Effect of different volumes of BAL fluid on arterial oxygen saturation

M. Pirożyński*, P. Śliwiński**, J. Zieliński**

Effect of different volumes of BAL fluid on arterial oxygen saturation. M. Pirożyński, P. Śliwiński, J. Zieliński.
ABSTRACT: We monitored arterial oxygen saturation ($S_{tc}O_2$) continuously using the OHMEDA Biox 3700 oximeter. We studied seven patients undergoing a 100 ml bronchoalveolar lavage (BAL-100), seven patients undergoing a 200 ml bronchoalveolar lavage (BAL-200), and seven patients during diagnostic fibreoptic bronchoscopy alone. Immediately following insertion of the bronchoscope a brief increase in $S_{tc}O_2$ level (0.3–0.5%) was seen, followed by a gradual decline, never exceeding 2–5% during the diagnostic bronchoscopy. Introduction of lavage fluid into a segmental bronchus always produced a further decline in $S_{tc}O_2$. In the BAL-100 group the fall did not exceed 7%, whereas in the BAL-200 group a fall of up to 15% from the baseline level was observed. Return to initial values was seen in most of the patients within 10 min following completion of the procedure. Only in those patients with the most profound $S_{tc}O_2$ fall was this period increased, up to 30 min.
Eur Respir J., 1988, 1, 943–947.

* Bronchological Unit
** Dept of Respiratory Medicine, Institute of Tuberculosis and Lung Diseases, Płocka 26, 01-138 Warszawa, Poland.

Transcutaneous pulse oximetry is a useful and accurate method of determining arterial oxygen saturation ($S_{tc}O_2$) [1–3]. Being non-invasive it can be safely and reliably used, without causing any discomfort to patients, in monitoring saturation during diagnostic procedures known to produce desaturation e.g. bronchoscopy [4–6].

BAL has become a commonplace procedure in pulmonology. It is carried out in patients of different respiratory functional status, ranging from mild asthma [7], sarcoidosis, to severe adult respiratory distress syndrome (ARDS) [8].

It has been implied that BAL produces deterioration of small and large airway function [9] as well as a significant fall in arterial oxygen pressure [10]. The safety of this procedure in some patients has, therefore, been questioned.

This study was undertaken to demonstrate the effect of bronchoscopy and BAL on saturation and to compare changes in saturation induced by different volumes of instilled lavage fluid.

Material and methods

Study and control groups

Fourteen consecutive patients undergoing BAL and seven consecutive patients undergoing routine diagnostic fibreoptic bronchoscopy were included in this study (tables 1 and 2). Depending on the volume of lavage fluid used the patients were alloted to one of two groups: BAL-100 when five aliquots of 20 ml were given, and BAL-200 when ten aliquots of 20 ml of saline were instilled.

Fibreoptic bronchoscopy (FOB)

Premedication consisted of oxycodone hydrochloride, never exceeding 10 mg, administered subcutaneously 30 min before the procedure. Bronchoscopic examination was carried out, according to generally accepted methods, using the transoral approach under topical anaesthesia (Xylocaine 2% ASTRA) [6]. OLYMPUS BF 1 TR endoscopes were used. All patients were examined in the supine position. Oxygen supplementation was not used. Diagnostic bronchoscopy always included bronchial washings, and/or brush, forceps and catheter biopsies.

Bronchoalveolar lavage (BAL)

BAL was carried out according to the method described by HUNNINGHAKE et al. [11]. The same site was lavaged in all patients (RB-5). Before each procedure the lavage fluid was warmed to 37°C. The volume of lavage fluid was randomly selected for each patient. The fluid was gently aspirated after each aliquot, using a syringe

Transcutaneous oximetry

We used the OHMEDA Biox 3700 oximeter with a finger probe for monitoring capillary oxygen saturation

Table 1. – Characteristics of subjects

Group	No. of patients	Sex	Age $\bar{x}\pm$SEM	Clinical diagnosis No. of cases	
BAL-100	7	M-5	33.7±2.5	Pulmonary sarcoidosis s. II	6
				Chronic obstructive pulmonary	
		F-2		disease	1
BAL-200	7	M-3	40.0±4.0	Pulmonary sarcoidosis s. II	5
				Pulmonary tuberculosis	1
		F-4		Pulmonary malignancy	1
Control*	7	M-6	50.0±8.3	Pulmonary malignancy	3
				Pulmonary tuberculosis	1
		F-1		Chronic obstructive pulmonary	
				disease	2
				Pneumonia	1

*: routine diagnostic fibreoptic bronchoscopy.

