Original Article/นิพนธ์ต้นฉบับ

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) มาทำการวัดระดับแรงดันย่อยออกซิเจนด้วยเครื่องตรวจวิเคราะห์ก๊าซในเลือดทุกๆ 5 นาที ที่เวลา 0, 5, 10, 15, 20, 25 นาทีหลังเริ่มการทดลอง แล้วนำค่าที่ได้มาเปรียบเทียบกัน

ผลการศึกษา: อัตราการเพิ่มของออกซิเจนในสารละลายที่ใช้ในการผ่าตัดตามีความแตกต่างกัน โดยบรรจุภัณฑ์ขวดแก้วที่ใช้ระบบรูอากาศ มีระดับออกซิเจนในสารละลายเพิ่มขึ้นตามเวลาที่ผ่านไป ในบรรจุภัณฑ์ขวดพลาสติกที่เป็นระบบปิด มีระดับออกซิเจนในสารละลายเพิ่มขึ้นอย่างรวดเร็วในช่วงแรกหลังจากนั้นจะคงที่ ส่วนบรรจุภัณฑ์ถุงพลาสติกมีระดับออกซิเจนในสารละลายน้อยที่สุดตั้งแต่ระยะเริ่มต้นจนสิ้นสุดการทดลอง

สรุป: กระบวนการผลิตและบรรจุภัณฑ์เป็นปัจจัยควบคุมแรงดันย่อยออกซิเจนในสารละลายที่ใช้สำหรับการผ่าตัดตา **จักษุเวชสาร 2558; กรกฎาคม-ธันวาคม 29(2): 75-80.**

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Original Article/นิพนธ์ต้นฉบับ

Oxygen Dissolution in Surgical Ophthalmic Solutions Used in Thailand

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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 (pO_2) 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 pO_2 rise among containers. The glass bottles which needed an air vented system produced more O_2 dissolution with respect to time. The closed system plastic bottles had acute rising of pO_2 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 pO_2 and O_2 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 (eg, 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 $\pm$ 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.

$$pO_2 \text{ at initial phase} = \frac{pO_2 \text{ at 5 min} - pO_2 \text{ at 0 min}}{pO_2 \text{ at 0 min}} \times 100\%$$

