0 min}} \times 100\%
\]

**Table 1** Mean pO₂ (mmHg) in four ophthalmic solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSS glass</td>
<td>117.08</td>
<td>143.26</td>
<td>151.52</td>
<td>167.44</td>
<td>177.60</td>
<td>187.00</td>
</tr>
<tr>
<td>BSS bag</td>
<td>188.80</td>
<td>191.00</td>
<td>191.93</td>
<td>191.87</td>
<td>192.00</td>
<td>191.43</td>
</tr>
<tr>
<td>BSS plus</td>
<td>100.20/128.78*</td>
<td>140.86</td>
<td>146.38</td>
<td>157.56</td>
<td>168.68</td>
<td>176.20</td>
</tr>
<tr>
<td>Ocusol</td>
<td>170.60</td>
<td>194.47</td>
<td>192.93</td>
<td>194.47</td>
<td>193.20</td>
<td>194.93</td>
</tr>
<tr>
<td>Optosol</td>
<td>46.90</td>
<td>79.22</td>
<td>66.82</td>
<td>57.30</td>
<td>60.96</td>
<td>71.36</td>
</tr>
<tr>
<td>OSS</td>
<td>189.44</td>
<td>197.94</td>
<td>200.68</td>
<td>200.16</td>
<td>198.28</td>
<td>200.84</td>
</tr>
</tbody>
</table>

* BSS plus pO₂ after adding buffer

**Figure 1** Partial pressure of oxygen with time
Discussion

The initial partial pressure of oxygen in the solutions depends on the manufacturing process and packaging. The comparison of $pO_2$ among BSS solutions shows that BSS in the plastic bag package has highest initial $pO_2$ which is approximately the same as room air $pO_2$. Both BSS and BSS plus in glass bottle have lower initial $pO_2$ than BSS in the plastic bag. It can be concluded that packaging of the solution has an effect on initial $pO_2$ and the plastic bag allows more oxygen diffusion. The buffer adding process in BSS plus may be the factor causing higher curve of rising rate in initial phase than BSS. The air vent system in glass bottles allows a higher amount of oxygen diffusion during the initial phase then the rising rate is steady until the end of experiment time while $pO_2$ in the plastic bottle rises during first 5 minutes then stabilizes until the end. The diffusion of oxygen in the initial phase is caused by the pressure gradient while the $pO_2$ in the steady phase involved packaging of the product. The plastic bottle allows rapid oxygen diffusion in the initial phase resulting in equilibrium of $pO_2$ to room air in the steady phase. The time of the experiment could be extended to decide whether glass bottle $pO_2$ will be end up at the same equilibrium point toward room air $pO_2$ as in the plastic bag and bottle. However in practice most of the uncomplicated phaco-

Table 2  Percentage of oxygen diffusion during rising phase

<table>
<thead>
<tr>
<th>Solutions</th>
<th>BSS glass</th>
<th>BSS bag</th>
<th>BSS plus</th>
<th>Ocusol</th>
<th>Optosol</th>
<th>OSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>22.36</td>
<td>1.16</td>
<td>40.57</td>
<td>13.99</td>
<td>68.91</td>
<td>4.48</td>
</tr>
</tbody>
</table>

* Calculated from $pO_2$ at 5 min - $pO_2$ at 0 min / $pO_2$ at 0 min x 100

Figure 2  BSS partial pressure of oxygen with time
emulsification time limits are within 30 minutes and longer time of operation needs a second bottle of solution.

The production of free hydroxyl radicals is lower in BSS plus compared to BSS\(^2\) but the trends of \(\text{pO}_2\) are the same between them which means the production of hydroxyl radicals is the same but the buffer in BSS plus (glutathione, glucose, sodium bicarbonate) can reduce hydroxyl radicals better than acetate and citrate in BSS. Optosol has the lowest initial \(\text{pO}_2\) and approaches its equilibrium point approximately at 60-70 mmHg after rising toward room air \(\text{pO}_2\) which could be explained by the self-collapsed system bottle. The time of experiment also should be extended to observe if \(\text{pO}_2\) of Optosol remains stable at the lower point or increases further but at as lower rate.

There is evidence suggesting that hydroxyl radicals, whose production depends on the presence of oxygen, damage endothelial cells\(^2\) and that keeping low \(\text{pO}_2\) can reduce the risk of endothelial cell damage\(^2\); still there is no direct evidence to correlate the amount of \(\text{pO}_2\) with the production of hydroxyl radicals and damage to endothelial cell.

In conclusion, there were differences in rate of \(\text{pO}_2\) rise among containers. The results confirmed that glass bottles which needed an air vented system produced more \(\text{O}_2\) dissolution with respect to time. The closed system plastic bottle had acute rising of \(\text{pO}_2\) in the first period and the plastic bag allowed the least amount of oxygen to diffuse into the solution. The \(\text{pO}_2\) was lowest in Optosol solution at all points of time. Therefore, the factors controlling the initial \(\text{pO}_2\) and \(\text{O}_2\) dissolution may be related to the manufacturing and packaging.

References