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First-day computed tomography: does it has a role in the assessment of patients with inhalation lung injury?

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Abstract

Background Inhalation lung injury occurs in almost one-third of all serious burns and is responsible for a considerable proportion of burn patient fatalities each year. History of closed space fire or unconsciousness at the accident site, occurrence of pharyngeal or facial burns, hoarseness, and wheezing, and laboratory tests that include blood gas abnormalities or Carboxyhemoglobin levels in blood ˃ 10% are used to diagnose inhalation lung injury. It is also characterized by radiological findings of alveolar or interstitial edema, atelectasis, and/or consolidations, as well as the presence of erythema with laryngeal or tracheal edema in the bronchoscope.

Objectives To study the diagnostic and prognostic efficacy of radiologist score and bronchial wall thickening as radiological CT findings in inhalation lung injury.

Methods This prospective case–control study included 48 patients with inhalation lung injury (ILI) as a case group and 10 patients without ILI were selected as the control group, all recruited from the burn and plastic department. Within the first 12 h of suspected ILI, a fiberoptic bronchoscope was done to confirm the diagnosis. An initial chest X-ray was done followed by computed tomography through which the radiologist score (RADS) together with bronchial wall thickening (BWT) was done.

Results Duration of ventilation was higher in cases than in controls (8.50 ± 3.94 vs 3.25 ± 0.50). The hospital duration was higher in cases than in controls (13.6 ± 4.68 vs9.50 ± 4.52). The BWT was 2.12 ± 0.66 (mean ± SD) in the ILI group while the control group was 1.32 ± 0.48 (mean ± SD). Correlating between baseline PaO2 and RADS score and BWT, it was found that there was a highly significant negative correlation between PaO2 and RADS score and BWT among inhalation lung injury patients (*P* value 0.001). The sensitivity of BWT in the detection of the need for mechanical ventilation was 83% at a cut-off point of 1.65. Its specificity was 78% and accuracy 75%.

Conclusion CT done within 24 h of burn patients has a good role in the diagnosis and management of ILI from the burn.

Keywords Inhalation injury, Bronchial wall thickening, Radiologist score, Computed tomography

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Introduction

Inhalation lung injury (ILI) is a significant risk factor for death in burn patients [1]. There is a weak awareness of diagnostic criteria and severity grading, and there is no standard therapy that minimizes morbidity and death in these individuals [2]. The degree of injury is determined by the length of smoke exposure, the temperature of the inhaled smoke, and the composition of the smoke [3]. The most important pathophysiologic alteration after an inhalation injury is induced mucosal hyperemia with edema, increased mucous production, and airway exudation that hinders the mucociliary escalator. Overall, these insults exacerbate airway narrowing by forming casts of inspissated mucus, and fibrin clots together with epithelium debris which affect the ventilations. Rapid bronchoscopic diagnosis and multimodal therapy enhance patient outcomes [2]. Early diagnosis and classification of inhalation injuries enhance patients' treatment results [4]. Chest computed tomography (CT), fiberoptic bronchoscopy (FOB), radionuclide imaging using 133Xenon, carboxyhemoglobin (COHb) measurement, and pulmonary function tests are all methods for confirming inhalation damage. Fiberoptic bronchoscopy is the gold standard for its diagnosis and recent investigations have shown an association between the severity of inhalation injuries on FOB and death [5, 6]. The bronchoscopy scale of inhalation injury was classified into five grades according to the presence and degree of the injury [4]. Neither FOB nor chest X-ray provides an analytical summary of pulmonary injury. Theoretically, chest CT may be used as an alternative or adjunct to the FOB approach, as well as a diagnostic and prognostic tool for critically sick burn patients, especially those with ILI [7] In this study, we tried to assess the diagnostic and prognostic efficacy of the radiologist score (RADS) and bronchial wall thickening as radiological CT findings in inhalation lung injury.

Methods

This study included 48 patients with inhalation lung injuries recruited from the burn and plastic department, at Menoufia University Hospitals from December 2015 to January 2019. In addition, 10 patients without ILI were selected as the control group. The Ethics Committee of Menoufia University Hospitals approved the study's protocol. In addition, before enrollment; informed written consent was obtained from the patients. Exclusion criteria were patients less than 18 years old, patients who had their CT scan after 24 h of their admission, patients who could not finish all of the study steps, or patients that are known to have any parenchymal lung disorders.

All patients were subjected to history taking and general and local examinations. The burning type (physical or chemical), depth (superficial or deep), and extent (as a percentage) were assessed, (Fig. 1), together with the degree of sepsis, if present, and any associated injuries. In addition, early signs of airway damage were evaluated by, e.g., presence of coughing, hoarseness of voice, wheezes, painful throat, and/or odynophagia. Also, the data regarding admission to the ICU, duration of ICU admission, if the patients were mechanically ventilated or not, and their prognosis were gathered. Laboratory studies were also conducted on all patients on admission and baseline arterial blood gases (ABG), complete blood picture (CBC), albumin, urea, creatinine, electrolytes anion gab, and hemoglobin concentration were tested.

Within the first 12 h of suspected ILI, FOB was done (using Pentax v 18, Japan) to confirm the diagnosis. After confirming the diagnosis, an initial CXR was done followed by CT (using CT Toshiba Aquilion 1) in the first 24 h.