Table 2. – Lung function parameters of subjects

Group		Height cm	Pao_2 mmHg	VC l	FEV_1 l	TLC l	RV%TLC %	sGaw $cmH_2O^{-1} \cdot s^{-1}$	Cst $ml \cdot cmH_2O^{-1}$	Pst cmH_2O
BAL-100	$\bar{x}$	175.8	76.8	4.0	3.0	5.9	30	2.1	188	34.2
	SEM	3.4	3.3	0.4	0.5	0.7	6	0.3	23	3.6
BAL-200	$\bar{x}$	170.1	75.8	4.3	3.4	5.6	23	2.9	193	27.8
	SEM	2.8	3.6	0.5	0.4	0.5	3	0.5	21	3.1
Control	$\bar{x}$	172.0	74.1	3.9	3.1	5.5	24	2.9	194	26.9
	SEM	2.9	2.9	0.6	0.4	0.5	3	0.4	22	3.0

Pao_2: oxygen tension in arterialized capillary blood; VC: vital capacity; FEV_1: forced expiratory volume in one second; RV%TLC: residual volume as a percentage of total lung capacity; sGaw: specific conductance of the airways; Cst: static compliance of lung; Pst: static pressure of lung

$(S_{tc}o_2)$. Following premedication and before administration of a local anaesthetic, $S_{tc}o_2$ monitoring was started using the continuous recording method. Baseline saturation values and heart rate were recorded as well as values after insertion of the endoscope and during lavage. Monitoring was continued for at least 5 min after the examination was completed; in the five patients with the lowest $S_{tc}o_2$ it was continued for another two hours.

Statistical analysis

Results were compared using Student's t-test.

Results

Continuous pulse oximetry demonstrated a transient rise of $S_{tc}o_2$ immediately following insertion of the bronchoscope in all of the patients examined. As seen in figure 1 this increase ranged from 0.3–0.5% and lasted only 30–60 s. It was followed by desaturation, the degree

depending on the procedure (bronchoscopy or lavage).

In both BAL groups similar desaturation patterns were observed. A steady decrease of $S_{tc}o_2$ lasting approximately 2–5 min was recorded immediately following instillation of the first aliquot of BAL fluid. This fall did not produce any discomfort to the patient, although it was accompanied by a slight increase in heart rate. After completion of BAL, a steady normalization of $S_{tc}o_2$ was seen, returning to baseline values in most of the patients within 5–10 min. In the five patients with the most profound decrease of $S_{tc}o_2$ the return to baseline values was prolonged, by 10–30 min, after completion of fibreoptic bronchoscopy. No further change in saturation or heart rate was seen.

