Eur Respir J, 1996, 9, 1470–1474
DOI: 10.1183/09031936.96.09071470
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European Respiratory Journal
ISSN 0903 - 1936

Combined smoke inhalation and body surface burns injury does not necessarily imply long-term respiratory health consequences

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Combined smoke inhalation and body surface burns injury does not necessarily imply long-term respiratory health consequences. J. Bourbeau, Y. Lacasse, M.Y. Rouleau, S. Boucher. ©ERS Journals Ltd 1996.

ABSTRACT: This study was undertaken to assess the long-term respiratory health consequences of smoke inhalation in patients who are burns survivors.

Patients with smoke inhalation resulting from domestic flame or fire were studied. Medical records were the primary source for the selection of the patients. Smoke inhalation was diagnosed on the basis of the visual appearance of the airways on the reported bronchoscopy. Patients who participated in the study were compared on important characteristics with those who did not participate. The participants were then assessed by questionnaire, physical examination, chest radiograph and pulmonary function tests.

Twenty three out of 45 patients who had survived smoke inhalation participated in the study. Participants and nonparticipants were comparable with respect to gender, age, time since injury, aetiology of injury, and total body surface burned. Participants had more facial burns, more severe bronchoscopic findings of smoke inhalation and required intubation more frequently. Respiratory symptom assessment and pulmonary function tests were performed 45±23 months after smoke inhalation. Four patients reported an increase in dyspnoea, one an increase in cough and one an increase in phlegm. All the patients had pulmonary function tests and bronchial responsiveness (provocative concentration of histamine resulting in a 20% fall in forced expiratory volume in one second (PC_{20})>16 $mg \cdot mL^{-1}$) within normal limits. The four patients complaining of increased dyspnoea had results within normal limits for cardiac and respiratory variables on maximal exertion.

The present study indicates that, in burn patients, smoke inhalation resulting from a single domestic fire does not necessarily imply long-term respiratory health consequences.

Eur Respir J., 1996, 9, 1470–1474

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Keywords: Airway disease
burn patients
lung disease
smoke inhalation

Received: February 3 1995
Accepted after revision March 29 1996

Supported by a grant from the Fondation de l'Hôpital du St-Sacrement and the Légion Royale Canadienne filiale "La Citadelle" No. 260. JB is supported by Chercheur-boursier, Fonds de la Recherche en Santé du Québec (FRSQ).

Smoke inhalation, together with age and total body surface burned, has an independent effect on respiratory morbidity and mortality during hospitalization [1, 2]. Previous studies have shown that pulmonary function abnormalities in burn patients depend on the type of injury [3, 4]. In the recent literature, bronchial hyperresponsiveness and airways obstruction have been reported to be frequent following acute exposure to smoke from a single fire incident [5–8]. Studies have shown that pulmonary function abnormalities usually improved with time [4, 5, 7]. However, the long-term respiratory health effects of smoke inhalation are unknown. The current study was undertaken to assess the long-term respiratory health consequences of smoke inhalation in patients who are burns survivors.

Material and methods

Study subjects

The medical records of all patients admitted to a 10 bed burns unit during a 5 year period were reviewed. Of the 397 patients admitted to the burns unit during this period, 90 were suspected of having smoke inhalation on the basis of clinical examinations and history. All these patients had bronchoscopy, and 66 had a diagnosis of smoke inhalation confirmed according to visual appearance of the airways. Of the 66 patients with a bronchoscopic diagnosis of smoke inhalation, 45 patients survived and were discharged from the hospital. An attempt was made to reach all patients, and informed consent was obtained from those who agreed to participate. The study and informed consents were approved by the Hospital's Review Committee for Research involving Human Subjects.

Study design

The diagnosis of smoke inhalation was made retrospectively, according to the visual appearance of the airways on the bronchoscopy written report. Bronchoscopy was normally performed within 24 h of the patients admission for each patient suspected of smoke inhalation on the basis of clinical examination and history. To

confirm the diagnosis of smoke inhalation, the bronchoscopic findings had to include the presence of soot and airways oedema, inflammation or mucosal ulceration. Although there is no universally applied system of classification, the bronchoscopic findings were graded according to the distribution, *i.e.* smoke inhalation of the upper airways included bronchoscopic findings at the vocal cord, and of the major airways included the trachea and bronchus. The bronchoscopy was performed by the same three chest physicians throughout the period under study. Patients were usually intubated if they had any sign of respiratory failure at the time of the bronchoscopy, or to prevent upper airway obstruction if there was visual appearance of upper airways oedema. When diagnosis of smoke inhalation was confirmed, patients were contacted and invited to participate and be further evaluated.