The presence of any degree of erythema, bronchorrhea, carbonaceous depositions, bronchial constriction, or signs of mucosal sloughing, necrosis, or endoluminal constriction is required for bronchoscope diagnosis of ILI. [4]

For the evaluation of CT findings of ILI [8], the following two methods were used:

1- Radiologist score (RADS): the radiologist assigned grades to each CT scan based on the grading scheme previously outlined [9]. In summary, CT scans of each patient were examined using 1-cm axial slices from the apex to the diaphragm level. The right and left lung fields in each slice were subdivided into 4 quadrants. Each quadrant was awarded a score ranging from 0 to 3 based on the

Fig. 1 A 29-year-old female patient presented with a direct flame burn about 35% deep in nature, 4th-degree affecting the face, scalp, both upper limbs, and chest. In the bronchoscope airway was edematous. Full of soot in mouth and nose

Table 1 Radiologist score (RADS) [9]

Finding	Score
Normal	0
Increased interstitial markings	1
Ground glass opacities	2
Consolidations	3

severity of the results (Table 1). The highest score inside a quadrant was awarded as the final score, and a total score was produced for each slice. The total score for each slice was then added together for the full CT scan to get the RADS overall. To standardize the score based on the number of axial CT scan slices, the total RADS was divided by the number of slices read for each CT to get the RADS for each slice which was utilized to statistically compare the groups.

2- Bronchial wall thickening (BWT): scans were acquired at the inspiration ending by utilizing one second time scan with a high spatial frequency. Two centimeters distal to the tracheal bifurcation, the BWT was measured.

Figures 2 and 3 showed CT of 2 participants in the study that showed areas of the alveolar filling and bronchial thickening respectively.

Statistical analysis

Data were gathered, tabulated, and statistically analyzed using an IBM personal computer running version 19 of Statistical Package for Social Science (SPSS) (SPSS, Inc., Chicago, IL, USA). Quantitative data were provided as mean, standard deviation (SD), and range, whereas qualitative data was given as numbers and percentages. The chi-square test ($\chi 2$) was employed to investigate the relationship between two qualitative variables. The Student *t* test is used to compare two groups with regularly distributed quantitative data. The Mann–Whitney test is used to compare two non-normally distributed groups using quantitative data. Spearman's correlation: used for correlation of two quantitative variables not normally distributed. Roc curve analysis was used to detect the sensitivity of bronchial wall thickness in the detection of mechanical ventilation Significance level was set at a *p* value < 0.05.

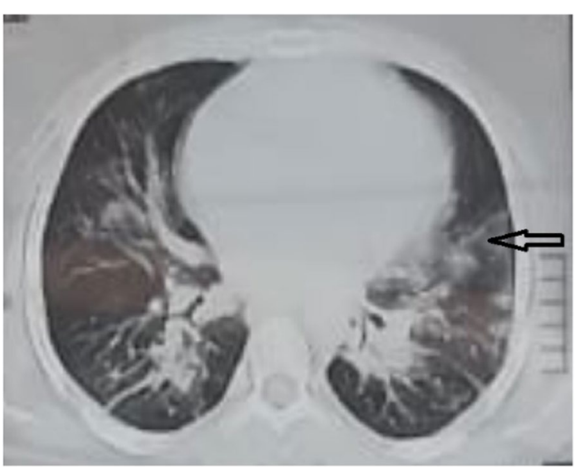

Fig. 2 CT of a female patient presented with 25% burn CT chest show areas of the alveolar filling (black arrow)

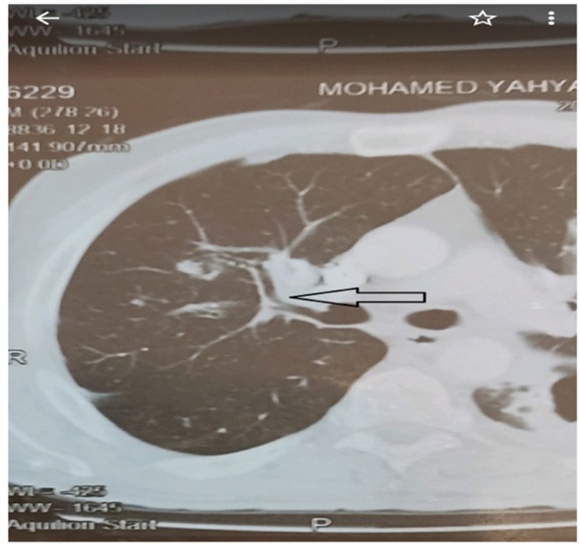

Fig. 3 CT of a male patient with ILI showing bronchial wall thickening (arrow)

Results

This prospective case–control study was done including 48 burn patients with inhalation lung injury (ILI) and 10 patients with burn without a history or symptoms of inhalation lung injury as a control group. The participants' mean age of the ILI group was 48.1 years, 21(43.8%) of the patients were males, 17(35.4%) were smokers, while the control group's mean age was 51.8 years, 4 (40.0%) of patients were males and 4 (40.0%) were a smoker. There was no considerable variation between cases and controls concerning their age, sex, smoking, presence of comorbidities, and percentage of burn (*P* value > 0.05) (Table 2).

There was a significant difference between cases and controls as regards the need for ICU admission 79.2% of cases were admitted compared to 40% in controls also, the mean duration of ICU admission was more in cases in comparison to controls (10.2 ± 4.50 vs 6.00 ± 1.89).