The most evident fall of $S_{tc}o_2$ was observed in patients of the BAL-200 group (fig. 2). This is clearly seen when comparing lowest saturation readings to baseline values (fig. 3). Differences in desaturation were found to be significant when comparing BAL-100 with BAL-200 values ($p<0.05$) and control with BAL-200 values ($p<0.05$).
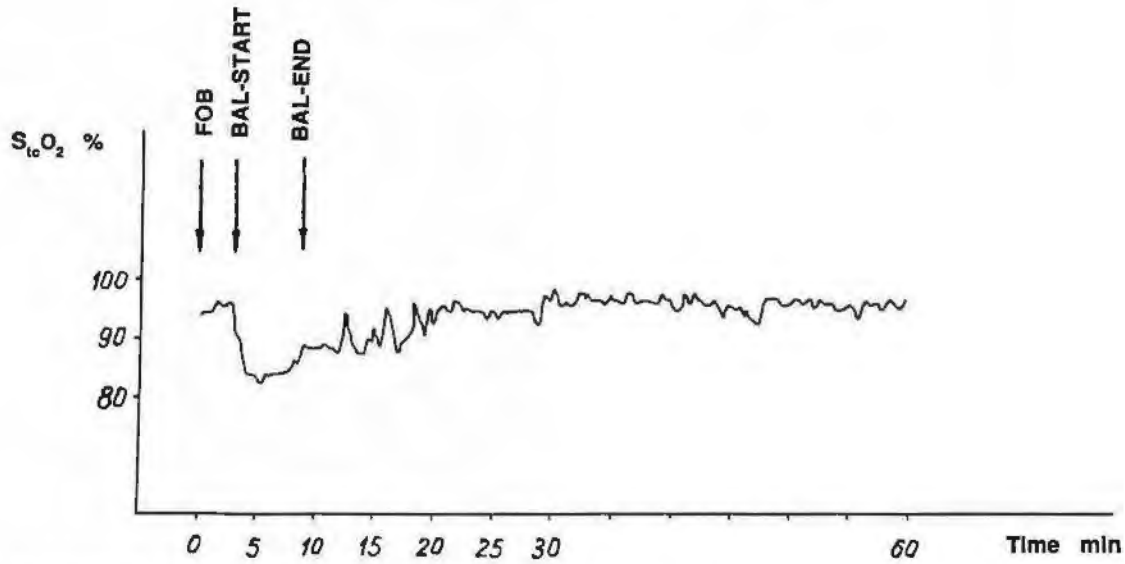
In the control group, i.e. in the patients undergoing

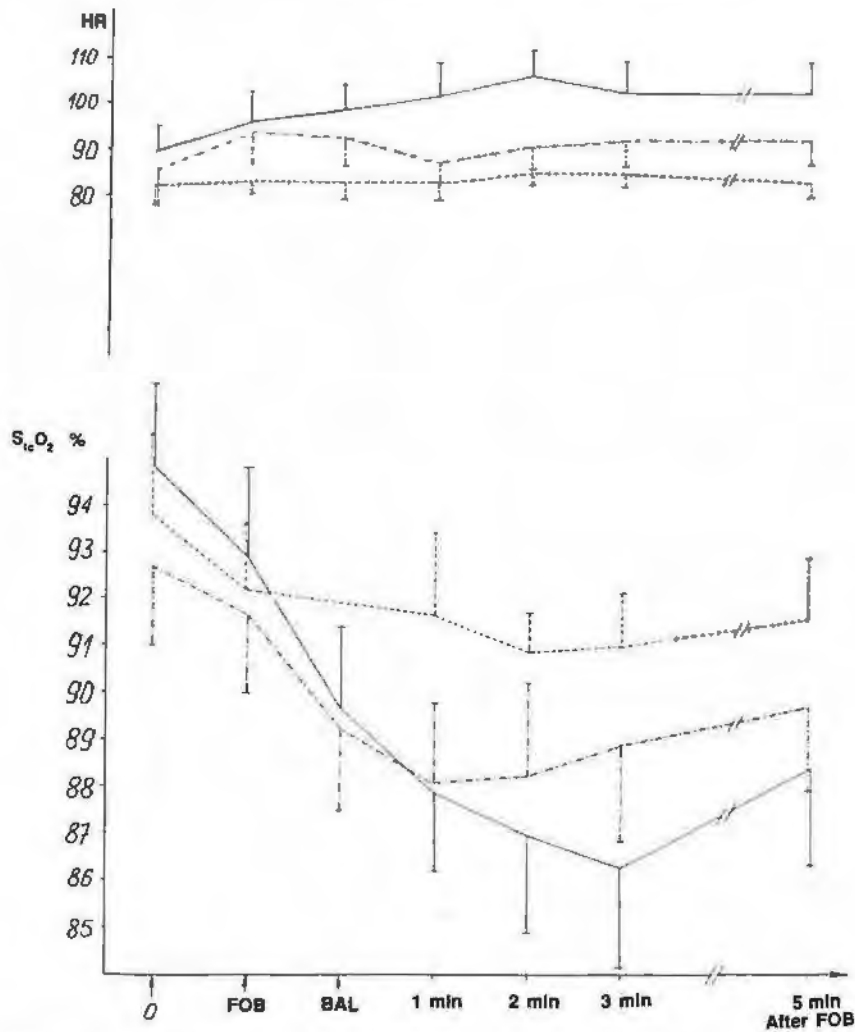Fig. 1. – An example of $S_{tc}O_2$ recording during a BAL-200 procedure; FOB: start of fibreoptic bronchoscopy.

