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Fiberoptic Bronchoscopy and Bronchoalveolar Lavage as a Routine Procedure in Confirming Diagnosis and Treatment of Inhalation Burns

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ABSTRACT

Inhalation injury has now become a major cause of death in burned patients. It has been recently reported that the presence of inhalation injury increases burn mortality by 20 percent and that inhalation injury predisposes to pneumonia. This prospective study included 60 burned patients. Their total body burned surface area (TBSA%) ranged between 20-60%. They had signs of inhalation injury according to clinical scoring system (CSS). All patients were subjected to emergency fiberoptic bronchoscopy within 8 hours after admission. Patients who were proved to have inhalation injury by bronchoscope were 42 patients divided into two equal groups. Bronchoscopic group were treated with repeated fiberoptic bronchoscopic examination, and repeated bronchoalveolar lavages (BAL). This was repeated till the airways became clear from soot and carbonaceous secretions. The lavages were examined cytologically by light microscopy. The other conventional group were treated by all lines of therapy like the previous group except for therapeutic bronchoscopy and bronchoalveolar lavages. Fiberoptic bronchoscopy was proved to be more accurate in diagnosing inhalation injury. After bronchoalveolar lavages, there was progressive improvement of all of the bronchoscopic findings and severity in bronchoscopic group throughout the course of the study, thus denoting the effectiveness of bronchoscopy and bronchoalveolar lavage in managing inhalation injury and improving the outcome of patients. Mortality rate and length of hospital stay were decreased in bronchoscopic group.

INTRODUCTION

The two most critical injuries caused by fires are cutaneous burns and inhalation injury. The multitude of respiratory complications caused by smoke inhalation, cutaneous burns, and their treatment optimizes the clinical challenge that confronts burn care providers today [1].

Advances in medical care have changed the principal cause of death in burn patients from burn shock to wound sepsis to pulmonary complications. With the advent of vigorous fluid resuscitation, the development of topical and systemic antimicrobial agents, advances in nutritional support for the hypermetabolic response, and the use of surgical techniques for early burn wound excision have now changed the primary cause of death from wound sepsis to pulmonary sepsis, which often follows inhalation injury [2]. The presence or absence of inhalation injury may be a stronger determinant of mortality than the size of burn wound [3].

A high index of suspicion for inhalation injury is essential to avoid missed injuries. A history of closed-space smoke exposure is common among these patients [4]. The specificity and sometimes the sensitivity of these findings are poor. The inability of clinicians to depend on historical details and physical findings to identify patients with inhalation injury requires the use of fiberoptic bronchoscopy to establish the diagnosis. The use of fiberoptic bronchoscopy also allows immediate institution of therapy if severe inhalation injury or impending airway obstruction is diagnosed. Nasotracheal intubation may be conveniently performed under direct visualization over the bronchoscope [5].

Fiberoptic bronchoscopy permits the clinician to perform a detailed examination of the supraglottic area and identify patients with marked edema who are at risk from acute airway obstruction. Careful examination of the major airways allows the diagnosis of tracheobronchial inhalation injury to be made based on the presence of infraglottic soot or early inflammatory changes of the tracheal mucosa (hyperemia, edema, superficial mucosal sloughing, and ulceration). These changes are often present before arterial blood gas abnormalities, together with deteriorting pulmonary function tests [6].

Fiberoptic bronchoscopy has proven effective. In addition to its diagnostic function, bronchoscopy has an important therapeutic applications. Inspissated secretions, particularly when hardened by the presence of blood to form casts, may prove resistant to all simpler method of removal from the tracheobronchial tree [7]. Bronchoscopy allows instrumentation of the airway under direct vision and enables meticulous pulmonary toilet (bronchoalveolar lavage BAL) to be maintained in patients with severe inhalation injury [8]. This technique is known as bronchoalveolar lavage (BAL). It helps to remove toxic inhaled materials. It also provides a means of sampling a body fluid that can provide a valuable information about the reaction of the lung [9].

The main objective of this study is to evaluate the role of bronchoscopy and tracheobronchial toilet or lavage in diagnosis and treatment of inhalation injury in deep burn wound patients. The outcome of this study could support a rationale for introduction of this tool in all burned patients with suspected inhalation injury.