Regarding the need for mechanical ventilation, 62.5% of cases were mechanically ventilated compared to 20%

Table 2 Demographic data of the studied groups

Studied variables		Cases (*N* = 48)	Controls (*N* = 10)	Test of significance	*P* value
Age/years	Mean ± SD	48.1 ± 14.5	51.8 ± 13.6	U = 0.773	0.440
	Range	21 – 70	21—62		
Gender	Male	21(43.8)	4(40.0)	FE = 0.047	0.828
	Female	27(56.3)	60(60.0)		
Smoking	Yes	17(35.4)	4(40.0)	FE = 0.075	0.784
	No	31(64.6)	6(60.0)		
Comorbidities	No	26(54.2)	4(40.0)	X2 = 2.05	0.842
	DM	8(16.7)	2(20.0)		
	HTN	2(4.2)	0(0.00)		
	IHD	5(10.4)	1(10.0)		
	Others	7(14.6)	3(30.0)		
ICU admission	Yes	38(79.2)	4(40.0)	FE 6.36	**0.011***
	No	10(20.8)	6(60.0)		
Duration of ICU admission	Mean ± SD	10.2 ± 4.50	6.00 ± 1.89	U = 2.04	**0.041***
	Range	3 – 18	4—8		
Mechanically ventilated	Yes	30(62.5)	2(20.0)	FE = 6.04	**0.032***
	No	18(37.5)	8(80.0)		
Duration of mechanical ventilation	Mean ± SD	8.50 ± 3.94	3.25 ± 0.50	U = 2.39	**0.017***
	Range	2 – 18	3—4		
Duration of hospital admission	Mean ± SD	13.6 ± 4.68	9.50 ± 4.52	U = 2.21	**0.027***
	Range	6 – 24	2—16		
% of burn	Mean ± SD	26.8 ± 15.0	26.7 ± 7.66	U = 0.062	0.951
	Range	15 – 40	15—38		
Prognosis Died/discharge	Death	15(31.3)	0(0.00)	FE = 4.22	**0.040***
	Discharge	33(68.7)	10(100)		

FE Fisher exact test, *U* Mann Whitney test, X^2 Chi-squared test

* Significant

in controls, the difference between cases and controls was statistically significant. Also, the duration of ventilation was higher in cases than in controls (8.50 ± 3.94 vs 3.25 ± 0.50). The hospital duration was higher in cases than in controls (13.6 ± 4.68 vs9.50 ± 4.52) (Table 2).

The findings reported changes significantly between cases and controls regarding their prognosis, 15 patients (31.3%) of cases died and all cases of controls were discharged (Table 2).

Comparing case and control groups, regarding laboratory and radiological findings on admission. It was found insignificant changes between both groups in WBC count, percent of hemoglobin (Hb), platelets number, creatinine, blood urea nitrogen (BUN), albumin, pH, HCO_3, anion gap, RADS, and CXR findings. However, there were considerable statistical differences between both groups in PO_2, O_2 saturation (SaO_2), and BWT which were highly significant. BWT mean and SD was 2.12 ± 0.66 in the ILI group and 1.32 ± 0.48 in the control group (Table 3).

Comparing the patients who needed ICU admission and those who did not need it among the patients of ILI, there were no significant statistical differences in gender, smoking, white blood cell (WBC) count, PaCO2, RADS, and CXR findings. While there were significant statistical changes regarding age, presence of comorbidities, Hb concentration, creatinine, BUN, albumin, pH, and BWT. High significant statistical differences were found with PaO2, SaO2, HCO3, anion gap, and percent of burn (Table 4).

Comparing the patients who needed mechanical ventilation and those who didn't need it among the patients of ILI, there were insignificantly statistical variations for gender, smoking, WBC count, albumin, pH, PaCO2, and RADS while there was a significant statistical difference for creatinine. High significant statistical differences were found with age, presence of comorbidities, Hb concentration, BUN, PaO_2, SaO_2, HCO_3, BWT, anion gap, percent of burn, and X-ray findings (Table 5).

Searching for the relation between patient prognosis and different parameters in ILI patients, there was

Table 3 Laboratory & radiological findings on admission

Studied variables		Cases ($N=48$)	Controls ($N=10$)	Mann Whitney test	P value
WBC	Mean ± SD	13.1 ± 3.81	13.7 ± 3.49	0.433	0.658
	Range	5.50 – 20.1	7.80 – 19.0		
Hb%	Mean ± SD	11.9 ± 2.04	10.7 ± 1.35	1.77	0.77
	Range	8 – 15	8.30 – 12.4		
Platelet	Mean ± SD	320.6 ± 92.1	278.7 ± 116.9	1.09	0.275
	Range	150 – 450	150 – 444		
Creatinine	Mean ± SD	1.27 ± 0.56	1.42 ± 0.39	1.25	0.210
	Range	0.60 – 3.10	0.90 – 1.90		
BUN	Mean ± SD	57.1 ± 15.4	50.1 ± 15.9	1.67	0.093
	Range	34 – 90	32 – 80		
Albumin	Mean ± SD	2.51 ± 0.63	2.14 ± 0.40	1.39	0.163
	Range	1.50 – 3.50	1.80 – 3.10		
pH	Mean ± SD	7.34 ± 0.13	7.35 ± 0.13	0.371	0.710
	Range	7.10 – 7.49	7.13 – 7.48		
PaO2	Mean ± SD	51.9 ± 6.20	59.1 ± 3.54	3.88	**0.001***
	Range	39 – 68	55 – 68		
SaO2	Mean ± SD	77.1 ± 6.59	83.6 ± 6.76	2.68	**0.007***
	Range	65 – 90	67.9 – 90		
PaCO2	Mean ± SD	38.4 ± 8.18	38.9 ± 6.39	0.630	0.529
	Range	29 – 65	33 – 54		
HCO3	Mean ± SD	18.5 ± 4.38	18.1 ± 3.31	0.413	0.679
	Range	10 – 28	13 – 23		
Anion gap	Mean ± SD	13.4 ± 8.39	13.5 ± 6.09	0.434	0.665
	Range	4 – 34	7 – 24		
RADS	Mean ± SD	6.52 ± 1.92	5.60 ± 2.06	1.31	0.191
	Range	3.20 – 11.2	3 – 9		
BWT	Mean ± SD	2.12 ± 0.66	1.32 ± 0.48	3.27	**0.001***
	Range	1.30 – 3.80	0.80 – 2.20		
CXR	Normal	28(58.3)	6(60.0)	X2 = 0.944	0.624
	Bronchopneumonia	4(8.30)	0(0.00)		
	Increased BVM	16(33.3)	4(40.)		