Information on sociodemographic characteristics, previous respiratory disease, smoking habits, date of injury, aetiology of injury, areas and surface burned, smoke inhalation by bronchoscopy, and intubation requirement were reviewed in the medical records. In addition, the patients were invited to be evaluated in hospital. The outcome measures included a respiratory symptom questionnaire, physical examination, chest radiograph, and pulmonary function tests. Pulmonary function tests included spirometry, lung volumes, transfer factor of the lungs for carbon monoxide ($T_{L,CO}$) and nonspecific bronchial challenge for all patients. Exercise testing and alveolar-arterial oxygen pressure differences ($P_{(A\text{-}a),O_2}$) at rest and on maximal exertion were performed on patients who complained at the time of the study of increased dyspnoea after smoke inhalation.

Methods

In addition to the administration of a validated French translation of the American Thoracic Society (ATS)-DLD-78 questionnaire [9], respiratory symptoms of dyspnoea, cough, and phlegm were also assessed, as recalled by the patient before burn and smoke inhalation and at the time of the study questionnaire. Dyspnoea was scored as: grade 1, when performing strenuous physical activities; grade 2, when hurrying on a level surface or walking up hill; and grade 3, when walking on a level surface with people of normal health and of the patient's own age. Cough and phlegm were assessed as being either present or absent. A physical examination, including a complete chest examination, was performed at the time of the study.

Chest radiographs were obtained on maximal inspiration in posteroanterior and lateral projections with the conventional 1-83 m focus film distance.

Pulmonary function tests, as measured by an automated system (PK Morgan AutoLink), were performed by the same two research assistants using standard techniques. Spirometry was carried out according to the published standards of the ATS [10]. The best forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and maximum mid-expiratory flow rate (MMEFR) were retained for analysis. Predicted values were those of KNUDSON *et al.* [11]. Lung volumes were measured by a multiple-breath gas dilution method. Functional residual capacity (FRC) was measured, residual volume (RV) was obtained by subtracting expiratory reserve volume from FRC, and total lung capacity (TLC) by adding maximum vital capacity to RV. The $T_{L,CO}$ was measured according to the published ATS standards single-breath $T_{L,CO}$ [12]. Predicted values were those of CRAPO *et al.* [13, 14]. The progressive multistage exercise test, on an electronically-braked cycle ergometer (Quinton) was conducted using the method described by JONES and CAMPBELL [15]. Patients began at 20 W and the workload was increased by 20 W each minute until exhaustion, if possible. An arterial blood gas evaluation was performed and the $P_{(A\text{-}a),O_2}$ was calculated at rest and on maximal exertion. The equipment was calibrated before each test.

The nonspecific bronchial challenge was carried out using the method described by COCKROFT *et al.* [16]. Briefly, during successive 2 min periods of tidal volume breathing, the patients first inhaled phosphate-buffered saline, concentrations of histamine increasing from 2 to 16 $mg \cdot mL^{-1}$ at 5 min intervals. Aerosol was generated with a handheld Wright nebulizer, calibrated daily to produce 0.13 $mL \cdot min^{-1}$. FEV_1 was measured 30 and 90 s after each dose, and the test was stopped if FEV_1 fell by 20% or more or if the concentration of 16 $mg \cdot mL^{-1}$ was reached.

Descriptive statistics

Data obtained from the medical records were compared between the patient survivors and nonsurvivors with smoke inhalation, and then between the patient survivors with smoke inhalation who took part in the study and those who did not participate. The data from the medical records and after the fire incident are presented individually for each participant.

Results

Compared to the 21 nonsurvivors, the 45 patients who survived smoke inhalation did not show differences according to the localization of the smoke inhalation, *i.e.* upper and major airways abnormalities at bronchoscopy, but they were usually younger and had less extensive total body surface burn.