PATIENTS AND METHODS

This prospective study was performed in burn-unit of emergency hospital, Mansoura University. The study included 60 patients ranged from 16 to 60 years. Their total body burned surface area (TBSA%) ranged between (20-60%). They had manifestations of inhalation injury. Signs suggestive for the presence of inhalation injury according to the clinical scoring system (CSS) were facial and neck burn, signed nasal hairs, conjunctivitis, dyspnea or stridor oropharyngeal inflammation, coughing carbonaceous particles, tachypnea, hoarsness of voice, ronchi and altered level of consciousness (Table 1).

Patients with the following criteria were excluded: 1- Patients with history of chest illness, 2- Associated chronic debilitating disease e.g. renal failure or cancer and 3- Cutaneous burn more than 60% due to high incidence of mortality from the cutaneous rather than inhalation burn. Tracheostomy or endotracheal intubation and ventilation were performed to all inhalation injury patients who developed manifestations of airway obstruction depending upon the condition of the neck (if burned or not), or presented to us with coma or respiratory failure. They were subjected to endotracheal intubation and continuous positive airway pressure (CPAP). Humidified oxygen was given as a rule for all patients with suspicious of inhalation injury, especially those presented with dyspnoea. We started with a rate of 6 litres per minute through the facemask. This dose was changed guided by the clinical picture and values of repeated estimation of arterial blood gases (ABG).

Fluid resuscitation started using Parklanal formula (4mL/kgm B.wt./1% burn/24 hours) plus 30% of the calculated amount to compensate the loss in the respiratory tree and soft tissues in the head and neck. Cutaneous burns, which usually accompanying inhalation injury were managed according to the regimen of our unit. Silver sulphadiazine 1% cream were applied twice daily.

Nebulizer sessions were done every 4 hours using (Salbutamol as bronchodilator, Ambroxol as mucolytic agent, Heparine, Acetyl cysteine, and saline 0.9%).

All patients were subjected to emergency fiberoptic bronchoscopy within 8 hours after admission. Scoring of the severity of inhalation injury was estimated using bronchoscopic scoring system (Table 2). Bronchoscope used was (Fujinon fiberoptic bronchoscope 120t, fuji ophoto optical Co. Ltd. Japan).

Patients who were proved to have inhalation injury by bronchoscopy in our study were 42 patients (Table 3) divided into two groups:

1- Bronchoscopic group: That included 21 randomly selected patients. This group was treated with repeated fiberoptic bronchoscopic examination, bronchoalveolar lavage (BAL) for removal of crusts and secretions. This was performed immediately after admission and was repeated according to the course and condition of the patient every 2 to 3 days. Fifty mL syringe filled with saline 0.09/ and heparine was used in lavage followed by suction. This was repeated till the airways were clear from soot and carbonaceous secretions. The BAL fluid was collected and centrifuged for 10 minutes. The precipitate was smeared on slides, fixed with absolute alcohol (70% ethyl) stained with haematoxyline and eosin stains then examined cytologically by light microscopy.

2- Conventional group: Included 21 randomly selected patients. This group treated by all lines except for therapeutic bronchoscopy and bronchoalveolar lavage.

Statistical analysis:

Normally distributed data was presented as mean ± SD. Qualitative data was presented as number and percent. Comparison between groups was done by Chi-Square test. Quantitative data was tested for normality by Kolmogrov-Smirnov test. Paired *t*-test was used for comparison within the same groups. Data was analyzed using SPSS (Statistical Package for Social Sciences) Version 10. $p<0.05$ was considered to be statistically significant.

Table (1): Clinical scoring system (C.S.S) (Lee and Leung, 1992) **[10]**.

Severity	No. of features	Features
Mild	1-4 features present	1- Face and neck burns 2- Signed nasal hair 3- Mucosal burns of lip and oral cavity 4- Soot in nostril and throat 5- Sputum streaked with carbonaceous material
Moderate	5-8 features present	6- Dyspnea or stridor 7- Tachypnea 8- Hoarsness of voice 9- Sore throat 10- Cough 11- Rhonchi
Severe	9 or more features present	12- Poor conscious level 13- Associated injuries

Table (2): Bronchoscopic scoring system (B.S.S).