U Mann Whitney test, *FE* Fisher exact test

* Significant

no significant statistical difference regarding gender, smoking, WBC count, and PaCO2. while there was in pH. High significant statistical differences were found with age, presence of comorbidities, Hb concentration, creatinine, BUN, albumin, PaO2, SaO2, HCO3, RADS, BWT, anion gap, percent of burn, and CXR findings (Table 6).

Correlating between baseline PaO2 and RADS score and BWT, it was found that there was a highly significant negative correlation between PaO2 and RADS and BWT among inhalation lung injury patients (*P* value 0.001) (Table 7), (Figs. 4 and 5).

The sensitivity and specificity of BWT for the detection of the need for mechanical ventilation among ILI patients were 83% and 78% respectively with a cut-off point of 1.65 and an accuracy of 75% (Fig. 6).

Discussion

In this prospective case–control study, it was found that there was no significant difference between cases of ILI and controls regarding their age, sex, smoking, presence of comorbidities, and percentage of burn while for ICU admission, 79.2% of cases were admitted compared to 40% in controls also, the mean duration of ICU admission was higher in cases than controls (10.2 ± 4.50 vs 6.00 ± 1.89). Regarding mechanical ventilation 62.5% of cases were mechanically ventilated compared to 20% in controls, the difference between cases and controls was

Table 4 Comparison between ICU admission and non-ICU admission among patients with ILI

Studied variables	ICU patients ($N=38$)	Non-ICU ($N=10$)	Test of sig	*P* value
Age/years	50.5 ± 14.6	39.3 ± 10.7	U = 2.31	**0.021***
Gender	N(%)	N(%)		
Male	19(50.0)	2(20.0)	FE = 2.89	0.152
Female	19(50.0)	8(80.0)		
Smoking				
Yes	15(39.5)	2(20.0)	FE = 1.31	0.459
No	23(60.5)	8(80.0)		
Comorbidities				
No	16(42.1)	10(100)	X2 = 10.6	**0.013***
Diabetes Mellitus	8(21.1)	0(0.00)		
Hypertension	2(5.30)	0(0.00)		
Ischemic heart diseases	5(13.2)	0(0.00)		
Other heart diseases	7(18.4)	0(0.00)		
Chronic chest disease				
Yes	9(23.7)	0(0.00)	FE = 2.91	172
No	29(76.3)	10(100)		
Laboratory investigations				
WBC	13.4 ± 3.77	11.7 ± 3.82	U = 1.09	0.275
Hb%	10.8 ± 2.28	12.6 ± 2.06	U = 2.07	**0.038***
Creatinine	1.65 ± 0.83	0.97 ± 0.24	U = 2.12	**0.034***
BUN	59.7 ± 16.1	47.3 ± 6.41	U = 2.05	**0.040***
Albumin	2.23 ± 0.72	2.85 ± 0.54	U = 2.43	**0.015***
pH	7.31 ± 0.14	7.14 ± 0.19	U = 2.55	**0.011***
PaO2	50.5 ± 5.95	57.2 ± 4.02	U = 3.17	**0.002***
SaO2	75.2 ± 6.38	80.7 ± 1.56	U = 2.97	**0.003***
PaCO2	38.8 ± 9.04	37.1 ± 3.31	U = 0.293	0.770
HCO3	17.6 ± 4.16	22.3 ± 3.16	U = 3.35	**0.001***
RADS	6.76 ± 2.07	5.65 ± 0.75	U = 1.86	0.062
BWT	2.23 ± 0.68	1.67 ± 0.27	U = 2.44	**0.014***
Anion gap	15.1 ± 8.44	7.10 ± 4.20	U = 3.08	**0.002***
% of burn	28.2 ± 7.71	21.5 ± 2.67	U = 2.68	**0.007***
Chest XR				
Normal	19(50.0)	9(90.0)	X2 5.28	0.071 NS
Bronchopneumonia	4(10.5)	0(0.00)		
Increased BVM	15(39.5)	1(10.0)		