Of the 45 patient survivors with smoke inhalation according to the visual aspect of the airway abnormalities at bronchoscopy, 23 participated in the study, 1–7 yrs after their injury. Three patients died after they left the hospital (death was related to lung cancer, severe respiratory infection with respiratory failure not related to the smoke inhalation, and myocardial infarction), three had serious psychiatric disease, six refused to participate, and 10 were lost to follow-up. The participants and the nonparticipants were comparable with respect to gender, age, time since injury, aetiology of injury, and total body surface burned. Facial burns, smoke inhalation with bronchoscopic findings specifically to the tracheobronchial tree, and intubation requirement were more frequent in the participants compared to the nonparticipants.

Table 1 presents the characteristics of the participants for all burned patient survivors with smoke inhalation. The patients were young adults, mainly smokers or exsmokers, although none had a previous history of respiratory disease. The aetiology of the burn injury was mainly

Table 1. – Hospital data on burn patient survivors with smoke inhalation who participated in the study

Characteristics	Burn patient survivors with smoke inhalation
Gender M/F	18/5
Age yrs	34±12
Previous medical history %	
Asthma or COPD	0
Other lung disease	0
Smoking history %	
Nonsmoker	35
Ex-smoker	18
Smoker	47
Time since the injury* months	45±23 (13–80)
Aetiology of injury %	
Domestic fire/flame	87.5
Electricity	12.5
Total body surface burn* %	31±18 (0–70)
Facial burns %	88
Smoke inhalation† %	
Upper airways	20
Major airways	80
Intubation requirement %	88

*: values are mean±SD and range in parenthesis; †: smoke inhalation of the upper airways include the bronchoscopic finding of soot and mucosal abnormalities at the vocal cord, and of major airways include the trachea and the bronchus. M: male; F: female; COPD: chronic obstructive pulmonary disease.

related to domestic fire. Total body surface burn varied but facial burns were present in most of the patients. Smoke inhalation assessed by bronchoscopy was present mainly in the major airways. Intubation was required because of respiratory insufficiency or to prevent upper airways obstruction in a large proportion of the patients.

Table 2 presents the respiratory symptoms, and results of the chest examination and the chest radiograph of the participants. The respiratory symptom questionnaire and the chest examination were completed in 23 participants, and the chest radiograph in 17 of the 23 participants. Most patients (22 out of 23) reported that before the injury, dyspnoea occurred only upon strenuous physical activity. However, at the time of the study, four patients reported increased dyspnoea. Only one patient reported cough, and another reported phlegm at the time of the study, but not before the injury. Chest examination was normal in all patients except for scars of the skin resulting from skin burns. The chest radiograph was abnormal in only one patient, showing linear densities in the lower lobes compatible with lung scar of unknown aetiology.

Table 3 presents the FEV_1, FEV_1/FYC, MMEFR, TLC, $T_{L,CO}$ and the nonspecific bronchial challenge results of the participants. Spirometry and the lung volume measurements were completed in 17 of the 23 participants and nonspecific bronchial challenge in 16. The FEV_1 was equal or greater than 78% of predicted in all patients. FEV_1/FVC was equal or greater than 80% in all patients. MMEFR was equal or greater than 75% of predicted in all except one patient. TLC was equal or greater than 80% of predicted in all patients. The $T_{L,CO}$ was equal or greater than 80% of predicted in all except one patient; this patient had a TLC greater than 100% of predicted, a normal exercise test and lung compliance, a normal chest radiograph and did not report any increase in dyspnoea and cough. The provocative concentration of histamine resulting in a 20% fall in FEV_1 (PC_{20}) resulting from the nonspecific bronchial challenge was greater than 16 $mg \cdot mL^{-1}$ of histamine in all patients, which represents a normal bronchial responsiveness.

Table 4 presents the results for cardiac and respiratory variables at rest and on maximal exertion during the cycle ergometer multistage exercise test in the four patients who reported an increase in dyspnoea. Two patients reached their maximum predicted oxygen consumption ($\dot{V}'O_2$). Three patients stopped because of general exhaustion and one because of leg pain related to skin graft. Maximum heart rate was equal to or greater than 85% and maximum ventilation was equal to or less than 75% of predicted in all patients. The $P_{(A\text{-}a),O_2}$ at rest and on maximum exertion were within normal limits in all patients. The physiological dead space volumes normally about 1/3 of the tidal volume at rest increased for two patients (Nos. 12 and 16), although it fell in all patients during exercise.