Severity	No. of features	Features
Mild	Less than 4 features	Edema Blistering
Moderate	4-6 features	Carbonaceous material Soot Haemorrage
Severe	More than 6 features	Inflammation Ulceration Necrosis of mucosa

Table (3): Patients characteristics in both groups of the study.

Severity			Bronchoscopic	Conventional
Age			31.19±13.059	31.43±11.64
Sex	Male	No.	10	7
	Female	No.	11	14
% of burn			37.76±14.13	34±11.558
% of 3^{rd} degree burn			24.34±8.757	27.38±8.89

RESULTS

This study included 60 patients were presented with clinical manifestations of inhalation injury based on the clinical scoring system (Table 1). They had variable percentages of cutaneous burns. All patients were subjected to fiberoptic bronchoscopy. Eighteen patients were proved to be free of inhalation injury (false positive) and excluded. The remaining 42 patients were proved to have inhalation injury. This demonstrated that clinical examination has 70% accuracy in diagnosing inhalation injury (Table 4). From this table we found that the most specific clinical presentations among the patients were mucosal burns of oral cavity, soot in the nostril, dyspnea or stridor, hoarseness of voice and ronchi.

After clinical examination and airway visualization by bronchoscope 42 patients were proved to have inhalation injury. Those patients were divided into two groups, (Bronchoscopic group and conventional group). There was no clinical difference between severity of inhalation injury in both groups. Findings of diagnostic bronchoscopy in both groups showed that there was no significant difference between both groups (Table 5).

After bronchoalveolar lavage (BAL), there was progressive improvement of all of the bronchoscopic findings and severity in bronchoscopic group throughout the course of the study, thus denoting the effectiveness of bronchoscopy and bronchoalveolar lavage in managing of inhalation injury as shown in Figs. (1,2,3) and Table (6).

In bronchoscopic group, by cytological examination of (BAL) there was progressive improvement. The majority of the specimens showed moderate carbon particles deposition in the specimens. In the subsequent bronchoscopies it was reduced. Also, RBCs and carbon laden pulmonary macrophages (CLPM) were reduced in second and third BAL procedures.

Lymphocytes and neutrophils were plenty in the first BAL cytology. Second and third BAL specimens showed decreasing the percentage of them denoting that inflammation began to be resolved (Table 7 and Fig. (4).

Measurement of arterial blood gases showed marked improvement of bronchoscopic group in comparison to conventional group as present in (Table 8).

There was significant difference between both groups in mortality rate, time of death and length of hospital stay. Mortality rate was decreased (4 in bronchoscopic group and 7 in conventional group). Time of death was longer in bronchoscopic group. Also, length of hospital stay was shorter in the same group, this is shown in Table (9).

Fig. (1): Oedema of vocal cords.

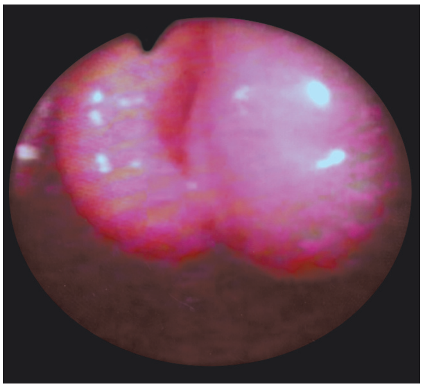


Fig. (1-A): 1st bronchoscopic session 8 hours after admission.

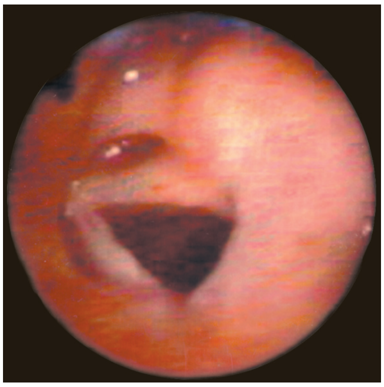


Fig. (1-B): 2nd bronchoscopic session with mild oedema after 3 days.

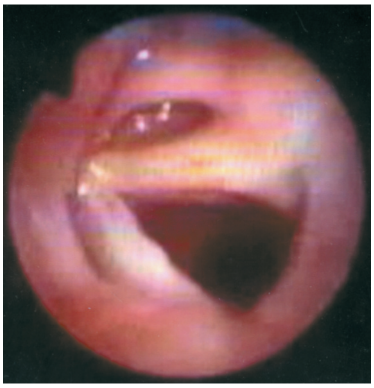


Fig. (1-C): 3rd bronchoscopic session with resolution of oedema after 7 days.