FE Fisher exact test, *U* Mann Whitney test, X^2 Chi-squared test

* Significant

Table 5 Comparison between MV patients and non-MV among patients with ILI

Studied variables	MV patients ($N=30$)	Non-MV patients ($N=18$)	Test of sig	*P* value
Age/years	53.1 ± 14.2	39.8 ± 10.9	t-test = 3.39	**0.001***
Gender	N(%)	N(%)		
Male	10(33.3)	11(61.1)	X2 = 3.52	0.060
Female	20(66.7)	7(38.9)		
Smoking				
Yes	9(30.0)	8(44.4)	X2 = 1.02	0.311
No	21(70.0)	10(55.6)		
Comorbidities				
No	9(30.0)	17(94.4)	X2 = 19.1	**0.002***
Diabetes Mellitus	7(23.3)	1(5.60)		
Hypertension	2(6.70)	0(0.00)		
Ischemic heart diseases	5(16.7)	0(0.00)		
Other heart diseases	7(23.3)	0(0.00)		
Chronic chest disease				
Yes	9(30.0)	0(0.00)	FE = 6.64	**0.018***
No	21(70.0)	18(100)		
Laboratory investigations				
WBC	13.3 ± 3.84	12.6 ± 3.82	t-test = 0.624	0.535
Hb%	10.2 ± 2.02	12.7 ± 1.97	t-test = 4.24	**0.001***
Creatinine	1.66 ± 0.75	1.25 ± 0.82	U = 1.96	**0.049 ***
BUN	63.1 ± 16.5	47.3 ± 4.93	t-test = 3.92	**0.001***
Albumin	2.20 ± 0.65	2.62 ± 0.79	t-test = 2.00	0.051
pH	7.27 ± 0.14	7.28 ± 0.21	t-test = 0.281	0.781
PaO2	49.7 ± 5.50	55.6 ± 5.63	t-test = 3.55	**0.001***
SaO2	73.5 ± 5.23	80.9 ± 4.64	t-test = 4.91	**0.001***
PaCO2	38.1 ± 10.1	38.8 ± 3.44	t-test = 0.344	0.732
HCO3	16.4 ± 4.09	22.1 ± 1.93	t-test = 6.42	**0.001***
RADS	6.97 ± 2.05	5.79 ± 1.45	U = 1.90	0.057
BWT	2.40 ± 0.68	1.65 ± 0.21	t-test = 5.49	**0.001***
Anion gap	17.6 ± 8.02	6.55 ± 2.03	U = 4.89	**0.001***
% of burn	29.9 ± 7.59	21.5 ± 2.85	t-test = 5.49	**0.001***
CXR				
Normal	11(36.7)	17(94.4)	X2 15.5	**0.001**
Bronchopneumonia	4(13.3)	0(0.00)		
Increased BVM	15(50.0)	1(5.60)		

FE Fisher exact test, *U* Mann Whitney test, X^2 Chi-squared test

* Significant

Table 6 Relation between patient prognosis and different parameters in inhalation lung injury patients

Studied variables	Prognosis		Test of sig	*P* value
	Died (*N* = 15)	Discharged (*N* = 33)		
Age/years	63.8 ± 4.10	41.0 ± 11.6	t-test = 7.38	**0.001***
Gender	N(%)	N(%)		
Male	7(46.7)	14(42.4)	X2 = 0.075	0.784
Female	8(53.3	19(57.6)		
Smoking				
Yes	6(40.0)	11(33.3)	X2 = 0.200	0.654 NS
No	9(60.0)	22(66.7)		
Comorbidities				
No	1(6.70)	25(75.8)	X2 = 23.8	**0.001***
Diabetes Mellitus	4(26.7)	4(12.1)		
Hypertension	2(13.3)	0(0.00)		
Ischemic heart diseases	4(26.7)	1(3.00)		
Other heart diseases	4(26.7)	3(9.10)		
Chronic chest disease				
Yes	6(40.0)	3(9.10)	FE = 6.64	**0.018***
No	9(60.0)	30(90.9)		
Laboratory investigations				
WBC	14.1 ± 3.63	12.6 ± 3.85	t-test = 1.24	0.221
Hb%	9.64 ± 1.13	11.8 ± 2.41	t-test = 3.41	**0.001***
Creatinine	2.14 ± 0.49	1.21 ± 0.73	t-test = 5.12	**0.001***
BUN	76.0 ± 10.0	48.6 ± 7.96	t-test = 9.33	0.001*
Albumin	1.83 ± 0.17	2.60 ± 0.76	t-test = 3.83	0.001*
pH	7.19 ± 0.11	7.31 ± 0.17	t-test = 2.91	0.017 *
PaO2	46.7 ± 5.07	54.3 ± 5.16	t-test = 4.72	0.001*
SaO2	70.5 ± 4.16	78.9 ± 4.97	t-test = 5.70	0.001*
PaCO2	40.2 ± 13.5	37.6 ± 3.91	t-test = 0.742	0.470
HCO3	13.7 ± 2.25	20.8 ± 3.08	t-test = 8.06	0.001*
RADS	7.86 ± 2.12	5.92 ± 1.49	U = 2.64	0.008*
BWT	2.90 ± 0.47	1.76 ± 0.35	t-test = 9.19	0.001*
Anion gap	22.4 ± 4.95	9.39 ± 6.17	U = 4.88	0.001*
% of burn	36.7 ± 3.10	22.2 ± 3.20	t-test = 14.6	0.001*
CXR				
Normal	2(13.3)	26(78.8)	X2 21.0	**0.001***
Bronchopneumonia	4(26.7)	0(0.00)		
Increased BVM	9(60.0)	7(21.2)		

FE Fisher exact test, *U* Mann Whitney test, X^2 Chi-squared test

* Significant

Table 7 Correlation between baseline PaO2 and RADS score and BWT

Studied variables	PaO2	
	r	*P* value
RADS score	-0.516	**0.001***
BWT	-0.621	**0.001***

* Significant

statistically significant. Also, the duration of ventilation was higher in cases than in controls (8.50 ± 3.94 vs 3.25 ± 0.50). The hospital duration was higher in cases than in controls (13.6 ± 4.68 vs 9.50 ± 4.52). Oh and his colleagues in their retrospective study found no difference in age, total burn surface area, % full thickness burn, tracheostomy, or COHb level between their inhalation injury group and the non-inhalation injury group [7].