Table 2. – Long-term consequences of smoke inhalation on burn patient survivors according to respiratory symptoms, chest examination, and chest radiograph

Pt No.	Symptoms*			Chest exam§	Chest radiograph
	Dyspnoea†	Cough‡	Phlegm‡		
1	1/1	0/0	0/+	N	N
2, 3	1/1	+/+	+/+	N	N
4,7,9–11,14,17	1/1	0/0	0/0	N	N
5	1/1	0/0	+/+	N	N
6	1/1	+/+	0/0	N	N
8	1/1	0/+	0/0	N	N
12	1/3	0/0	0/0	N	N
13	1/2	0/0	0/0	N	N
15	1/2	0/0	+/+	N	N
16	1/2	0/0	0/0	N	Abn
18	2/2	0/0	0/0	N	NA
19–23	1/1	0/0	0/0	N	NA

*: Respiratory symptoms assessed by questionnaire are presented as recalled by the patient before the injury/at the time of the study; †: dyspnoea grade 1=important physical activities, grade 2=hurrying on a level surface or walking up a hill, and grade 3=walking on level ground with normal people of about one's own age; ‡: +=present and 0=absent; §: normal chest examination excludes the presence of scar resulting from skin burns. Pt: patient; N: normal; Abn: abnormal; NA: not available.

Table 3. – Long-term consequences of smoke inhalation on burn patient survivors according to pulmonary function and nonspecific bronchial challenge tests*

Pt No.	FEV_1 L	FEV_1 (% pred)†	FEV_1/FVC %	MMEFR L	MMEFR (% pred)†	TLC L	TLC (% pred)‡	$T_{L,CO}$ % pred‡	PC_{20} mg.mL^{-1}
1	2.30	(95)	86	2.14	(75)	4.45	(104)	80	>16
2	4.36	(105)	82	3.52	(82)	7.64	(109)	125	>16
3	3.73	(91)	80	2.64	(61)	7.74	(112)	107	>16
4	2.98	(115)	86	3.48	(113)	4.48	(98)	93	>16
5	3.57	(101)	81	3.43	(95)	6.26	(93)	113	>16
6	2.59	(103)	86	2.47	(83)	4.54	(103)	75	>16
7	4.49	(97)	84	4.54	(92)	7.37	(106)	116	>16
8	4.62	(125)	83	6.32	(160)	6.60	(106)	118	>16
9	3.99	(86)	83	3.48	(75)	6.47	(93)	118	>16
10	3.43	(86)	81	3.15	(78)	6.46	(90)	91	>16
11	2.33	(89)	80	2.40	(80)	6.64	(104)	89	>16
12	2.97	(101)	82	2.42	(85)	6.40	(113)	124	>16
13	4.01	(95)	84	4.59	(100)	5.42	(86)	98	>16
14	5.02	(108)	84	5.24	(106)	7.02	(104)	123	>16
15	4.74	(106)	80	3.72	(80)	7.95	(112)	84	>16
16	3.27	(78)	81	3.13	(75)	6.20	(89)	127	>16
17	3.16	(79)	82	3.09	(77)	5.43	(80)	84	NA

*: the pulmonary function tests could not be performed in six participants who lived more than 500 km from a hospital facility; †: for FEV_1 and MMEFR, predicted values were those of KNUDSON *et al*. [11]; ‡: for TLC and $T_{L,CO}$, predicted values were those of CRAPO *et al*. [13, 14]; Pt: patient; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; MMEFR: maximum mid-expiratory flow rate; TLC: total lung capacity; $T_{L,CO}$: transfer factor of the lungs for carbon monoxide; % pred: percentage of predicted value; PC_{20}: provocative concentration of histamine resulting in a 20% fall in FEV_1; NA: not available.