Fig. (2): Carbon particles deposition in the bronchi.

Fig. (2-A): 1st bronchoscopic session showed heavy deposition of carbon particles 5 hours after admission.

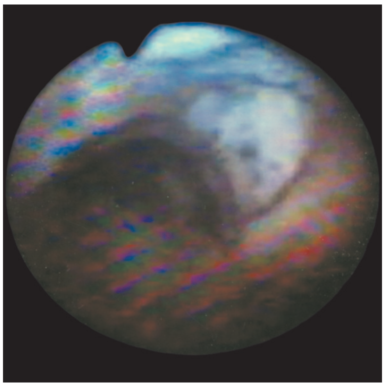


Fig. (2-B): 3rd bronchoscopic session showed the same area 7 days after lavage with decrease of carbon deposition.

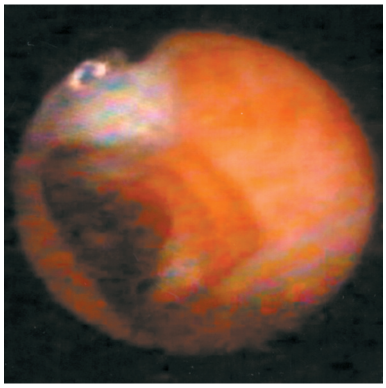


Fig. (3): Hemorrhage in the bronchi.

Fig. (3-A): 1st bronchoscopic session showed multiple areas of hemorrhage.

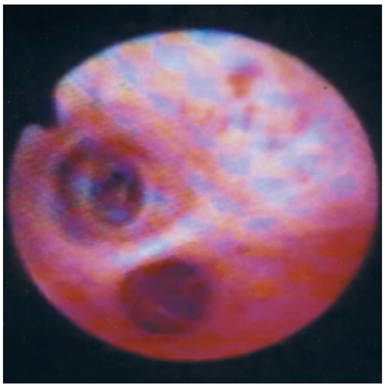
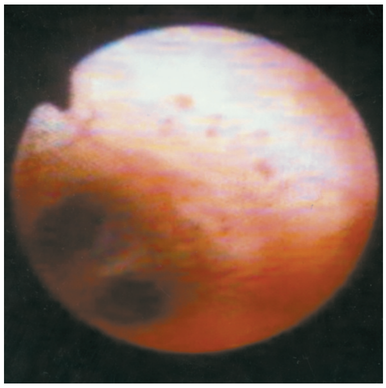


Fig. (3-B): 3rd bronchoscopic session showed decrease in size of hemorrhagic areas 7 days post burn.



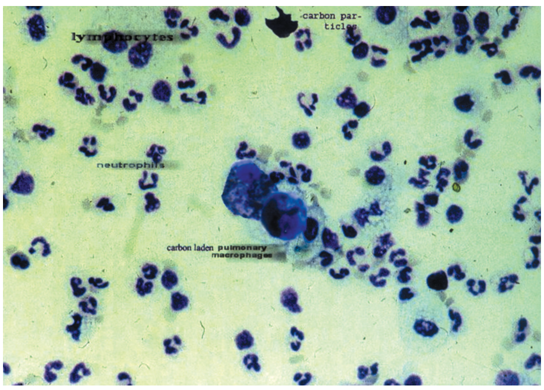


Fig. (4-A): Histological examination of bronchoalveolar lavage fluid after 1st session of bronchoscopy showed neutrophils, lymphocytes, carbon particles and carbon laden pulmonary macrophages.

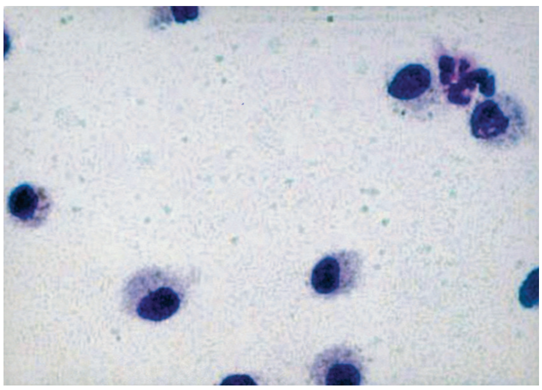


Fig. (4-B): Histological examination of bronchoalveolar lavage after 3rd session of bronchoscopy showed absence of all cells with presence of normal pulmonary macrophages.