Fig. 2. – Mean values of $S_{tc}O_2$ and heart rate (HR) at baseline; during insertion of endoscope into the trachea (FOB); start of lavage (BAL); during the first, second and third minute of the lavage; and five minutes after the completion of endoscopy. Bar indicates 1 SEM. ----: control; -----: BAL-100; —— : BAL-200.
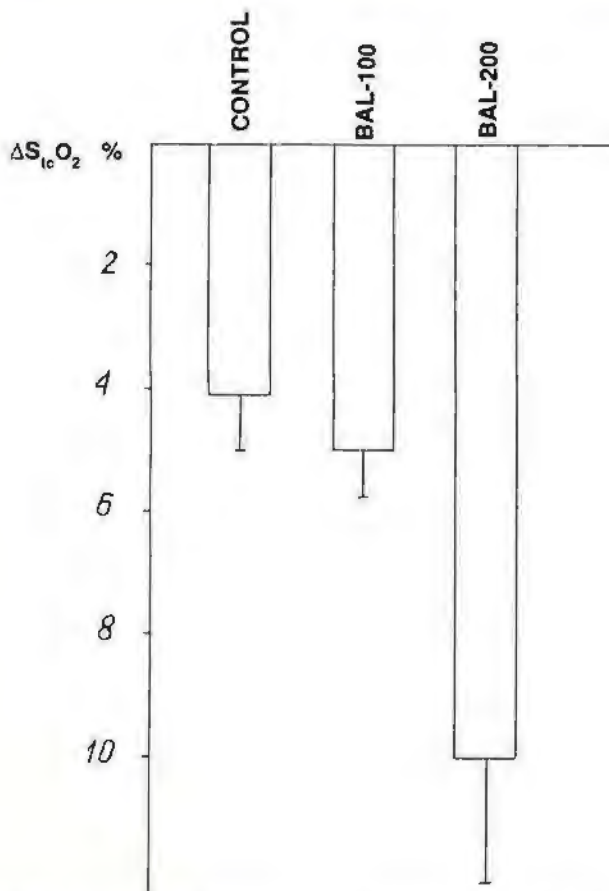
Fig. 3. – Mean values of maximal desaturation in comparison to baseline values ($\Delta S_{tc}O_2$) in the control, BAL-100, and BAL-200 groups. Bars indicate 1 SEM.

routine fibreoptic bronchoscopy, saturation changed only slightly. Although this group was older than both BAL groups and presented with poorer respiratory function, falls in $S_{tc}O_2$ were minimal and usually, after reaching an average level of 4.4% below baseline values, did not decrease further (figs 2 and 3).

The return of BAL fluid did not differ significantly between groups. The mean±SEM being 66.4±11.3% in the BAL-100 group and 78.6±3.6% in the BAL-200 group.

The heart rate (HR) was not significantly affected by either diagnostic bronchoscopy or BAL, although a steady rise of HR was seen in the BAL-200 group throughout the procedure, reaching a mean increase of 8.5% in relation to baseline values.

Discussion

Continuous monitoring of arterial oxygen saturation proved to be a valuable method in demonstrating and monitoring changes in saturation observed during fibreoptic bronchoscopy and bronchoalveolar lavage.

Diagnostic bronchoscopy produced only slight decreases in saturation, probably due to an additive effect of airflow disturbances produced by the bronchoscope's position in the trachea and bronchi and the appliance of suction to remove excess mucus [4].

Instillation of lavage fluid produced a further decrease in saturation, which in some patients was quite profound (up to 15%). Furthermore the fall of $S_{tc}O_2$ was related to the volume of lavage fluid instilled (fig. 3).

Similar findings regarding desaturation measured directly have been reported previously by others [10, 12]. COLE et al. [10] observed a fall of the mean arterial oxygen tension (PaO$_2$) by 22.7 mmHg after lavage, down to a mean value of 61 mmHg, the lowest being 49 mmHg. These changes were observed despite oxygen supplementation. The effect of different lavage volumes on the fall of PaO$_2$ was not analysed.