Table 4. – Exercise tests with measurements of maximum V'_{O_2}, HR and ventilation, $P_{(A\text{-}a),O_2}$ and V_D/V_T on burn patient survivors with smoke inhalation complaining of increased dyspnoea

Patient No.	Age yrs	$V'_{O_2,max}$* mL·kg·min^{-1}	$HR_{,max}$* beat·min^{-1}	V'_{max}* L	$P_{(A\text{-}a),O_2}$ mmHg		V_D/V_T		Reason for stopping exercise
					At rest	On exertion	At rest	On exertion	
12	56	31 (106)	154 (88)	63 (58)	8.9	13.4	0.62	0.30	Exhaustion
13	22	19 (60)	163 (85)	62 (45)	8.0	NA	0.40	NA	Leg pain related to skin graft
15	37	45 (108)	173 (99)	115 (74)	7.5	20.0	0.33	0.21	Exhaustion
16	38	32 (82)	145 (85)	72 (65)	10.0	22.0	0.51	0.22	Exhaustion

*: values presented are maximum and, in parenthesis, the percentage of predicted according to JONES and CAMPBELL [15]. Pt: patient; $V'_{O_2,max}$: maximum oxygen consumption; $HR_{,max}$: maximum heart rate; V'_{max}: maximum ventilation; $P_{(A\text{-}a),O_2}$: alveolar-arterial oxygen pressure difference at rest and on a maximum exertion; V_D/V_T: ratio of dead space to tidal volume; NA: not available.

Discussion

The patients presented in this study were all burns patients with a diagnosis by bronchoscopy of smoke inhalation resulting mainly from domestic flame or fire. When the patients were evaluated 1–7 yrs after the injury, very few reported any increase in their respiratory symptoms, none presented significant airway obstruction and all had normal bronchial responsiveness. The only four patients complaining of increased dyspnoea did not show any significant exercise intolerance. The normal $P_{(A\text{-}a),O_2}$ and V_D/V_T on maximal exercise make the presence of a significant airway or lung disease unlikely.

Studies published so far have not assessed the long-term consequences of smoke inhalation in burn patients. The studies have evaluated respiratory symptoms and pulmonary function abnormalities over a short period of time [5, 7]. STENTON *et al*. [7] reported some improvement 4 months later on two subjects with bronchial hyperresponsiveness following smoke inhalation. KINSELLA *et al*. [5] reported some improvement during a 3 month observation period of all of nine patients with bronchial hyperresponsiveness following smoke inhalation.

Since the present study was retrospective, the pulmonary function tests were not systematically documented in the patients shortly after smoke inhalation. However, all the patients had macroscopic airway abnormalities at bronchoscopy compatible with smoke inhalation. The diagnosis performed by bronchoscopy represents at present the most direct and best clinical way to assess smoke inhalation. According to recent studies, in which the diagnosis of smoke inhalation was made primarily on the basis of history and clinical examination, the proportion of patients with bronchial hyperresponsiveness following smoke inhalation is high. CLARK *et al*. [8] reported airways obstruction in 39 of 73 patients with inhalation injury. SHERMAN *et al*. [6] reported airways obstruction and/or bronchial hyperresponsiveness in 11 of 18 firemen who experienced smoke inhalation. KINSELLA *et al*. [5] reported bronchial hyperresponsiveness in 15 of 18 patients with inhalation injury. Therefore, in our study, it is possible that some of the patients had normal pulmonary

function and bronchial responsiveness shortly after smoke inhalation, but with regard to the recent literature this is unlikely to be the case for most of the patients.

Since the study was retrospective, the loss in follow-up was significant and many patients could not be studied 1–7 yrs after the smoke inhalation. Only 23 of 45 patient survivors (51%) with inhalation injury participated in the study. However, according to the medical records, participants and nonparticipants were comparable with respect to gender, age, time since injury, aetiology of injury, and body surface burned. More relevant, intubation requirement and smoke inhalation with bronchoscopic findings of the tracheobronchial tree were observed in a higher proportion of the participants compared to the nonparticipants. Therefore, if anything, the potential bias of selection of the participants was directed towards more severe injuries of the tracheobronchial tree.

In conclusion, previous studies of patients who were burn survivors with smoke inhalation have shown that bronchial hyperrsponsiveness is frequent. Evaluation of lung function in individual patients would be important, especially in burn patients with smoke inhalation. Despite evidence that smoke inhalation and body surface burns injury in combination may cause significant problems, this does not necessarily imply long-term damage to the respiratory airways or lungs' as shown by this retrospective assessment of long-term lung function in patients with bronchoscopic evidence of smoke inhalation. The results of a prospective study of this subject with long-term follow-up are awaited.

Acknowledgements: The authors thank M. Krusky, J. Rousseau and F. Champoux for their work as research assistants and C. Valin for her secretarial assistance.

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