Table (4): Demonstrates the accuracy of clinical manifestation in diagnosis of inhalation injury.

Clinica manifestation	No. of patients	No. of true +ve by bronchoscope	% of accuracy
Face and neck burns	55	37	67.3
Signed nasal hair	48	31	64.6
Mucosal burns of lip and oral cavity	43	41	95.3
Soot in nostril and throat	42	40	95.2
Sputum streaked with carbonaceous material	36	30	83.3
Dyspnea or stridor	38	36	94.7
Tachypnea	30	20	66.6
Hoarseness of voice	40	37	92.5
Sore throat	39	23	58.9
Cough	34	25	73.5
Rhonchi	29	27	93.1
Poor conscious level	11	5	45.5
Associated injuries	–	–	–

Table (5): Finding of diagnostic bronchoscopy in both groups.

Finding	Bronchoscopic group	Conventional group
Oedema	20 (95.2%)	21 (100%)
Ulceration	10 (47.6%)	12 (57.1%)
Blistering	19 (90.5%)	18 (85.7%)
Haemorrage	10 (47.6%)	13 (61.9%)
Carbon particles	19 (90.5%)	21 (100%)
Inflammation	18 (85.7%)	14 (66.7%)
Necrosis	12 (57.1%)	10 (47.6%)
Soot	17 (81%)	19 (90.5%)

There were no differences between both groups as regard the bronchoscopic finding.

Table (6): Comparison between bronchoscopic group patients regarding to bronchoscopic finding and severity of inhalation injury in each session.

		1st session (21 patients)	2nd session (18 patients)	3rd session (7 patients)
Oedema		20 (95.2%)	10 (55.6%)	0
Ulceration		10 (47.6%)	7 (38.9%)	4 (57.14%)
Blistering		19 (90.5%)	8 (44.4%)	0
Haemorrhage		10 (47.6%)	14 (77.8%)	0
Carbonaceous material		19 (90.5%)	5 (27.8%)	0
Inflammation		18 (85.7%)	15 (83.3%)	5 (71.4%)
Necrosis		12 (57.1%)	7 (38.9%)	5 (71.4%)
Soot		17 (81%)	2 (11.1%)	0
Severity	Mild	2 (9.5%)	11 (61.1%)	7 (100%)
	Moderate	11 (52.4%)	6 (33.3%)	0
	Severe	8 (38.1%)	1 (5.6%)	0

Table (7): Representation of carbon particles, R.B.Cs, carbon laden pulmonary macrophages (C.L.P.M), lymphocytes and neutrophils in different bronchoalveolar lavage sessions for bronchoscopic group.

	1st session		2nd session		3rd session	
	No.	%	No.	%	No.	%
Carbon particles:						
Absent	0	0	7	38.89	4	57.1
Few	4	19	5	27.78	3	42.8
Moderate	12	57.1	6	33.3	0	0
Massive	5	23.8	0	0	0	0
R.B.C.s:						
Absent	8	38.1	11	61.1	7	100
Few	4	19	3	16.7	0	0
Moderate	7	33.3	2	11.1	0	0
Massive	2	9.5	2	11.1	0	0
C.L.P.M.:						
Absent	4	19	10	55.6	6	85.7
Few	6	28.6	6	33.3	1	14.3
Moderate	10	47.6	2	11.1	0	0
Massive	1	4.8	0	0	0	0
Lymphocytes:						
Absent	11	52.4	5	27.77	3	42.8
Few	9	42.9	4	22.2	2	28.6
Moderate	1	4.8	9	50	2	28.6
Massive	0	0	0	0	0	0
Neutrophils:						
Absent	0	0	0	0	3	42.8
Few	6	28.57	2	11.1	3	42.8
Moderate	9	42.9	6	33.3	1	14.3
Massive	6	28.57	10	55.6	0	0

All patients had 1st session, 18 patients needed 2nd session and 7 patients needed 3rd session.