In a study, which was conducted on 1058 patients treated at a single institution over the 5 years 1980–1984, 373 (35%) of these patients were diagnosed with ILI using bronchoscopy and/or ventilation-perfusion lung [10].

In this work, the need for ICU admission was in 79.2% of cases compared to 40% in controls also, the mean duration of ICU admission was higher in cases than controls (10.2 ± 4.50 vs 6.00 ± 1.89) which represents a statistically significant difference. In Oh et al. work, there was an insignificant disparity between ventilation-free days, and the incidence of pneumonia, or death. However, the frequency of ALI/ARDS was considerably greater in the inhalation injury group (79 vs 8%; $P = 0.0014$) and the incidence of the composite endpoint was significantly higher in the inhalation injury group (89 vs 20%; P 0.0001) [7].

In this work, regarding the need for mechanical ventilation 62.5% of cases were mechanically ventilated compared to 20% in controls, the difference between cases and controls was statistically significant. Also, the duration of ventilation was higher in cases than in controls (8.50 ± 3.94 vs 3.25 ± 0.50). The hospital duration was higher in cases than in controls (13.6 ± 4.68 vs 9.50 ± 4.52). This can be explained that many factors contribute to airflow obstruction in ILI like inflammation, mucus discharge, edema of the airway wall, and spasms of the bronchial smooth muscle. The BWT of the airway is seen in such patients, and these reversible alterations of the airway wall may result in refractory airway obstruction, loss of respiratory function, and the requirement for MV.

In the study of Yamamura et al., BWT evaluated by chest CT scans performed within a few hours of admission predicted the overall number of ventilator days and ICU-stay days for patients with smoke inhalation injuries [11].

In the current study, 31.3% of cases died as a consequence of burn and inhalation injury. With Thompson's work the probability of death concerning age, TBSA, burn percentage, and the occurrence of inhalation damage was shown. The incidence of inhalation injuries increased as the burn area grew. Also, the frequency of ILI increased with age; death was lowest in the 5- to 14-year-old age group and greatest in those older than 59 [12].

In their investigation, Shirani and his colleagues discovered that ILI alone increased death by a maximum of 20%, while pneumonia increased mortality by a maximum of about 60%. His findings indicate that inhalation injury and pneumonia have significant, independent,