Table 1 Mean pO_2 (mmHg) in four ophthalmic solutions

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

* BSS plus pO_2 after adding buffer

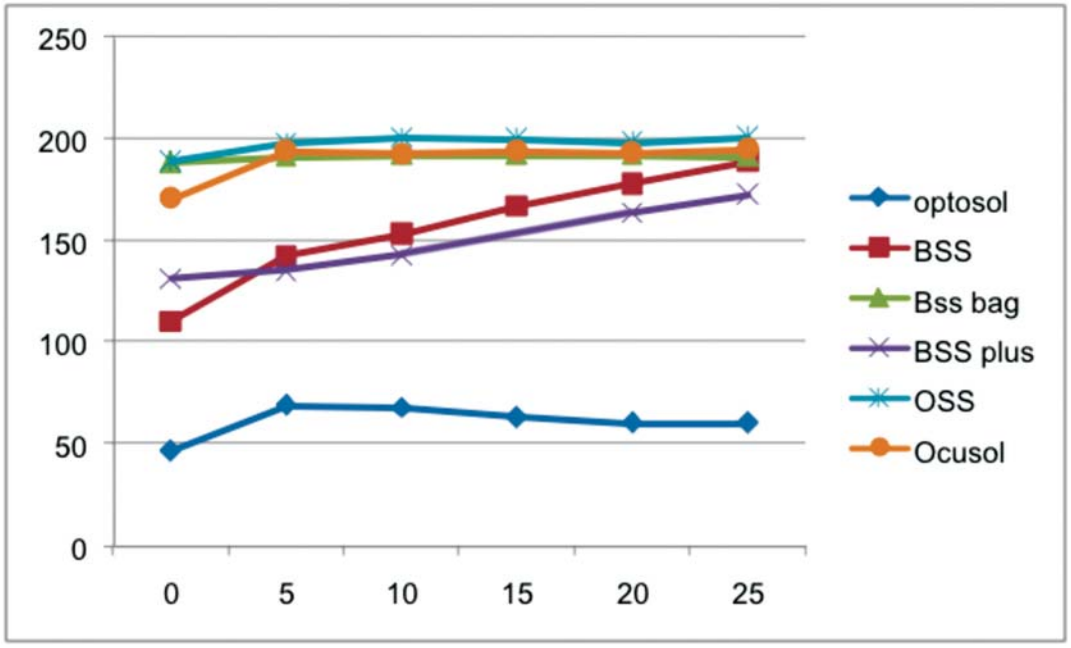

Figure 1 *Partial pressure of oxygen with time*

pO_2 in all solutions rose in the initial phase and further rose in BSS and BSS plus however pO_2 of OSS, BSS bag and Ocusol reached steady phase at 190-200 mmHg after first 5 minutes. Optosol pO_2 approached its steady phase at 60-70 mmHg after the first 10 minutes.

Table 2 Percentage of oxygen diffusion during rising phase*

Solutions	BSS glass	BSS bag	BSS plus	Ocusol	Optosol	OSS
Percentage	22.36	1.16	40.57	13.99	68.91	4.48

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

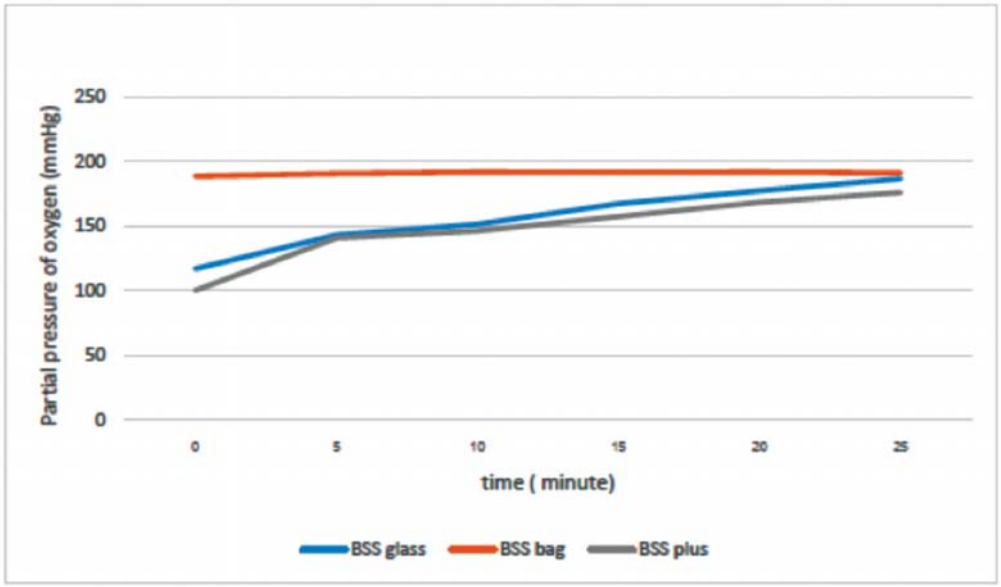

Figure 2 *BSS partial pressure of oxygen with time*

Discussion

The initial partial pressure of oxygen in the solutions depends on the manufacturing process and packaging[6]. 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 processin BSS plus may be the factor causing higher curve of rising rate in initial phase than BSS[6]. 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-

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 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 pO_2 and approaches its equilibrium point approximately at 60-70 mmHg after rising toward room air pO_2 which could be explained by the self-collapsed system bottle. The time of experiment also should be extended to observe if 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 pO_2 can reduce the risk of endothelial cell damage[2]; still there is no direct evidence to correlate the amount of pO_2 with the production of hydroxyl radicals and damage to endothelial cell.

In conclusion, there were differences in rate of pO_2 rise among containers. The results confirmed that glass bottles which needed an air vented system produced more O_2 dissolution with respect to time. The closed system plastic bottle had acute rising of pO_2 in the first period and the plastic bag allowed the least amount of oxygen to diffuse into the solution. The pO_2 was lowest in Optosol solution at all points of time. Therefore, the factors controlling the initial pO_2 and O_2 dissolution may be related to the manufacturing and packaging.

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