The observed differences in desaturation in lavaged patients cannot be attributed solely to the effect of retained fluid, since recovery was similar (BAL-100 66%; BAL-200 78.6%), and the difference between retained amounts of saline in both groups was quite small, only 8.8 ml.

Desaturation was possibly influenced by the duration of each lavage procedure. Longer lavage procedures enhance fluid diffusion into the interstitium and pulmonary capillaries. ALBERTINI et al. [13] demonstrated that the degree of hypoxaemia observed during bronchoscopy is related to actual bronchoscopy time. In the majority of the patients lavaged by us BAL did not exceed 3 min, except for the two patients in whom the 200 ml lavage lasted 4 min. In these two the desaturation was most profound.

The desaturation in all three groups was not influenced by the prelavage pulmonary function, prelavage gasometric values (PaO$_2$ in arterialized capillary blood), age and sex of the patients (tables 1 and 2).

Fibreoptic bronchoscopy alone does not usually produce significant changes of pulmonary function [14, 15]. GOLDENHEIM et al. [9] observed deterioration in lung function parameters following BAL, which reflected disturbances of airflow in large and small airways. These changes could induce desaturation. BURNS et al. [16] and RANKIN et al. [17] have also demonstrated that lavage-induced hypoxaemia is due to disturbances of airflow. COLE et al. [10] believe that the observed fall reflects local ventilation-perfusion mismatching rather than general ventilatory disturbances. In our patients we observed that larger falls in $S_{tc}O_2$ were accompanied by increased heart rate (fig. 2). This could imply over-perfusion of under-ventilated units. We also think that local irritation of airways by lavage fluid aggravates, through a reflex action, the local ventilation-perfusion mismatching thus enhancing profound falls in saturation. Some evidence for this was given by METZGER et al. [18] when observing bronchial mucosal changes after local allergen challenge, but unfortunately non-specific airway reactivity induced by BAL cannot be demonstrated in this way. GOEREE et al. [19] demonstrated that saline infusions lead to increased small airway resistance and KELLY et al. [20] showed that bronchoalveolar lavage increases bronchial responsiveness in certain patients. The temperature of instilled fluid seems to be critical [16] in producing desaturation; however, in our study we always introduced saline warmed to body temperature (37°C) in order to minimize this effect.

Return to prelavage $S_{tc}O_2$ values was generally slower in the BAL-200 group. This could imply that a reflex mechanism or the duration of the lavage procedure itself produced this phenomenon together with flooding of alveoli and surfactant inactivation [12].

Our results suggest that BAL-200 or BAL with even larger fluid volumes may result in profound desaturation of arterial blood, and that the degree of desaturation is related to the volume of fluid instilled. In patients with poor respiratory function and low initial saturation oxygen supplementation should be obligatory, as well as monitoring of $S_{tc}O_2$ values throughout the procedure.