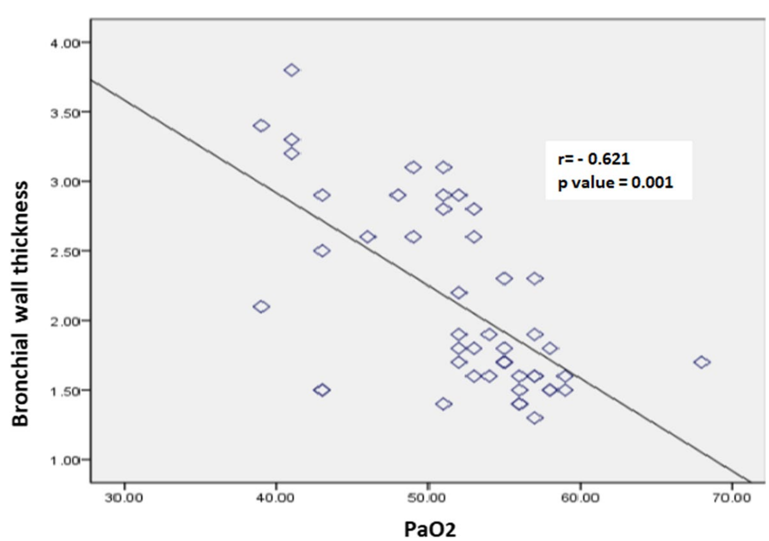

Fig. 4 Correlation between baseline PaO2 and bronchial wall thickness

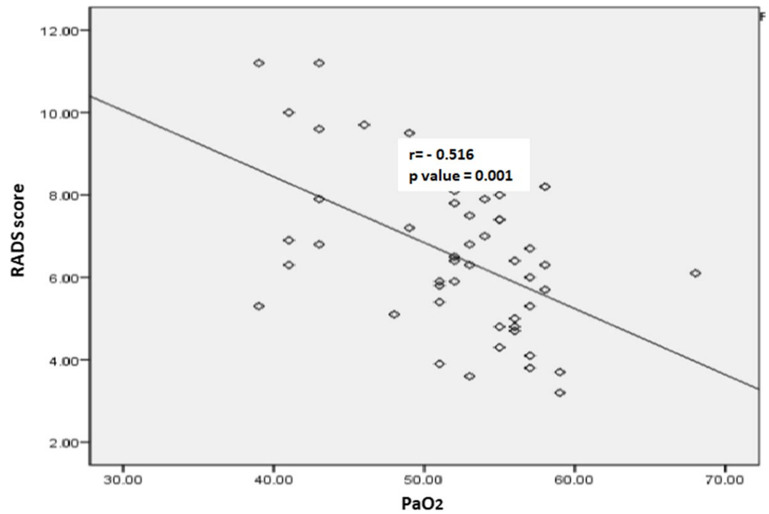

Fig. 5 Correlation between baseline PaO2 and radiologist score

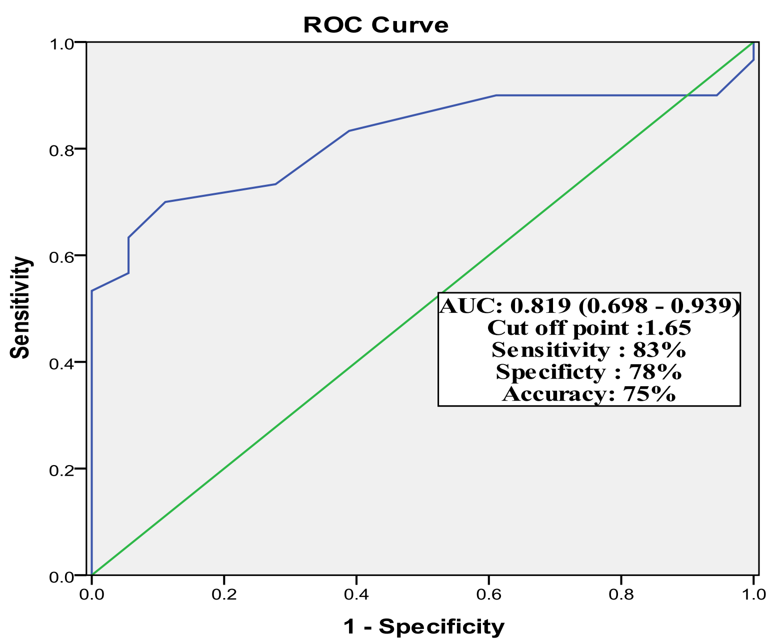

Fig. 6 The sensitivity and specificity of bronchial wall thickness for detection need for mechanical ventilation among inhalation lung injury patients

additive effects on burn mortality and that these effects vary predictably with age and burn size [10].

Charles et al. detected burns inhalation damage in 84 of 231 (36%) critically ill burns patients; 20 were moderate (grade 1), 41 were severe (grades 2 and 3), and 23 were unclassified bronchoscopically. 20% was the median of TBSA (10–40%). Mortality was considerably higher in patients with burns inhalation injury compared to those without burns inhalation injury (*p* 0.001; 38/84 [45%] vs. 35/147 [24%] vs. no burns inhalation injury, respectively). In their multivariable analysis, severe burns inhalation injury substantially increased mortality (adjusted HR = 2.14, 95% CI = 1.14 to 4.09, $p = 0.022$) compared to mild damage (adjusted HR = 0.58, 95%CI = 0.18 to 1.86, $p = 0.363$). Although pneumonia did not independently predict death, facial burns (adjusted HR = 3.13, 95%CI 1.69–5.79, *p* 0.001), greater TBSA (adjusted HR = 1.05, 95%CI 1.04–1.06, *p* 0.001), and older age (adjusted HR = 1.04, 95%CI 1.02–1.07, *p* 0.001) did [13].

In their 5-year retrospective analysis, Shirani and his colleagues examined 1058 patients treated at a single hospital. 373 (35%) of these patients were diagnosed with inhalation damage using bronchoscopy and/or ventilation-perfusion lung imaging. Multiple logistic equations were devised to predict mortality at any age and burn size for individuals without inhalation injury, pneumonia, or both. By subtracting the predicted mortality without inhalation injury or pneumonia from the expected mortality in the presence of either or both, extra mortality owing to these complications may be estimated [10].

In the current study, comparing case and control groups regarding laboratory & radiological findings on admission there was no significant statistical difference between the two groups in WBC count, percent of Hb, platelets number, creatinine, BUN, albumin, pH, HCO3, anion gap, RADS and X-ray findings. However, there were significant statistical differences between the two groups in PO2, SaO2, and BWT which were highly significant.

In the current study RADS per slice mean and SD in case and control groups were 6.52 ± 1.92 and 3.20–11.2 respectively. With Oh et al. research, when modeling RADS per slice as a binary variable ($>$ or ≤ 8), the difference between groups was not significant [7].

In the current work, BWT compared in case and control were 2.12 ± 0.66 (mean $\pm$ SD) with a range of 1.30–3.80 mm in the case group while in control were 1.32 ± 0.48 (mean $\pm$ SD) with a range of 0.80–2.20 mm which represent the high significant statistical difference. Yamamura and his colleagues found BWT on entry CT was 4.1 mm. The CT scan performed 24 h later revealed bilateral ground-glass shadows with a BWT of 4.4 mm. The CT scan acquired on the seventh day of hospitalization indicated just atelectasis and a BWT of 2.8 mm [11].

In the current work chest, X-ray findings in case and control groups were as follows: 58% X-ray was normal in ILI while 60% in controls, 8% had bronchopneumonia in the case group while 0% in controls finally 33% had increased broncho-vascular markings in the case group while 40% in controls had, this has no significant statistical differences.

Lee and O'Connell examined the impact of smoke inhalation damage on 45 individuals from a significant fire tragedy using serial chest radiographs. A 33 was admitted with abnormal chest radiography. There were 29 patients with bronchial wall thickening, 13 with subglottic edema, seven with pulmonary edema, and three with patchy consolidation. Following the first exposure, seven individuals had pulmonary edema. This resulted in the deaths of two individuals. Monitoring of pulmonary edema was facilitated by serial CXR. Bronchial wall thickening and subglottic edema were frequent early results and may thus portend a more severe respiratory embarrassment in the future. Subglottic edema is an observation not before documented. It may also signify injury to the lung parenchyma in addition to damage to the upper airways. It may potentially complicate endotracheal intubation. Consequently, the first chest radiograph is a substantial predictor of serious smoke inhalation damage, allowing for the identification of individuals likely to need ventilatory support [14].