Table (8): A.B.G. measurements in both groups.

	Bronchoscopic group	Conventional group	*p* value
PH:			
Before treatment	7.333±0.03	7.328±0.04	0.638
After treatment	7.377±0.02	7.333±0.03	0.000*
PaO_2:			
Before treatment	72.443±3.649	72.657±3.699	0.851
After treatment	76.833±4.109	74.024±4.332	0.037*
SaO_2:			
Before treatment	78.333±4.498	77.905±4.795	0.767
After treatment	82.476±5.105	78.809±4.854	0.022*
$PaCO_2$:			
Before treatment	51.143±4.053	50.571±4.308	0.660
After treatment	45.666±3.554	48.095±3.554	0.046*

p* value ≤ 0.05 significant.

Table (9): Comparison between bronchoscopic and conventional group as regarding to mortality rate, time, and length of hospital stay.

	Bronchoscopic group		Conventional group	
	No.	%	No.	%
Mortality	4	19.04%	7	33.33%
Time of death (days):				
Mean	23±10.58		10.36±9.15	
p value		0.036*		
Length of hospital stay (days):				
Mean	31.30±29.83		57.64±25.65	
p value		0.024*		

*p** value ≤0.05 significant.

DISCUSSION

Smoke inhalation principally affects the respiratory system, and constitutes a major cause of mortality and morbidity in victims of fire tragedies [11].

History together with clinical diagnosis may be helpful but not sure criteria for determining presence or absence of inhalation injury and its severity if present. Fiberoptic bronchoscopy is extremely useful in making an accurate diagnosis of inhalation injury in burn victims [11].

So, in our study we used a combination of clinical criteria (history of closed space, facial and neck burns, signed nasal hairs, soot in the nostril and oral cavity, mucosal burns of oral cavity, sputum streaked with carbonaceous material, dyspnea and tachypnea) together with direct visualization of the respiratory tract by fiberoptic bronchoscope (the frequent recorded finding in our study was oedema, erythema, soot, carbonaceous material) in addition of ABG estimation.

We found that the clinical scoring system has only 70% accuracy in diagnosing inhalation injury when compare with fiberoptic bronchoscopy. The most specific clinical manifestations among the patients were Mucosal burns of lip and oral cavity, soot in nostril and throat, dyspnea, stridor, rhonchi and hoarsness of voice respectively.

Mlcak and his collaegues found that clinical diagnosis of inhalation injury alone has a high incidence of false positivity when compared with bronchoscopic diagnosis thus they were found to be actually underestimate the true incidence of inhalation injury [12].

The concept of using fiberoptic bronchoscope for accurate diagnosis of inhalation injury was done by many authors and supported our results. Marek and associates who studied the value of bronchoscopic diagnosis of inhalation injury in two hundred and ninety-two patients suspected to have inhalation injury and found that diagnoses of an inhalation burn was confirmed by fiberoptic bronchoscopy in 261/292 (89.4%) patients [13]. Other authors also agree with the great value of fiberoptic bronchoscope in diagnosis of inhalation injury. This routine bronchoscopy enabled them to diagnose 46 patients among the 130 patients (35%) to have inhalation injury. This is because forty four of these 46 patients had chemical inhalation injury and could be missed if classical diagnostic criteria had been applied [14].

In this work the role of fiberoptic bronchoscope was not restricted in confirming or excluding inhalation injury but also to determine the severity of that injury which in some patients was not the same as clinical evaluation (B.S.S was significantly different from C.S.S). It also can be used for therapeutic management of patients with inhalation injury through bronchoalveolar lavage (BAL). BAL can be a useful tool to detect and quantify an inflammatory response. It has proved valuable in detecting respiratory tract toxicity of deposited materials, obtaining samples from the epithelial lining fluid from the respiratory tract so it can be analyzed for biomarkers of an inflammatory response in the respiratory tract [9].

The cytological study of the BAL fluid revealed that carbon particles were found to be present maximally in the first bronchoscopy (early after exposure) and gradually decrease in the subsequent bronchoscopies. CLPM decreases gradually and progressively throughout the sessions. RBCs decreased gradually from session one to session three. This was explained bronchoscopically because we found that erythema, ecchymosis and sloughing of the mucosa with its associated bleeding occurred in the early period after injury and disappeared after about seven to nine days. These findings supports the value of bronchoscopic interventions very early after exposure to remove carbon particles, R.B.C.s and shaded cells through performing bronchoalveolar lavages (BAL).