References

1. Burki NK, Albert RK. – Noninvasive monitoring of arterial blood gases. *Chest*, 1983, 83, 666–670.
2. Hansen JE, Casaburi R. – Validity of ear oximetry in clinical exercise testing. *Chest*, 1987, 91, 333–337.
3. Ries AL. – Oximetry - know the limits. *Chest*, 1987, 91, 316.
4. Berman L, Jones NL. – Fiberoptic bronchoscopy: monitoring oxygenation with ear oximetry. *Am Rev Respir Dis*, 1976, 114, 651.
5. Ghows MB, Rosen MJ, Chuang MT, Sacks HS, Teirstein AS . – Transcutaneous oxygen monitoring during fiberoptic bronchoscopy. *Chest*, 1986, 89, 543–544.
6. Sackner MA. – Bronchofiberscopy. *Am Rev Respir Dis*, 1975, 111, 62–88.
7. NHLBI Workshop Summaries. – Summary and recommendations of a workshop on the investigative use of fiberoptic bronchoscopy and bronchoalveolar lavage in asthmatics. *Am Rev Respir Dis*, 1985, 132, 180–182.
8. Crystal RG, Reynolds HY, Kalica AR. – Bronchoalveolar lavage. The report of an international conference. *Chest*, 1986, 90, 122–130.
9. Goldenheim PD, Tilles DS, Ginns LC, Hales CA, Kazemi H. – Bronchoalveolar lavage (BAL) causes deterioration in lung function. International Conference on Bronchoalveolar Lavage, May 16–18, 1984, Columbia MD, USA (abstract).
10. Cole P, Turton C, Lanyon H, Collins J. – Bronchoalveolar lavage for the preparation of free lung cells: techniques and complications. *Br J Dis Chest*, 1980, 74, 273–278.
11. Hunninghake GW, Gadek JE, Kawanami O, Ferrans VJ, Crystal RG. – Inflammatory and immune processes in the human lung in health and disease: evaluation by bronchoalveolar lavage. *Am J Pathol*, 1979, 97, 149–206.
12. Ancié P, Diaz P, Galleguillos F. – Pulmonary function changes after bronchoalveolar lavage in asthmatic patients. *Br J Dis Chest*, 1984, 78, 261–263.
13. Albertini R, Harrel JH, Moser KM. – Hypoxemia during fiberoptic bronchoscopy. *Chest*, 1974, 65, 117.
14. Neuhaus A, Markowitz D, Rotman HH, Weg JG. – The effects of fiberoptic bronchoscopy with and without atropine premedication on pulmonary function in humans. *Ann Thorac Surg*, 1978, 25, 393–398.
15. Matsushima Y, Jones RL, King EG, Moysa G, Alton JDM. – Alterations in pulmonary mechanics and gas exchange during routine fiberoptic bronchoscopy. *Chest*, 1984, 86, 184–188.
16. Burns DM, Shure D, Francoz R, Kalafer M, Harrell J, Witztum K, Moser KM. – The physiologic consequences of saline lobar lavage in healthy human adults. *Am Rev Respir Dis*, 1983, 127, 695–701.
17. Rankin JA, Snyder PE, Schachter EN, Matthay RA. – Bronchoalveolar lavage. Its safety in subjects with mild asthma. *Chest*, 1984, 85, 723–728.
18. Metzger WJ, Zavala D, Richerson HB, Moseley P, Iwamota P, Monick M, Sjoerdsma K, Hunninghake GW. – Local allergen challenge and bronchoalveolar lavage of allergic asthmatic lungs. *Am Rev Respir Dis*, 1987, 135, 433–440.
19. Goeree GW, Coates G, Powles ACP, Basalygo M. – Mechanisms of changes in nitrogen washout and lung volumes after saline infusion in humans. *Am Rev Respir Dis*, 1987, 136, 824–828.
20. Kelly C, Hendrick D, Walters H. – The effect of bronchoalveolar lavage on bronchial responsiveness in patients with airflow obstruction. *Chest*, 1988, 93, 325–328.

Effet de différents volumes de liquide de lavage bronchoalvéolaire sur la saturation en oxygène du sang artériel. M. Pironziyński, P. Śliwiński, J. Zieliński.

RÉSUMÉ: Nous avons suivi la saturation en oxygène du sang artériel par monitoring continu utilisant un oxymètre OHMEDA Biox 3700 ($S_{tc}O_2$) chez sept patients subissant un lavage de 100 ml, chez sept patients subissant un lavage de 200 ml, et chez sept patients pendant une fibroscopie bronchique isolée à visée diagnostique. Immédiatement après l'insertion du fibroscope, on note une augmentation brève de la $S_{tc}O_2$ (0.3–0.5%), suivie par une diminution graduelle du niveau de $S_{tc}O_2$, ne dépassant jamais 2 à 5% au cours de la fibroscopie diagnostique. L'introduction de liquide de lavage dans une bronche segmentaire produit toujours une diminution plus marquée de la $S_{tc}O_2$. Dans la groupe BAL-100 ml, elle ne dépasse pas 7%, tandis que dans le groupe BAL-200 ml une chute pouvant atteindre 15% du niveau basal a été observée. Le retour aux valeurs initiales est observé chez la plupart des patients dans les 10 minutes qui font suite à l'achèvement de l'acte diagnostique. Ce n'est que chez les patients où la chute de $S_{tc}O_2$ était la plus profonde, que cette période fut plus longue, atteignant jusqu'à 30 minutes.