Kim and his colleague in their work found 43 (47.8%) had abnormal CT findings that were compatible with inhalation injury; 28 (65.1%), had peri-bronchial ground glass opacity; 14 (32.6%), having segmental or sub-segmental consolidation; 17 (39.5%) having atelectasis; 12 (27.9%) having branching linear attenuation; 7 (16.3%) having bronchial wall thickening; 5 (11.6%) having interlobular septal thickening, and 1 (2.3%) having bronchiectasis. The age, sex, burn size, initial carboxyhemoglobin level, and PaO2/FiO2 ratio showed no significant differences ($P > 0.05$) [15].

In the present study, it was found comparing the patients who needed ICU admission and those who didn't need it among the patients of ILI, there were no significant statistical differences in gender, smoking, WBC count, PaCO2, RADS, and X-ray findings. While there were significant statistical differences in age, presence of comorbidities, Hb concentration, creatinine, BUN, albumin, pH, and BWT. High significant statistical differences were found with PaO2, SaO2, HCO3, anion gap, and percent of burn. Those results which make a significant difference can be explained as old age usually has low immunity and also the presence of comorbidities, all vital systems functions are lower than young age so needing ICU is explainable. Also, inhalation injury causes acute respiratory distress which causes severe affection on ventilation causing a low PaO2/FiO2 ratio.

Also, comparing the patients who needed mechanical ventilation and those who didn't need it among the patients of ILI, there were no significant statistical differences in gender, smoking, WBC count, Albumin, pH, PaCO2, and RADS. While there were significant statistical differences in creatinine. High significant statistical differences were found with age, presence of comorbidities, Hb concentration, BUN, PaO2, SaO2, HCO3, BWT, Anion gab, percent of burn, and X-ray findings. The sensitivity of bronchial wall thickness in the detection of the need for mechanical ventilation was 83% at the cut-off point of 1.65. Its specificity was 78% and accuracy 75%.

Bronchoscopy may be utilized to diagnose upper- or large-airway issues; however, it does not improve or predict the need for mechanical ventilation, as described by Bingham and his colleagues. PEEP level, duration of intubation, and survival seem to be unrelated to initial bronchoscopic results [16].

In Onishi and his colleagues' study to determine the reason for early intubation, the patient's symptoms, BWT, and COHb proved to be effective indicators. Eighty patients out of 205 were diagnosed with inhalation damage, and 34 patients were intubated. Intubation seemed to be associated to burn size, face burns, neck burns, usage of auxiliary respiratory muscles, and COHb. The positive predictive value for early intubation was 1.00 if the patient had a total body surface area burn of 27% and a BWT of 3.5 mm. The negative predictive value for early intubation was 0.97 if the patient had a minor cutaneous burn without a neck burn and a COHb of less than 4%. The majority of fiberoptic bronchoscopy observations above the glottis were associated with patient complaints. The majority of findings from below the glottis were associated with BWT and COHb [17].

Yamamura et al. discovered that BWT measured by chest CT scans performed within a few hours of admission was predictive of the total number of ventilator days and ICU-stay days in patients with SII. Their findings suggest that BWT of the airway appears in patients with SII and that these reversible changes of the airway wall can cause deterioration of respiratory function and refractory airway obstruction [11].

In the current work, there was a highly significant negative correlation between PaO2 and RADS score and BWT among inhalation lung injury patients (P value < 0.001).

Yamamura and his colleagues discovered significant relationships between admission BWT and pneumonia development ($R^2 = 0.41$; P 0.0001), the total number of ventilator days ($R^2 = 0.56$; P 0.0001), and ICU-stay days ($R^2 = 0.17$; $P = 0.01$). An admission BWT cut-off value of > 3.0 mm indicated pneumonia progression with a sensitivity of 79%, specificity of 96%, a positive predictive value of 91%, and a negative predictive value of 88%, as determined by receiver operating characteristic curve analysis [11].

Using CT scanning on entry, Yamamura et al. discovered that patients with smoke inhalation injury (SII) had thicker airway walls than control patients without SII. Airflow constriction due to BWT was associated with the development of pneumonia and the number of mechanical ventilation days in patients with SII. Airflow restriction is a significant contributor to respiratory embarrassment in SII [18].

In their investigation to evaluate pulmonary function in the early phase of patients with smoke inhalation damage from a fire, the researchers found that lung function was significantly impaired. Kim and his colleagues discovered that, out of seven patients who underwent HRCT, four (57.1%) had CT results consistent with lung involvement in inhalation damage [19].

Conclusion

CT done within 24 h of burn patients has a good role in the diagnosis and management of ILI from the burn. Although serial CT scans are recommended in further studies to assess lung healing from inhalation injury.

Abbreviations

BMT	Bronchial wall thickening
COHb	Carboxyhemoglobin
CT	Computed tomography
CXR	Chest X-ray
FOB	Fiberoptic bronchoscopy
ILT	Inhalational lung injury
RADS	Radiologist score
TBSA	Total burn surface area

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Authors' contributions

Study design: R.E. Data collection: R.E, M.M, M.A, and M.E. Data analysis: N.A and M.E. Interpretation of results: N.E, R.E, A.E, M.M. Initial draft: R.E, A.E, and M.E. Final review of the manuscript content: all authors. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Menoufia University Hospital (IRB:12/2022COM2). Informed written consent from all participants was obtained following the local ethical committee at Menoufia University Hospital. This study was performed in line with the principles of the Declaration of Helsinki.

Consent for publication

The authors affirm that the participant of the image in Figs. 1, 2, and 3 was provided informed consent for the publication.

Competing interests

The authors declare that they have no competing interests.

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