Lymphocytes and neutrophils were found to increase progressively in the early periods, then follow stationary course after that due to decrease in the inflammatory reactions that start after hours of exposure and decrease after a peak of few days (Fig. 4). Thus BAL fluid cytology can be used to estimate the severity and follow-up the progression of inhalation injury in bronchoscopic group.

Khoo and collaegues who used the cytology to diagnose inhalation injury in patients with seemingly normal bronchoscope to increase the diagnostic sensitivity of bronchoscopic examination through the correlation between clinical scoring, bronchoscopic scoring and the total cellular scoring in the cytology of BAL. They concluded that the total cellular score may have a superior predictive value over the clinical and bronchoscopic modalities for diagnosing inhalation injury. They stated that BAL cytology was not used only for diagnosis but also for assessment of severity and as a guide for subsequent management. They also stated that BAL fluid cytology together with clinical and bronchoscopic data could be used to estimate both the severity and the prognosis of inhalation injury and found that RBCs decrease after six to nine days after injury, carbon particles decrease gradually and progressively in the subsequent bronchoscopic sessions **[15]**.

Arterial blood gas measurements provide crucial information with regard to the status of alveolar ventilation and hypoxemia resulting from intrinsic pulmonary abnormalities or agents including carbonmonoxide **[16,17]**. Monitoring of the included patients were done using arterial blood gases (ABG) parameters (PH, PaO_2 and $PaCO_2$). They were used as an index for the degree of success of treatment among both bronchoscopic and conventional group. In the present study there was no statistical difference between both groups on admission as regarding to all ABG parameters. However, the mean value of ABG parameters during the study showed a significant difference in the bronchoscopic group in comparison with the conventional group (more balanced PH, a significant increase in both SaO_2 and PaO_2 together with a more noticeable reduction in $PaCO_2$ than in the conventional group). This improvement in the readings of A.B.G. in the bronchoscopic than the conventional group confirms that the bronchoscopic treatment including repeated BAL cessions led to reduction in the respiratory complications. Changes in ABG parameters were also very important for the follow-up of those patients and their need for oxygenation and/or ventilation.

In consistent with these results many studies found that ABG parameters were significantly improved after bronchoscopic treatment **[18,19]**. Cha and Collaegues in their study on 13 burned patients that were presented with ventilatory insufficiency and manifested by significantly lowered pH and higher $PaCO_2$ levels. Toilet bronchoscopy allowed for early liberation from mechanical ventilation and there was marked improvement of ABG parameters **[18]**. So, it is important to have targeted arterial blood gas values set to aid the clinical team in proper management **[12]**.

In this study there was significant difference in the mortality rate between the two groups $p<0.05$. This reflects the efficacy of the BAL using heparin as a fibrinolytic agent dissolving the already formed fibrin threads in the tracheobronchial tree and removing of all toxic inhaled materials. Also, the length of hospital stay was also decreased in bronchoscopic than conventional group $p<0.05$. This may be due to rapid and early improvement of patients by frequent bronchoaveolar lavages that make them ready within short time for early surgical intervention. Cha and associates supported these results and found decreased mortality rate in patients with inhalation injury managed through repeated bronchoalveolar lavages when compared to previous studies. They concluded that toilet bronchoscopy would appear to be the most effective therapy for early liberation from mechanical ventilation in such patients and consequently improvement of the prognosis of them **[18]**.

Conclusion:

Based on our findings we concluded that fiberoptic bronchoscopy was shown to be useful method in routine clinical practice to confirm diagnosis and treatment of inhalation burns. Bronchoscope is also useful when clinical suspicion is low, to identify cases of inhalation that would be missed. Further, we support the usefulness of fiberoptic bronchoscopy in routine burn care, such as for pulmonary toilet and endotracheal intubation of difficult airways. Frequent bronchoalveolar lavages had been proved valuable in decreasing respiratory tract toxicity and removal of deposited materials. Also, samples can be obtained for analysis to detect changes in inflammatory response of the respiratory tract.

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